CIMMYT REVIEW 1979

CIMMYT REVIEW 1979

CENTRO INTERNACIONAL DE MEJORAMIENTO DE MAIZ Y TRIGO 1979

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DIRECTOR GENERAL'S OVERVIEW

In November, 1978, after seven years of service, Mr. Haldore Hanson retired as CIMMYT's second Director General. During his tenure, Mr. Hanson helped plan and and implement the substantial expansion of international agricultural research activities made possible through the creation of the CGIAR system.

During 1978, four new trustees joined CIMMYT's Board. They bring new skills and insights to the Board and particularly to the functioning of the Trustees Program Committee.

CIMMYT's mandate

CIMMYT's efforts in international agricultural research have served as a catalyst to accelerate agricultural research activities within national programs and in the international arena. Millions of people in Africa, Latin America and Asia are better nourished today and living fuller, more productive lives, due largely to the worldwide cooperation and dedication of agricultural scientists, policy makers, and administrators in developing and introducing improved agricultural technologies and policies for wheat and maize.

CIMMYT's basic mandate and objectives remain unchanged today. Its commitments to strong multidisciplinary and pragmatic research programs in maize and wheat improvement and to a close and respectful collaboration with cooperating national programs continue.

CIMMYT's relative institutional maturity and size do not mean that we can stop questioning, challenging and revising our programs and activities. Many national research programs with whom CIMMYT collaborates are reaching a high degree of maturity and justified pride in their accomplishments. Other national programs are just beginning to take shape and develop their scientific manpower. CIMMYT will need to develop even more effective ways to relate to this range of institutions and their circumstances.

During the decade of the 1980's the world community must find the ways and means to feed adequately an additional one to two billion people and improve the livelihood of millions of small farmers. To meet these agricultural development goals, national and international institutes must grapple with more complex and difficult challenges in terms of both biological and economic policy constraints.

Looking to the 1980's

A number of initiatives are under way at CIMMYT and in collaborating national programs in response to these new challenges. In wheat, efforts continue to develop more stable resistance to disease pathogens, both through new genetic research and through approaches such as the multiline composite described later in this report.

CIMMYT is intensifying its efforts to develop cultivars with greater tolerance to toxicities found in many problem tropical soils and cultivars which are more productive in environments where drought and temperatures currently limit yields. Such research offers new hope for maize and small grain farmers in developing countries, particularly for the many problem-bound resource-poor farmers.

CIMMYT is evolving new institutional strategies such as regional programs and new cooperative ventures to better serve breeding, pathology, agronomy, and economic research activities within and among collaborating national programs. By 1980, thirty per cent of our staff will be based outside Mexico.

National collaborators have heightened our awareness of the economic and policy dimensions involved in agricultural research. Staffing at CIMMYT now reflects this awareness. Our economics staff, considerably increased in recent years, now works in full partnership with our biological scientists on production problems. We see this integration as vital to the development of more effective strategies to meet the food-nutrition problems of the next decade.

About this report

In the pages which follow, our staff has assembled a review of its recent programs and activities. This report by design, focuses on the scope and logic behind CIMMYT's activities. It is mainly directed toward the agricultural administrator, donor groups and informed laymen. More detailed scientific reporting on particular research activities is done through other CIMMYT publications. We hope we have adequately described what we are doing and why.

R. D. Havener
Director General

maize improvement

INTRODUCTION TO MAIZE

Maize production in developing countries expanded during the 1960's and 1970's faster than population growth. FAO Yearbooks show that area planted to maize has increased 33 per cent, yields per hectare are up 24 per cent, and the maize harvest has increased 66 per cent (Table 1, next page).

These numbers can be misleading when more than 100 developing countries are grouped together in one composite picture. At CIMMYT we work with most developing countries individually, and we find that no more than half of the maize consuming countries are making significant improvements in the crop, while other countries are temporarily on a production plateau. We think the situation of individual countries is the more meaningful because that is where we identify our problems.

Maize trials

CIMMYT supplies material to various cooperating countries for comparison with local materials for identification of superior and adaptable genotypes. We shipped seeds in 1978 to 80 developing countries comprising the international maize network. These countries produce about 95 per cent of the maize in developing countries.

By concentrating on these countries, CIMMYT feels it can make a greater contribution to improving maize production and productivity. This can be done in the following ways:

(1) more effective land use
(2) better varieties and production techniques.

On-farm research

For several years CIMMYT has advocated that scientists in developing countries test their experimental varieties first in the research station and then on farmers' fields. The purpose is two-fold. First, we want to develop appropriate technology

Table 1: Maize production in developing countries 1961-77.

	Maize area (million hectares)	Maize yield (kg/ha)	Maize production (million m. tons)
1961-65 (mean)	44.9	1136	51.0
1966-70 (mean)	51.0	1248	63.6
1971-75 (mean)	53.8	1296	69.6
1976	54.5	1324	72.2
1977	56.3	1375	77.2
Increase 1961-77	33%	24%	66%

Source: FAO Production Yearbooks.

which would be superior under the farmers' conditions. Second, we want the farmer to see what happens when new technology is applied alongside his own crop. This process helps scientists to recommend technology which is appropriate to the farmers' conditions and acceptable economically.

We see now an increasing number of national maize programs adopting this practice of on-farm research. And there is a high correlation between the use of on-farm research and rising maize production, made possible through the combination of better materials and production techniques.

We see another change, closely related. More countries are asking for supplemental maize seed from CIMMYT, to be multiplied and used for on-farm research. In 1976, seventeen countries asked for supplemental seed; in 1977, 40 countries; in 1978, 4l countries. So about half the countries who take part in the international network asked for supplemental seed during 1978.

Success brings problems

When a maize-growing country moves from deficit to self-sufficiency, or even to surplus, new problems arise. For example, Honduras conducted a successful four-year campaign to increase its maize production and turned its deficit into self-sufficiency, and at least temporarily, a surplus.

Several options are open to countries when a surplus occurs. Most deficit countries—when suddenly confronted with a surplus—have not planned on how to cope with this luxury. Options to be considered include these:

(1) Government purchase of surplus grain and storage from year to year. Rarely is there immediate financing on hand.

(2) Feeding more grain to poultry and milk-producing animals thus enriching the protein in the diet. This takes some lead time.

(3) Exporting grain. This requires a sizable amount. And since most developing countries are subsidizing the price of fertilizer and other inputs used by farmers, the export of grain will often be at a loss except to immediate neighbors where export costs may match the world prices.

(4) Processing maize into industrial products such as corn starch, corn oil, corn alcohol and the residues into animal feeds. (Here again, developing countries may not be able to compete on the world industrial market, but they can satisfy their domestic needs and perhaps sell to their neighbors.)

(5) Finally, if a maize surplus remains for several years and a profitable form of disposal is not found, it is time to consider a shift in cropping pattern, reducing the area planted to maize and increasing the area of other needed crops such as cotton, oilseeds, fresh fruits and fresh vegetables.

Self-sufficiency

When self-sufficiency in maize production is attained in countries where maize is not the No. 1 food grain (for example, in the Asian rice bowl stretching from India to Indonesia) the problems are more complicated because governments do not give the same high priority to maize as to rice. Nevertheless, the options are similar to those noted above for Honduras.

India subsidizes fertilizers, irrigation and other agricultural inputs; hence, exports of surplus maize may be at a loss. India has factories for industrial starch, but cassava is a cheaper raw material for starch than maize. India feeds some grain to poultry and that remains a feasible market, although not sufficiently flexible for quick changes.

India is experimenting with a novel public works program called "food for work", designed to help Indian states to carry out labor intensive construction programs (such as road and canal development), paying for some of the labor in the off-season partly with India's more than 20 million tons of "surplus" grain. Other places such as Taiwan, South Korea and the Peoples Republic of China have found ways to distribute their increased grain stocks to rural people in periods of slack work, in return for needed public works which will further increase future food production.

CIMMYT collaborated with India in organizing a conference of South Asia planners to review the options on utilization of food grains when "surplus" is reached. A similar conference may be needed in Latin America at a later date.

About this report

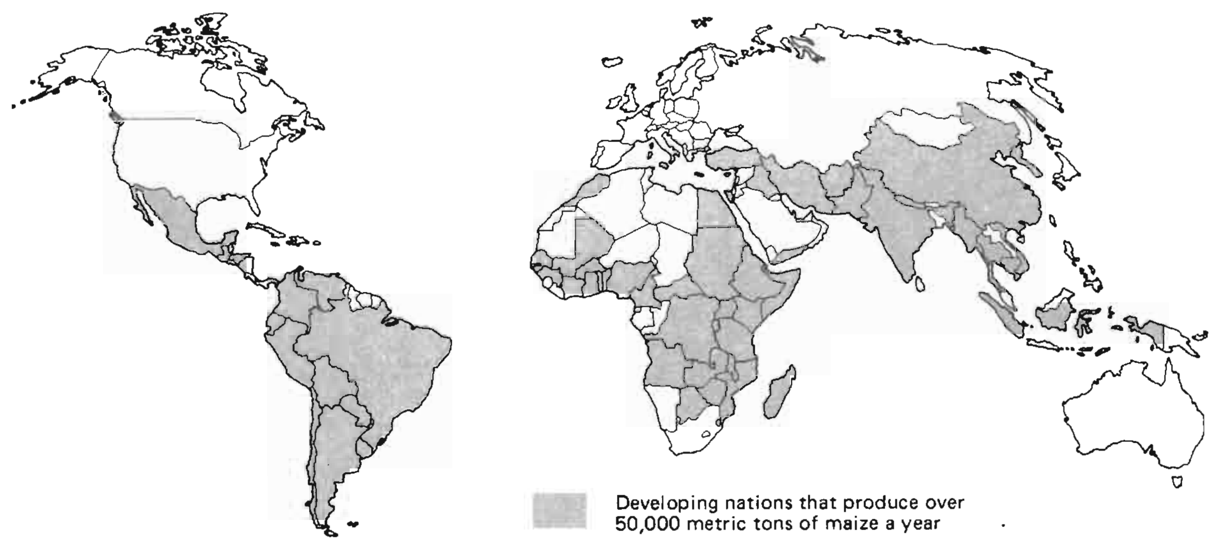
In pages which follow, the maize staff has reviewed the recent work in maize improvement.

In 1978, 67 young scientists from developing countries were brought to Mexico to spend one cropping season with our staff. They are now back home, participating in the international network.

CIMMYT headquarters staff travelled to almost 50 countries in 1978 to see the international trials, to visit former trainees, to observe production problems in farmers' fields and to discuss policy questions.

These current reports indicate the maize network is gaining in strength and is better able to contribute to further crop improvement and production in the 1980's.

E. W. Sprague


Developing nations that produce over
50,000 metric tons of maize a year

PROCEDURES FOR IMPROVEMENT OF MAIZE POPULATIONS AND DEVELOPMENT OF NEW VARIETIES

During the 1970's CIMMYT has evolved a number of germ plasm pools (early stages of improvement) and advanced populations (improved over many generations). Selections from these pools and populations are tested in Mexico, then the superior materials selected in Mexico are tested by a network of collaborators in over 80 countries. The judgment of the worldwide network thus guides the national programs, and helps CIMMYT develop more productive populations and experimental varieties for shipment to them.

The release of new varieties to farmers is a decision made by each collaborating government.

This process of population improvement and varietal development is summarized in the Maize Pyramid diagram (next page).

GERM PLASM BANK

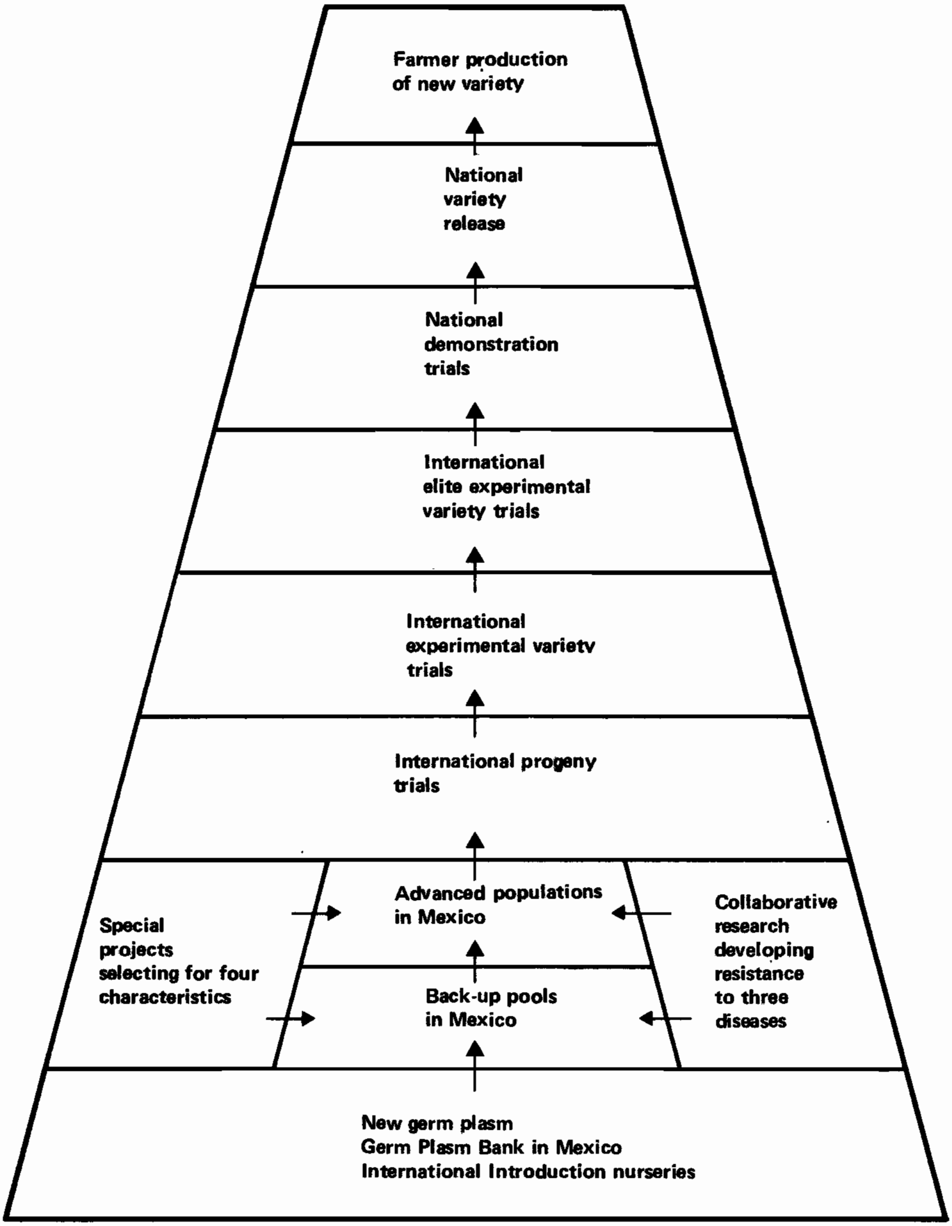
The germ plasm bank is a service unit for researchers. The bank unit maintains and regenerates seed, tests and catalogs them and ships seed to users.

The 13,000 items in the CIMMYT bank were gathered from more than 50 countries, mainly by an agency of the Mexican Ministry of Agriculture during the 1940's and 1950's. Over 90 per cent of the collection consists of the species *Zea mays L.* (standard type of cultivated maize). The collection also contains the near relatives *Zea mexicana* (commonly called teosinte) and *Zea perennis* (perennial teosinte). This bank represents the vast amount of variation found within the maize species in the Americas and parts of Asia.

The bank is stored in concrete chambers at a temperature of 0 degrees C. There are over 20,000 labelled storage tins of 2-liter and 4-liter capacity containing 40 tons of seed. The tins are arranged on steel shelving like library stacks.

A duplicate seed supply from the CIMMYT collection (500 grams per item) is being deposited for long term storage at the U.S. National Seed Storage Laboratory in Colorado. So far 5,500 items have been delivered to Colorado and shipments continue at about 500 items per year.

THE MAIZE PYRAMID



National variety release
Based on local farmer demonstrations, and worldwide data, each national program decides whether to release a new variety.

National demonstration
National programs alone decide whether an elite experimental variety with appropriate production technology justifies wider demonstration on farmers' fields. CIMMYT supplies basic seed for increase by governments.

Elite experimental variety trials
Remnant seed of the elite varieties is increased in Mexico to generate the quantity required for testing the following year. For the first time, some trials are held on private farmers' fields.

International experimental variety trials
In Mexico during the off-season CIMMYT intercrosses the 10 best families from each test site using reserve seed and the random mating method, to produce an experimental variety which will be tested by collaborators at 20-40 sites, worldwide, during the following year. Data from these 20-40 sites determine the selection of elite experimental varieties for the following year.

International progeny trials
The 250 progenies from each population are sent to collaborators at five sites, worldwide, to be grown in 250 5-meter rows, with six local checks, forming a 16 x 16 simple lattice with two replications. Ten best progeny are identified by the collaborator at each site, to form one experimental variety for the following year.

From collaborators' data CIMMYT identifies the 10 best families giving superior performance across all test sites, and uses these to develop an "across-site" variety. CIMMYT also identifies 100 families on the basis of across-site performance to reconstitute the advanced population for the next generation.

Advanced populations in Mexico
Here materials continue to be grouped by agro-climates, but unlike the pools, the advanced populations have completed several generations of selection for better plant type, better disease and insect resistance, better yield. These populations are grown in Mexico, and 250 superior families (progeny) are developed from each population for international testing every second year.

Special projects
Special projects deal with specific characteristics like shorter maturity, wider adaptation, more efficient tropical plants (those putting a larger amount of dry matter into grain) and drought tolerance.

Collaborative research
Collaborative research develops resistance to three diseases: downy mildew in Asia, streak virus in Africa, corn stunt in Latin America.

Back-up pools in Mexico
Here germ plasm is classified into 34 pools (genetic groups) according to three climatic regions (tropical lowlands, tropical highlands, temperate zone), four grain types (flint or dent, white or yellow), and three lengths of growing season (early, intermediate, full season). There are 12 pools for the lowland tropics, 14 pools for the highland tropics, and 8 pools for the temperate zone. The pools are grown every year in Mexico and seed from superior families is moved into the appropriate advanced populations.

New germ plasm
Each year new germ plasm is tested and some is selected for addition to the back-up pools. Selections may come from the germ plasm bank (13,000 accessions of varieties, lines, wild types) which are continuously being classified; or from introduction nurseries (new materials received from national programs).

Regeneration

Fresh seed was grown for over 8,300 bank accessions between 1969 and 1978.

Classification

Over 8,300 of the bank accessions have been documented for agronomic characteristics, and 3,000 of these have been tested in replicated yield trials. An inventory on computer is in preparation giving name of each accession, country of origin, current quantity of seed, location of storage tin, etc.

Shipments to clients

CIMMYT offers free samples of seed from the bank to all research organizations. From 1966 to 1978 the bank made approximately 700 shipments to 80 countries, representing more than 30,000 seed items. During 1978 there were 48 shipments totalling 1,173 seed items to 22 countries.

CIMMYT continues to fulfill the role of caretaker and shipping agent for the world's largest maize germ plasm collection.

FLOW OF GERM PLASM

Each year, raw germ plasm newly arriving at CIMMYT or drawn from the bank is tested, and the superior materials are added to the back-up gene pools. After recombinations and improvement, superior progenies from the back-up pools are moved into the advanced populations. Superior progenies from the advanced populations are moved to the national programs for use in their research and production programs. This continuous flow of germ plasm is an essential part of CIMMYT's delivery system.

Introduction nurseries

During 1978 over 1,000 materials newly arrived in Mexico from national programs were planted in observation nurseries. The best will be moved into the corresponding back-up pools in 1979. New materials are especially needed for earliness and disease-insect resistance.

Improvement of pools

All highland and temperate and tropical lowland pools were improved during 1978 by the method of half-sib selection (half brother or half sister), as modified by CIMMYT. In the summer season each pool was grown at more than one site in Mexico. The 400 to 800 families comprising each pool were planted in a pattern of two female rows alternating with one male row. Male seed was a mixture giving equal representation of superior families in the pool. Female rows were completely detasselled. Tall, diseased, or otherwise undesirable plants in the male rows were also detasselled before shedding pollen. This avoided pollination of the female rows from inferior males. In early maturity pools, when 70 per cent of the plants in the pool had silked, all male plants were also detasselled. This prevented the late male plants from giving pollen and the late female plants from receiving pollen, thus eliminating them from the pool.

At the end of the season, superior families were identified at each location by an interdisciplinary team of scientists. Yield potential, height, maturity, lodging, disease and insect resistance, and uniformity were taken into account. Superior families were identified at each site and best plants were selected within those families. At harvest the best ears were chosen from the selected plants in each pool at each site. These ears formed the half-sib families for the next planting cycle.

Improving pest resistance in gene pools

Each of the 34 pools has been classified according to the geographic area it will serve, and the principal disease or insect of maize to be encountered in that area. To strengthen the gene pools for their resistance to two classes of insects (borers and fall army worms) and two classes of diseases (ear rots and stalk rots), the back-up unit is applying the following procedures.

Scientists inoculate pools with the disease pathogen or insect larvae which represents the principal pest threatening that pool. At the end of each cycle, the superior plants in the families with the least damage are retained for the following cycle. In 1979 this procedure is being applied to eight tropical lowland pools and four sub-tropical pools. Over a three year period the increased level of genetic resistance will be measured, and thereafter, all pools may be subjected to the procedure.

The new gene pools in 1978

In 1978 CIMMYT began to assemble three new gene pools adapted to (1) the extreme northern range of the temperate region, (2) the southern temperate range, and (3) the intermediate belt of the temperate region. The objective of these pools is to introduce exotic germ plasm into temperate base materials, which in turn will serve as a mechanism to move genes from the temperate region into tropical and highland germ plasm. CIMMYT is cooperating with breeding programs in temperate areas to develop the adaptation and genetic transfers required for the tropical and highland areas. This is stimulating a greater interest and understanding of the need to broaden genetic variability.

Agro-climatic characteristics considered in classifying maize gene pools.

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

* Mean of main growing season.

ADVANCED UNIT

The advanced unit is an interdisciplinary team of maize scientists who engage in population improvement and international testing. This is where CIMMYT maize materials reach out to national programs.

At the beginning of 1979 the advanced unit was working with 26 populations, each designed to serve a tropical, subtropical, or temperate climate. Populations are further classified by maturity period (early, intermediate, late), by grain color (white-yellow), and by kernel type (flint-dent) to fit the requirements of farmers in different countries.

Before each international trial, the advanced populations are grown three cycles in Mexico, undergoing continous reselection within families for shorter plant height, fewer days to maturity and better resistance to diseases and insects.

Because of the large number of populations undergoing improvement in this program the 250 full-sib families (full brother and sister relationship) in each advanced population are tested once every two years internationally at six sites, worldwide. International trials serve two purposes. First, the 10 best progeny are identified by each international collaborator, to be converted into an experimental variety. Second, 30-40 per cent of the best progeny across sites are chosen to reconstitute the population for further improvement.

Selection pressures increase here. Whereas 85-90 per cent of the families are retained after each observation cycle in the gene pools, only 30-40 per cent are selected when reforming the advanced population, and only 2.5 to 4 per cent are selected when forming an experimental variety (7 to 10 families out of 250).

Results of some recent international trials are given later in this report.

Testing population improvement in Mexico

If advanced populations at CIMMYT are to provide continuous service to national programs, the populations must undergo steady improvement—achieved by discarding inferior families and introducing superior families from the gene pools. To monitor this process, it is necessary to test advanced populations periodically to see whether the latest cycles are better than their predecessors. Such a monitoring occurred in 1978 for 13 tropical lowland populations.

Bulk samples of the original material of these populations were grown in competition with improved cycles at two sites in Mexico. The latest cycles showed significant gain in yield of 4.2 per cent per cycle and these same tropical materials were shorter by 3 centimeters and earlier by 1.4 days (days were counted from planting to 50 per cent silking).

Overall, the population improvement program was found to be achieving its objectives in the late 1970's. Results suggest that future progeny trials and experimental variety trials—drawing materials from these 13 populations—should continue to demonstrate successive improvements.

DISEASE AND INSECT RESISTANCE

Maize germ plasm contains many genes for resistance to diseases and insects. By gradual accumulation of these genes in selected populations, the maize crop would be able to tolerate pest hazards much better than at present. By achieving resistance without use of chemicals, or in combination when necessary, the new maize varieties would benefit all classes of maize farmers, but especially the smaller, poorer farmers in developing countries.

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

To determine how families from maize populations react to pathogens and insects, the scientists subject these families to timely, uniform, artificial inoculations and/or infestations.

For disease resistance, populations are inoculated with stalk and ear rotting organisms. At harvest each family is scored for disease damage, and progenies with the least damage are retained for succeeding generations.

For insect resistance, the populations are artificially infested with larvae of fall army worms, ear worms, sugarcane borer and Southwestern corn borer. These are the most widespread and important maize pests in the tropics and subtropics of the Western Hemisphere, and constitute a pest complex with near relatives on other continents. At appropriate intervals after infestation, visual ratings for insect damage are made for each family. Progenies showing the least damage are retained and those most severely damaged (most susceptible) are discarded.

In the course of the breeding activities new techniques and apparatus are developed to improve and speed the work. One such device is the bazooka used for larvae infestation. With the bazooka 1,500 plants can be uniformly infested in one hour—a 300 per cent increase over former methods. CIMMYT is distributing bazookas to national collaborators.

The scientists score the results of these selections with a 1-5 rating for each disease or insect (lower score indicates less damage, hence greater resistance). Progress toward economic levels of genetic resistance is slow, particularly for insect resistance. CIMMYT's development of adequate techniques for mass production and infestation of insects was a major achievement during 1974-78. Additional cycles of selection will be needed before adequate resistance can be reported.

Insect-rearing laboratory

Large numbers of insect larvae are required to artificially infest the families of the pools and populations. An insect rearing laboratory has been established which has the capacity to produce the insect larvae required to infest the progenies to be evaluated. In the last 2 cycles of 1978 CIMMYT produced and used for infestation: 3,900,000 fall armyworm *(Spodoptera frugiperda);* 1,700,000 sugarcane borer *(Diatraea saccharalis);*210,000 Southwestern corn borer *(D.grandiosella);* and 200,000 corn ear larvae.

More efficient rearing techniques still are needed for Southwestern corn borer and neotropical corn borer *(D. lineolata).*

Larvae replace egg masses

A new insect infestation technique has made infestations more uniform and speeded up insect resistance work.

Previously the maize plants were infested with egg masses on squares of wax paper which were pinned to the maize leaves, and as the eggs hatched, the larvae began feeding. With the new technique, egg masses are hatched in the laboratory, larvae are mixed in an inert carrier (ground corn cobs), and this mixture is applied in maize plant whorls with a portable field applicator (bazooka). The new technique shows several advantages: (1) use of the larval mixture facilitates handling both in the laboratory and the field, (2) field application is 3 to 4 times faster (up to 1,500 plants per man-hour), (3) infestation is more uniform (the number of insects per plant varies only 15 per cent), and (4) escaping plants are very few (1 to 5 plants per 1,000).

Use of the new CIMMYT applicator is being taught to all trainees from developing countries. Other international agricultural research institutes are testing the CIMMYT applicator on their crops. This applicator also is being supplied to collaborating national programs.

COLLABORATIVE RESEARCH FOR RESISTANCE TO THREE MAJOR DISEASES

Starting in 1974 a collaborative breeding project was organized between CIMMYT and six national maize programs which are jointly developing germ plasm resistant to three major diseases of maize.

The diseases are: downy mildew *(Sclerospora spp)*, caused by a fungus pathogen found in Asia from Indonesia to India and spreading rapidly to other continents; maize streak virus, disseminated by a leafhopper *(Cicadulina spp)* in tropical Africa; and corn stunt, a disease also spread by a leafhopper *(Dalbulus spp)* in tropical Latin America.

The participating national programs include two Asian countries, Thailand and the Philippines; two African countries, Tanzania and Zaire; and two Latin American countries, Nicaragua and El Salvador. Each country is situated in an area where one of the diseases is severe.

In 1974, CIMMYT assembled in Mexico three broad-based maize populations which could have general acceptance in the tropics provided they carried resistance to the three diseases. The three base populations (one white dent, one white flint, and one yellow flint-dent), were crossed to known sources of resistance to the three diseases.

Each year CIMMYT sends to the collaborating countries several hundred progenies from these base populations for screening under disease conditions. Superior plants in families showing resistance and good agronomic characters are then self-pollinated. Part of the resulting seed is planted again in the collaborating country and another part in Mexico where families are selected using information on performance in the collaborating countries. The Mexico plants are inter-pollinated to produce full-sib progenies and the harvested ears are sent again to the collaborating countries.

In 1979, the project entered its 4th cycle of selection for resistance to stunt or downy mildew, and the 3rd cycle for streak resistance. The materials show considerable improvement in resistance to the three diseases individually and subpopulations have been created for resistance to pairs of diseases.

Five CIMMYT advanced populations with good yield potential in downy mildew areas are being improved for downy mildew resistance. Experimental varieties from these populations will eventually benefit maize growers in more than half of the developing countries of the world where the disease is a problem.

NUTRITIONAL IMPROVEMENT IN MAIZE

Scientists at CIMMYT and elsewhere have been working for more than 10 years to improve the quality of maize protein.

Maize protein can be improved by introducing one or more mutant genes affecting the balance of amino acids but the added genes bring undesirable side effects which have to be corrected to make the high quality protein maize acceptable to farmers.

One breeding approach is to use the opaque-2 gene (the name comes from the appearance of the kernel) but soft opaque-2 maize suffers the following problems:

(1) Reduced grain yield (down 5-15 per cent)
(2) Unacceptable chalky kernel appearance
(3) Greater vulnerability to ear rots and storage pests
(4) Slower loss of moisture from grain after physiological maturity.

Since 1969 CIMMYT breeders have been developing opaque-2 populations with modified hard endosperm, normal appearance, resistance to ear rots, and higher tolerance for stored-grain insects. During these changes the high protein quality has been maintained by constant selection based on laboratory monitoring.

Continued progress in 1978 was indicated by the following:

(1) CIMMYT now has five advanced populations carrying the opaque-2 gene, but with normal-looking hard endosperm kernels. These materials are undergoing further improvement in yield, agronomic traits, and kernel characteristics. One cycle of selection is completed every two years. The period between cycles is used for

within-family improvement for traits most deficient in each population.

(2) CIMMYT has developed hard endosperm opaque-2 versions of 20 gene pools and 19 advanced populations with tropical and temperate adaptation. Further accumulation of stable genetic modifiers is practiced by growing these materials two cycles a year—one for selection of stable modifiers, the other for recombination of stable families.

(3) Hard endosperm opaque-2 versions of 12 highland gene pools have also been developed. Because only one cycle of selection per year is possible the highland materials have not made progress equal to the lowland and temperate pools.

(4) CIMMYT maintains one tropical, 3 temperate, and one highland opaque-2 back-up gene pools with hard endosperm. The major emphasis in these pools has been to accumulate modifiers for kernel hardness without sacrificing protein quality. Most pools have completed seven or more cycles of selection in a simple half-sib (half-sister) breeding technique. Agronomically and in kernel appearance, the materials in the back-up pools are acceptable for national programs and can be of service either as breeding parents or as populations for further selection under local environments.

(5) The highland opaque-2 program also has two broad-based opaque-2 composites with soft endosperm. These two materials have been improved considerably for yield and ear rot resistance.

(6) Progress toward the development of opaque-2 versions of floury-1 materials (cross between two mutants) has been remarkable. Ear rots and larger kernel size are still receiving major selection emphasis.

(7) The sugary-2/opaque-2 composite (another cross between two mutants) has undergone several cycles of selection, resulting in improved kernel type and size. The future of this material is now promising.

(8) Worldwide testing of the opaque materials has speeded up. Eight experimental varieties carrying the opaque-2 gene were tested at 38 sites in 1977. Results from 22 sites were received. At 15 reporting sites the top opaque variety was either equal in yield or better than the

normal check entry included in the trial. In some countries these opaques can now compete with the best varieties.

(9) International progeny trials for opaque materials were organized in 1978 in the following manner. First, superior families, stable for kernel hardness and having good agronomic characteristics, were identified from within the hard endosperm opaque-2 versions of the advanced populations. Next, these were recombined —separately for each population—to constitute entries in an international trial sent to 45 locations. Results will be available in 1979.

(10) Twelve national programs are now developing opaque-2 varieties suitable for local agro-climates.

The area planted commercially with opaque-2 maize is still negligible. But development of competitive and acceptable type quality-protein materials has received new hopes by recent progress in Mexico, and it is probable that these developments will provide stimulation to maize breeders elsewhere.

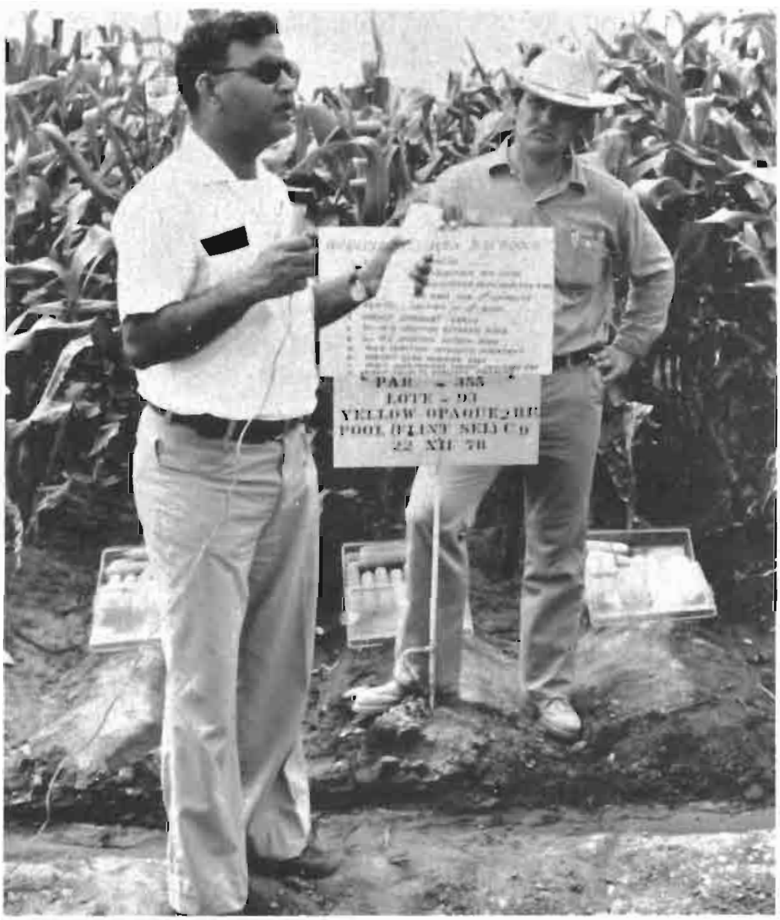
Continuing UNDP support

The United Nations Development Program, which has supported CIMMYT research on maize protein since 1970, reviewed the project in mid-1978 with the assistance of an external evaluation team—a maize breeder, a nutritionist and an agricultural economist—and subsequently approved financial support for another five year period 1979-84.

The continuing project takes account of shifting opinions on malnutrition in the world scientific community. In the 1960s malnutrition in developing countries was viewed primarily as protein deficiency (FAO/WHO/UNICEF, 1969). United Nations agencies therefore gave support to programs for increasing protein supplies through plant breeding and other means. In maize the breeding of high lysine varieties was intended to serve this purpose.

In the 1970s differences developed among nutritionists whether protein or calories are more limiting in the diets of low income groups. A reevaluation of energy and protein requirements shifted the balance of opinion toward calorie shortages (FAO/WHO, 1973). Still more recent publications point to deficiencies of both calories and protein in the diets of vulnerable groups (Scrimshaw, 1977) and the daily intake of both calories and protein was found below the safe level in several countries (Waterlow and Payne, 1975). In this debate vulnerable groups include pregnant women, children under 5, and persons suffering fevers or intestinal infections—all of whom have higher protein requirements.

CIMMYT's work on nutritional quality maize continues to give attention both to more total calories (higher yields) and to greater utilizable protein (higher lysine and tryptophan).



Several hard endosperm normal looking opaque-2 maize populations have been developed at CIMMYT. Yields of this improved protein quality maize under farmer conditions are within 5 per cent of their normal type counterpart.

INTERNATIONAL MAIZE TESTING

In 1978 CIMMYT shipped maize seed for testing by collaborators in 80 countries. These shipments included progeny trials at 76 locations; experimental varieties at 339 sites; and elite varieties at 206 sites. This was the most extensive participation in international maize trials during CIMMYT's 13 year history.

By the end of 1978 results from about 10 per cent of the trials had arrived in Mexico. The report on international testing which follows will be based upon 1977 trials because the final reports for that year are available.

International progeny trials

Each year CIMMYT selects the best progenies from half its advanced maize populations (in 1978 that meant 13 populations out of 26) and sends the seed from each population for testing by collaborators at six sites worldwide.

Each collaborator receives seed for 250 progenies from a single advanced population, which he grows in comparison with the best commercial hybrids or varieties (checks), and from this trial he chooses the 10 best progenies. The trial is scored on highest yield, shorter plant height, fewer days to flowering, resistance to diseases and insects, and absence of lodging.

When CIMMYT receives a collaborator's report listing the 10 best entries, the breeders in Mexico create an experimental variety—using remnant seed saved for this purpose—intercrossing the 10 progenies in all possible combinations and bulking the produce. The experimental variety is identified for the site of the collaborator. Each experimental variety will be tested the following year at 30 to 40 sites worldwide.

In 1977 about half the reporting collaborators found that the best progenies outyielded their best checks, generally by 10 per cent to 50 per cent. Some of the progenies also had shorter plant height, fewer days to flowering, superiority in disease and insect resistance, and better lodging resistance.

CIMMYT developed 82 experimental varieties from the reports of collaborators in 1977. Seventy-one of the varieties carried the name of the 1977 testing site, while 11 consisted of the progenies which had performed best "across sites" and were expected to show wide adaptation.

Experimental and elite variety trials.

Experimental variety trials were sent in 1977 to 196 locations, and data from the trials was received back from 101 sites.

At 70 per cent of the reporting sites the collaborators reported that the top experimental variety distributed by CIMMYT outyielded all local checks—in most cases the superiority of yield was in the range of 10-50 per cent. A sampling of data from these reports is given in Table 2.

Elite varieties tested in 1977 gave a similar picture. Over half the 70 collaborators who grew the trials and submitted their data found that the best elite variety at their location outyielded the best local variety by more than 10 per cent and a few by more than 50 per cent.

Some interpretations of experimental varieties

Table 2 reports an arbitrary selection of 15 trials in

Table 2. Sampling of data from International Maize Experimental Variety Trials, 1977.

Testing site	1977 trial number	Name of top experimental variety	Maize yield of top variety as o/o of best check
Central America			
Guatemala (San Jerónimo)	15	Cotaxtla 7537	121
Honduras (Danli)	13	Tocumen 7428	136
Nicaragua (La Calera)	14A	Ferke 7526	136
Panama (Tocumen)	13	Across 7536	132
South America			
Argentina (Tucuman)	15	Ferke 7537	133
Bolivia (Santa Cruz)	13	Suwan 7528	142
Chile (La Platina)	16	Obregon 7442	120
Peru (San Ramón)	13	Across 7527	142
Africa			
Botswana (Good Hope)	14A	La Maquina 7635	120
Egypt (Sakha)	14A	Suwan 7535	189
Zaire (Gandajika)	12	Ferke 7529	130
Asia			
Bangladesh (Joydebpur)	16	Pirsabak 7642	147
Malaysia (Serdahg)	14A	Santa Roza 7624	119
Philippines (Laguna)	15	Suwan 7539	144
Pakistan (Pirsabak)	15	Ferke 7537	160

which the top experimental variety outproduced the best local check. Several interpretations can be drawn. First the geographic spread of successful trials covers Asia, Africa and Latin America. Second, the list of testing sites includes some of the strongest national programs and some which are weak; there are benefits for both. Third, all 15 collaborators in Table 2 requested additional seed which will be multiplied and tested on farmers' fields.

Table 2 also gives interesting evidence how developing countries are helping each other with maize research. For example, the highest yielding experimental variety at Tucuman, Argentina was selected from progeny data submitted by African scientists at Ferkessadougou in Ivory Coast. The top variety at Santa Cruz, Bolivia was chosen at Suwan, Thailand, 20,000 kilometers away. The best experimental variety in Botswana, Central Africa was selected at La Maquina, Guatemala.

Requests for seed increase

Forty national maize programs asked CIMMYT for supplemental seed in 1977 and 41 in 1978, with intention to increase the seed for demonstrations on farmers' fields. Such a step often precedes release of a new variety. The seed requests come from all climatic regions. In 1978 the requests came from:

Central America and Caribbean, 12 countries.
South America, 4 countries.
Mediterranean and Mideast, 4 countries.
Africa south of the Sahara, 11 countries.
South and Southeast Asia, 8 countries.
Oceania, 1 country.
Western Europe, 1 country.

1979 international trials

Requests for international maize trials in 1979 continue to increase over preceding years. Progeny trials are planned at 78 locations in 31 countries. Trials for experimental varieties and elite varieties are proposed in 84 countries at 626 sites. These trials involve virtually all developing countries in which maize is an important crop.

Distribution of International Maize Trials 1976-79

Region and Nation	1976 trials	1977 trials	1978 trials	1979 trials*
Central American and Caribbean	**196**	**176**	**194**	**187**
Antigua	0	1	0	1
Bahamas	2	2	2	2
Barbados	0	0	0	3
Belize	7	5	4	6
Costa Rica	11	11	14	12
Dominica	0	0	4	4
Dominican Republic	11	5	3	4
El Salvador	12	9	12	13
Grenada	2	1	1	1
Guatemala	17	12	16	14
Haiti	7	10	12	10
Honduras	15	12	20	17
Jamaica	9	9	13	12
Mexico	76	74	59	50
Nicaragua	10	8	12	13
Panama	10	10	19	17
St. Kitts	0	0	0	1
St. Vincent	0	0	1	1
Trinidad	7	7	2	6
South America	**90**	**92**	**124**	**118**
Argentina	7	6	6	8
Bolivia	10	13	31	24
Brazil	28	35	30	28
Chile	1	2	2	6
Colombia	17	12	15	14
Ecuador	8	8	10	10
French Guyana	0	0	2	4
Guyana	3	3	4	4
Peru	13	9	17	11
Surinam	0	1	2	2
Venezuela	3	3	5	7
Mediterranean/Mideast	**38**	**46**	**61**	**53**
Algeria	0	2	2	2
Egypt	12	13	16	14
Iraq	6	6	3	4
Iran	2	0	0	0
Jordan	0	0	2	4
Morocco	0	0	2	2
Saudi Arabia	1	3	7	6
Sudan	2	4	2	2
Syria	0	0	3	3
Tunisia	0	1	2	2
Turkey	8	4	4	5
Yemen A.R.	7	13	13	4
Yemen, South	0	0	5	5
Tropical and Southern Africa	**93**	**92**	**149**	**156**
Benin (Ex-Dahomey)	3	1	1	2

* **Proposed**

Distribution of International Maize Trials 1976-79 (Con't)

Region and Nation	1976 trials	1977 trials	1978 trials	1979 trials*
Botswana	2	3	5	3
Cameroon	10	7	7	6
Central African Empire	2	2	2	2
Chad	0	0	3	2
Ethiopia	6	4	12	11
Ghana	5	4	4	5
Guinea-Bissau	0	3	3	3
Ivory Coast	12	10	15	12
Kenya	5	3	2	7
Lesotho	0	0	2	3
Malawi	4	4	7	6
Mozambique	0	0	17	15
Nigeria	20	12	14	25
Rwanda	0	0	5	4
St. Helena	0	2	4	3
Senegal	1	0	9	7
Somalia	0	0	1	6
So. Africa Republic	0	8	9	7
Swaziland	1	1	1	2
Tanzania	8	12	9	9
Togo	2	1	1	1
Uganda	3	1	1	2
Upper Volta	2	2	2	2
Zaire	3	9	10	7
Zambia	4	3	3	4
South and East Asia	**96**	**70**	**78**	**95**
Afghanistan	2	2	2	2
Bangladesh	8	7	7	7
Burma	0	0	4	5
India	19	13	13	23
Indonesia	0	3	2	2
Malaysia	2	3	2	4
Nepal	24	8	6	12
Pakistan	15	10	10	11
Philippines	14	11	19	16
Sri Lanka	7	2	2	4
Thailand	5	11	11	9
Other	**3**	**1**	**15**	**17**
Canada	1	0	0	0
Greece	0	0	2	4
Hungary	0	1	2	2
New Guinea	0	0	7	6
Papeete	0	0	0	2
Puerto Rico	0	0	4	3
USA	2	0	0	0
TOTAL TRIALS	516	477	621	626
TOTAL COUNTRIES	59	64	80	84

SPECIAL RESEARCH PROJECTS IN MEXICO

CIMMYT staff explores new ideas and investigates new techniques for improving specific characteristics of the maize plant. For these situations special projects are created in which the researcher confines the study to one or a few populations. Four such special studies are now underway dealing with yield efficiency in tropical maize, drought tolerance, early maturity, and wide adaptation. These studies may require many years for completion, but the conclusions reached can ultimately be applied to all parts of the program, which in turn may benefit farmers in many countries.

Yield efficiency in tropical maize

Tropical maize allocates less of its total dry matter to grain than does maize in the temperate latitudes. One special project at CIMMYT is attempting to develop tropical plants with a higher "harvest index", i.e. with a greater proportion of their dry matter in grain and a lesser proportion in vegetative parts. Typically, maize in the temperate areas deposits approximately 50 per cent of its dry matter as grain (harvest index 0.5) whereas traditional maize varieties in the tropics allocate only 35-40 per cent.

Evolution by natural selection over centuries probably shaped the characteristics of tropical maize. The taller and leafier tropical plant rises above weeds and shades them out. A greater leaf area in tropical maize enables the plant to tolerate more insect or disease damage and still survive. These are useful characteristics to the subsistence farmer. But there are disadvantages. The tropical plant is bulky, takes too much space in the field, and permits fewer plants per hectare. Optimum planting density for traditional tropical maize is 15-25,000 plants per hectare whereas the smaller temperate zone plant can be grown at 50-70,000 plants per hectare.

These facts suggest the hypothesis for a special project: that the tropical maize plant of shorter height, less leaf area and smaller tassel might be more resistant to lodging, yield more grain and thus give higher harvest index.

This hypothesis is being tested by CIMMYT through several approaches.

First, researchers chose a population of the lowland tropical population Tuxpeño and began to select within the

The grain-to-stover ratio of the recent cycle of short plant selections of the tropical maize population Tuxpeño, about equals the ratios found in the U.S. Corn Belt. This research project has developed a tropical maize plant of shorter height, less leaf area and smaller tassel size that is resistant to lodging and higher yielding per unit area than traditional varieties.

population for shorter plant height. By 1979 these selections had reached cycle-17 and plant height had been reduced to about 60 per cent of the original height, in cycle-0. Starting at cycle-12 the researchers divided the seed for the shorter Tuxpeño into three parts, and began selecting separately for three characteristics: further reduced plant height, reduced tassel size, and reduced density of foliage.

Two other populations unrelated to Tuxpeño are being subjected to similar studies. In Eto Blanco researchers are selecting simultaneously for reduced tassel size and reduced foliage; in Antigua-Republica Dominicana they select separately for reduced tassel size and reduced foliage.

The effect of the reduction of height in Tuxpeño on productivity was reviewed in the summer of 1978 with a yield trial comparing five generations of Tuxpeño (Cycles-0, 6, 9, 12, and 15), grown at plant densities designed to span the optimum density for yield of each entry. Tested at three sites in Mexico—at elevations ranging from sea level to 1,000 meters—the trial showed that Tuxpeño had decreased in height by 8 cm per cycle, while yield had increased linearly by 190 kg/ha per cycle (i.e. 3 per cent per cycle).

Yield increase during the first six cycles of this study appears attributable to reduced lodging. In later cycles, when lodging became negligible, the yield increase seems the result of greater efficiency (higher harvest index) and a greater plant density tolerance, since the optimum planting density for Tuxpeño rose from 45,000 plants per hectare at cycle-12 to 65,000 plants at cycle-15 (average of three locations).

There was a side effect of reduced time to maturity during this study. Earliness is a function of the number of leaves: the fewer the leaves per plant, the earlier the plant. In this study Tuxpeño plants became 13 days earlier to flower and 11 days earlier to harvest over the 15 cycles of selection studied. In doing so, three leaves per plant were lost, all from below the ear.

This review showed that the short plant Tuxpeño is now approaching the harvest index of Corn Belt maize (temperate region), having increased its harvest index from 0.35 to 0.48 over 15 cycles.

Other approaches to increased efficiency will be similarly reviewed as the studies mature. Already there is agreement that this study offers preliminary evidence that CIMMYT's maize improvement procedures are producing results where it counts most—the harvest.

Drought tolerance

Throughout the tropics drought causes sizable yield reduction in maize. Droughts are most often caused by irregular distribution of rainfall and low water-holding capacity of soils.

Under natural selection over centuries a few races of tropical maize have apparently developed the ability to tolerate tissue water deficits (not by escape through earliness but by tolerance of stress). This trait has proved difficult to identify and to transfer genetically.

A special project at CIMMYT is attempting to develop techniques that will distinguish a series of genotypes superior in drought tolerance, so that scientists can intercross them and "pyramid the genes" for drought tolerance through cycles of recurrent selection, in a manner similar to that used in shortening the maize plant. Recognizable differences in drought tolerance are believed to be small and therefore many selection cycles may be needed.

To date, scientists looking at the drought tolerance of different maize populations have established that variations in drought tolerance exists among maize populations and that varieties can be developed that possess greater genetic tolerance to drought than found in many varieties.

The population Tuxpeño-1 is grown in several countries in the tropics. Families from this population were tested under three levels of moisture: no·stress (full irrigation); medium stress (no irrigation from plant emergence to 10 days after flowering); and severe stress (no irrigation following plant emergence). These trials took place in the dry season at Tlaltizapan station in Mexico.

A range of stress under the three levels of simulated drought is confirmed by the mean yields achieved: 6.1 tons/ha under full irrigation, 4.3 tons under medium stress, and 1.6 tons under severe stress.

Under severe stress, the experimental variety selected for tolerance to drought gave significantly higher yields than the other entries and outyielded the best yielding "full irrigation" experimental variety by 64 per cent. And even under full irrigation there was no significant yield difference between these materials.

Conclusions: despite results limited so far to one cycle with one population, the following tentative judgments can be drawn: (1) that variations for performance under water stress exist in maize; (2) that interactions between genotype and stress level can be identified; (3) that it is possible to select genotypes which perform best under moisture stress without sacrificing ability to perform well under full irrigation; and (4) the best genotypes under moisture stress can be identified by a series of growth measurements which include "relative extension index" (a measurement of stem and leaf growth during stress), synchronization between tasseling and silking, and "leaf tissue death score" (a measurement of dead leaves at maturity) as well as grain yields. The "extension index" has the advantage that it can be measured before flowering; hence by this criterion many families can be screened and rejected, if necessary, before crossing.

In 1979 CIMMYT has expanded the number of families in the drought project, which will continue for a number of years.

Shorter maturity in tropical maize

Many tropical maize growing countries seek good yielding varieties which mature earlier to fit a brief rainy season or a tight cropping sequence.

A special project is utilizing alternative approaches to develop earlier maturity with good yield. In one, short maturity tropical varieties are assembled from lowland tropical areas all over the world and composited. The present pool contains 33 collections from Indonesia, one from Colombia (Guajira 314), two from Honduras (Mata Hambre), one from El Salvador, and six from Pakistan (Bannu early group). These are being crossed in various combinations and tested at two locations.

One population being worked under this approach is an Indonesian-Colombian-Honduran mixture, in which the three parent materials had maturities of 72-85 days in their home countries, and the 3-way mixture now matures with good plant type in less than 90 days at Poza Rica, Mexico (lowland humid tropics).

Another approach is the crossing of the best tropical "earlies" with temperate material. The first tests by this approach at Poza Rica gave maize lines which were harvested in 80-85 days after planting.

Another approach involves recurrent selection for early maturity in a mix of outstanding tropical populations.

Maturities of maize are usually measured in number of days from planting to flowering, but closer examination of the life cycle indicates substantial differences occur in the proportions of growth cycle occurring before flowering and after flowering. A number of physiological studies have reported that the relative length of these two phases has impact upon yield.

To gain information on this aspect of tropical maize, an academic research project has been organized. A CIMMYT predoctoral fellow from Pakistan is conducting doctoral thesis research at Kansas State University on the manipulation of maize maturity, aiming to shorten the days from planting to flowering (vegetative stage) without reducing the days from flowering to maturity (grain filling stage). The results will be useful in understanding the relationship between earliness and yield, as well as in the development of early maturing material.

Wider adaptation

Broad adaptation of maize varieties is a concept basic to the CIMMYT program, so that improved varieties are expected to serve wide areas. To see how far this idea can be extended, a special project is developing a unique germ plasm pool.

In 1979 CIMMYT makes its 12th cycle of crosses in a maize population drawn from many climates (for example, northern Canada, equatorial Brazil, and the southern tip of Argentina). Initially the cold climate materials would not set seed in the lowland tropics, and vice versa, because of sensitivity to differing day lengths, temperatures, and diseases. Today this composite sets seed in all maize growing climates used in the selection procedures.

Each year selections from this mixture are grown in widely differing environments for example, in South America, Europe, and South Africa; then resulting seed is again recombined in Mexico, and sent the following year to additional sites. This selection for wide adaptation will continue over many years.

CIMMYT believes the special project in wide adaptation serves several ends: first, one widely adapted population can be used as a parent for transmitting wide adaptation to other populations; second, maize with adaptability gives greater yield stability under climates with fluctuating temperatures; third, wide adaptation in a parent serves as a vehicle for transmitting a variety of genes, almost anywhere in the world.

CROSSES BETWEEN GENERA (WIDE CROSSES)

While CIMMYT takes advantage of the variation found within maize germ plasm, breeders also seek to transfer additional desirable traits existing in related genera. Breeding barriers exist between maize and alien genera, but CIMMYT has been conducting a wide cross program since 1973 to overcome the barriers between maize and two other genera: *Tripsacum* and *Sorghum*. Tripsacum is a wild relative of maize which has shown resistance to a wide range of diseases and pests which are a problem to maize. Sorghum is more tolerant to drought and to waterlogged conditions than is maize.

Approximately 5,000 crosses were made between maize and tripsacum in 1978; two hybrids have been identified to date, and analysis continues. In addition 19 hybrids have been identified from crosses in previous years. Of this total of 21 hybrids, 14 were of the classical type that retain the expected complement of chromosomes from each parent.

They resemble tripsacum more than maize in appearance, are perennial, and like tripsacum, take approximately two years to flower. Two of these hybrids died before flowering and four have not yet flowered. The eight that have flowered have been male sterile, and no progeny have been obtained.

Seven hybrids were not of the classical type, and possessed a variable number of chromosomes in cells of the same root tip. Most cells examined contained 20 maize and no tripsacum chromosomes. Other cells contained 20 maize chromosomes and up to eight of tripsacum. However, in at least three hybrids some cells contained a total of 20 chromosomes of which up to four were tripsacum substitution chromosomes. These seven non-classical hybrids are more maize-like and are annual. Most have flowered within three months of germination. Although they have produced no viable pollen, five plants have set seed after backcrossing to maize. Whereas some of these backcross progeny appear to be normal maize, others retain some alien chromosomes. With such hybrids the incorporation from tripsacum to maize of desirable characteristics can be made more rapidly, and they can be tested for useful characteristics far earlier than the classical type.

CIMMYT hopes to transfer additional desirable traits to maize through attempting to cross maize with related genera possessing the desired traits. Work is focused on maize x tripsacum and maize x sorghum crosses with the hope of transferring to maize improved insect and disease resistance and tolerance to drought and waterlogged soils.

Over 14,000 crosses were made between maize and sorghum in 1978, and ten new hybrids have been identified to date. These ten, like the 15 produced in previous cycles, are non-classical hybrids. All are more maize-like in appearance, with erratic progressive chromosome elimination. In total, eleven of these 25 hybrids have given seed on backcrossing to maize. Subsequent generations were produced by intercrossing plants within each generation, and different generations of each hybrid were planted in winter season 1978-79 in Tlaltizapan for assessment of useful characteristics.

For more efficient utilization of the alien variation, it is necessary that CIMMYT obtain a better understanding of the cytological behavior of the hybrids and subsequent progeny. To this end CIMMYT employed a cytologist in 1978. In addition it will be necessary to produce more hybrids of wide genetic diversity both for further analysis and for use in plant improvement. Embryo culture is an essential tool for this; and close collaboration has been established with the University of Minnesota to improve such techniques. To aid this program seeds of some harvests were sectioned and examined microscopically to obtain a better understanding of hybrid embryo development.

One paper on this wide cross work has been accepted for publication by Euphytica in 1979.

MAIZE TRAINING

Training offered to scientists from developing countries is a major CIMMYT activity—some say the most important activity—because the developing countries are unable to introduce improved maize technology to their farmers without first testing the seeds and developing new practices under local environments, and this operation requires trained local scientists.

CIMMYT offers several kinds of training and experience to maize scientists from Asia, Africa, and Latin America:

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

–Master's degree program in cooperation with universities in Mexico or USA.
–Predoctoral fellows: 12 to 18 months in Mexico to do their thesis research under CIMMYT supervision.
–Postdoctoral fellows: 2-years service as an associate on CIMMYT staff.
–Visiting scientists or short-term residents.

In-service training

In-service training in the maize program in Mexico is 8 years old and over 400 participants from more than 50 countries have passed through the six months' course.

Approximately 30 trainees participate in each of two training cycles at CIMMYT annually.

At CIMMYT, in-service trainees learn by doing, spending long hours in the field designing experiments, monitoring their developments, harvesting and analyzing their results. The training emphasis continues to be on applying theoretical knowledge to actual field research conditions.

Although each in-service trainee may specialize in one of four categories—production research, maize improvement (breeding), protein evaluation, or experiment station management—the overriding concern is that each trainee will become immersed in production-level problems of the farmer. Such an approach requires that the trainee see through the farmer's eyes. The trainee is helped to look for the farmer's limiting factors; to uncover the constraints to greater production. Appropriate experiments can then be designed for on-farm research (that is, planting trials on the farmer's own fields), and demonstrations for farmers can later be established on the basis of data from the trials.

CIMMYT has developed complementary learning tools, all tied to field operations. The emphasis is on applied use of basic information concerned with fertilizers, pesticides, genetics, farm machinery, pathology, entomology, soil fertility, physiology, statistics, and economics.

Trainees deal with experimental design and data collection from pre-planting to harvest, plus interpretation of results.

Maize in-service trainees 1971-78

Region & Country	1971-78	1978
Central America and Caribbean	**123**	**12**
Belize	5	0
Costa Rica	6	2
Dominica	1	0
Dominican Republic	9	0
El Salvador	21	1
Grenada	1	0
Guatemala	14	0
Guyana	1	0
Haiti	9	2
Honduras	23	0
Mexico	15	1
Nicaragua	11	3
Panama	7	3
South America	**64**	**10**
Argentina	11	0
Bolivia	8	1
Brazil	3	0
Colombia	8	2
Chile	2	0
Ecuador	14	2
Peru	12	4
Venezuela	6	1
South and East Asia	**89**	**24**
Afghanistan	4	4
Bangladesh	2	2
India	7	5
Indonesia	3	3
Japan	5	1
Korea	2	1
Nepal	18	5
Pakistan	21	2
Philippines	17	1
Thailand	10	0
No.Africa & Mideast	**28**	**6**
Algeria	1	0
Egypt	14	2
Syria	1	1
Tunisia	3	0
Turkey	6	3
Yemen A.R.	3	0
Tropical Africa	**106**	**15**
Botswana	1	1
Cameroon	1	0
Ethiopia	3	0
Ghana	6	0
Ivory Coast	4	0
Kenya	3	0
Malawi	1	0
Nigeria	12	0
Rwanda	1	1
Senegal	1	0
Tanzania	46	9
Uganda	1	0
Zaire	22	2
Zambia	4	2
Other	2	0
Total training fellows	**412**	**67**
Total countries	**53**	**29**

Training in national programs

Since 1974 CIMMYT has offered in-service training for officers from national programs who were preparing to give short courses for production agronomists in their own country. Ten trainers have now been trained (Ecuador-3, El Salvador-3, Philippines-1, Pakistan-2, India-1). A Japanese scientist is participating in the trainers course in 1979, preparing to serve his government in Asia—the third Japanese training fellow at CIMMYT.

CIMMYT training staff in Mexico are occasionally lent to national programs where they assist with local courses. During 1978 the maize trainers in Mexico assisted with courses in Nepal, Ecuador and India. The Government of Ecuador organized a novel form of training for maize production workers—in 4 installments: a one-week course before maize planting, another week at mid-season, a third week at flowering time, and a final week before harvest. The head of CIMMYT's maize training staff participated.

CIMMYT often receives agricultural policy makers as short-term visitors. Here (left to right) Shri Bhanu Pratap Singh, Indian Minister of Food and Rural Development, Mr. N.K. Mukherji, Secretary to the Minister, Dr. D.P. Singh, Vice Chancellor of Bihar University and Dr. R.L. Paliwal, Assosiate Director of the Maize Program discuss the merits of improved open-pollinated maize varieties as an element in increasing maize yields in the tropics and subtropics.

Pre and Postdoctoral fellows

During 1978-79 CIMMYT is cooperating in the training of two master's candidates (Bolivia—1, Colombia—1) in Mexico; seven predoctoral fellows from Zaire in the USA; and nine postdoctoral fellows in maize research, from El Salvador 1, Germany 2, Guyana 1, Iceland 1, New Zealand 1, U.K. 2, and USA 1.

Visiting scientists

During 1978 the maize program received 62 visiting scientists and 32 short-term visitors. Visiting scientists are senior crop researchers or experiment station managers who usually spend a few weeks to one full crop season in Mexico to become familiar with world germ plasm and CIMMYT research methods and philosophy, which may be useful in their own national programs. Short-term visitors are often agricultural policy makers and administrators who usually spend a week at CIMMYT.

MAIZE COOPERATIVE PROJECTS OUTSIDE MEXICO

More than 80 maize-growing countries participate in a worldwide network which conducts maize trials and exchanges data. A few individual countries in the network have asked for staff assistance and CIMMYT has received extra core funds to provide this collaboration. Within this network some collaborators have formed regional groupings to whom CIMMYT has posted one or more staff scientists. Fourteen staff members were assigned to these cooperative projects at the beginning of 1979, as described below.

National programs

A national maize program typically fulfills the following purposes: (1) to conduct research in local experiment stations, including participation in international trials; (2) to test improved varieties on local farmers' fields; (3) to multiply seed; (4) to provide additional training for maize scientists; and (5) to formulate national agricultural policies which encourage greater food production. CIMMYT assigned staff share in these purposes, including the testing of germ plasm received from neighboring countries and from Mexico, and in the feedback of information to the network of scientists.

The following national programs participated in co-operative arrangements with CIMMYT at the beginning of 1979:

Cooperative Projects involving national programs, 1979

Country	Start of CIMMYT arrange-ment	1979 Popula-tion (millions)	CIMMYT assigned staff	Approx. maize crop (tons)	Donor*
Egypt	1968	40	1	2,900,000	UNDP
Zaire	1972	27	2	500,000	Zaire/USAID
Tanzania	1973	17	2	950,000	USAID
Guatemala	1976	7	2	750,000	USAID
Ghana	1979	11	1	350,000	Canada

* CIMMYT requires "extra core funds" for support of each national arrangement

Pakistan National Maize Program

Maize is the Number 3 crop in Pakistan after wheat and rice, and helps to feed a population of 77 million (1979) increasing 2.9 per cent a year.

The average yield of maize in Pakistan has risen 25 per cent in the past decade but population increased 30 per cent in the same period.

Since 1965 CIMMYT has posted one or two maize scientists to work with Pakistan's national research and training program. One CIMMYT maize agronomist remained attached to the Pakistan Agricultural Research Council in Islamabad until mid-1978. During his residence in Pakistan he participated in the P.A.R.C. program which included: (1) testing national and international maize nurseries; (2) organizing workshops for provincial maize workers; (3) conducting training courses within Pakistan and sending maize workers for training in Mexico (two in 1978); and (4) working with the Australian Government on development of the Pirsabak maize-sorghum research station.

Egypt National Maize Program

Egypt now imports three to four million tons of grain a year (some rice is exported), a deficit which represents about a third of national cereal requirements for a population of 40 million, growing at 2.3 per cent a year.

CIMMYT has maintained one scientist to work with the Egyptian maize program since 1968. Despite this well-managed program, maize yields over the last decade have not kept pace with the 25 per cent population growth. The breeder-agronomist assigned in 1978 shared with Egyptian scientists the following activities: (1) continued efforts toward the development of an interdisciplinary national maize program; (2) continued development of the population improvement program with emphasis on high yield, shorter plants, early maturity, and resistance to late wilt; (3) growing of international maize trials in collaboration with CIMMYT and other organizations; (4) development of a vigorous on-farm production research program; and (5) agronomy trials to develop better production practices.

The assignment of CIMMYT staff will be terminated in 1979 and Egypt will be served through regional staff.

Zaire National Maize Program

Zaire's 27 million people are primarily maize and cassava eaters. Zaire imports substantial amounts of wheat and rice, and about 200,000 tons of maize a year.

Since 1972 Zaire has financed a national maize research and production program which is assisted by a scientific team from CIMMYT. The annual maize crop of 400-500,000 tons represents about two-thirds of Zaire's grain production, and the low average maize yield (about 700 kg/ha) needs improvement.

Twenty-six university graduates have been sent to Mexico for one cropping season of experience and 11 Zairians have gone to the United States for higher degrees. These trained Zairians now form the nucleus of professional manpower for Zaire's National Maize Program.

Zaire participates in international maize trials shipped from Mexico, Kenya and Thailand. The best of the experimental varieties have been widely tested on farmers' fields, and three elite varieties have been released for commercial use, and constitute a major portion of the maize now grown in Zaire.

Tanzania National Maize Program

Like most people in tropical Africa, Tanzanians eat more maize than any other cereal. Tanzania is a food-deficit country partly because a semi-arid climate has caused wide fluctuations in local grain production. A population of 17 million is growing at 2.7 per cent a year.

CIMMYT works on maize in Tanzania as part of a USAID-supported project, in cooperation with our sister institute, IITA. CIMMYT has stationed two maize scientists in Tanzania since 1973. Forty-six young Tanzanian scientists have been sent to Mexico for one season of maize training including nine in 1978. Four Tanzanians have also been sent to U.S. universities for advanced agricultural degrees.

The maize breeding program is centered at Ilonga station, 300 kilometers west of Dar-es-Salaam. Here outstanding experimental varieties have been developed and several have been released by the Government.

The World Bank is supporting a 7-year maize production program concentrating on the Ujamaa-type villages (cooperative production units). A training program for maize extension workers has been operating at Mbeya research station, using on-farm trials as the means of communicating with farmers. This enables new technology to be put into immediate use.

Ghana National Maize Program

At the beginning of 1979 CIMMYT entered into agreement with Canadian International Development Agency (CIDA) and the Government of Ghana for a 6-year assistance plan to the Ghana Grains Development Project. Maize is the principal grain crop of Ghana (400,000 hectares, 400,000 tons) with lesser crops of rice, sorghum and millet.

Ghana's 11 million people in 1979 have been increasing at 2.9 per cent a year. The country has traditionally been self-sufficient in food grains but droughts during 1974-77 caused substantial food imports.

CIMMYT will provide an agronomist to serve as Joint Coordinator of the Grains Development Project for five years, sharing leadership with a Ghanaian maize breeder.

The Ghanaian project has assembled a number of maize composites—one of them developed from the Mexican population, La Posta, which has been released to farmers; another called Composite W, is a mixture of the best West Africa maize varieties.

Ghanaian maize research is headquartered at the Crops Research Institute, Kumasi (150 kilometers northwest of the capital, Accra). The project began on-farm trials in 1974 and by 1979 has expanded the trials to 1,000 locations. This is the most extensive on-farm testing program in tropical Africa.

Under CIDA financing, 14 Ghanaians will receive maize training in Mexico, 9 Ghanaians will study for the M.Sc. degree outside Ghana, and others will be sent to IITA and ICRISAT for training in legumes or sorghum-millets.

Guatemala National Maize Program

The year 1979 marks the fourth year that CIMMYT has assigned two maize scientists to collaborate with the maize program of ICTA, Guatemala's national agricultural research institute. Guatemala seeks to expand its maize production, the staple food crop, which has fluctuated in recent years between 500,000 and 800,000 tons a year. About two-thirds of the crop is in the lowlands (below 1,500 m) and one-third in the highlands.

The national maize program of Guatemala is among the most diverse in the Western Hemisphere. Research is progressing for both the highland and lowland tropics. Breeders aim to release both open-pollinated and hybrid varieties. High quality protein maize is studied in collaboration with INCAP (Institute for Nutrition in Central America and Panama). Guatemala's on-farm testing program is the largest in Central America (565 sites in 1978). A vigorous young seed industry has been established using procedures which could become a model for the region.

Guatemala recently released two open-pollinated varieties for the lowland tropics derived from CIMMYT advanced populations—designated La Maquina (1978) based on CIMMYT population 22; and ICTA B-1, based on CIMMYT population 21. Use of the new varieties is spreading as rapidly as seed increase permits.

Three family hybrids are being developed by intercrossing CIMMYT experimental varieties. These are designated HB-11 (short plant type, white kernels, from a cross between CIMMYT populations 21 and 22); and HA-34 and HA-44, both with yellow kernels, one a double cross, the other a 3-way cross, involving CIMMYT populations 26, 27, 28, and 36. An earlier variety hybrid, ICTA T-101, has been improved in agronomic characteristics and is being multiplied extensively. All four hybrids are intended for the lowland tropics.

The seed industry developing in Guatemala is remarkable. As recently as 1978 Guatemala still imported 1,000 tons of hybrid maize seed each year at a cost of about one million dollars but this foreign exchange drain should rapidly be eliminated by the domestic seed production strategy which involves: (1) carefully selected private seed growers (12 in 1977, 24 in 1978); (2) foundation seed furnished by ICTA; (3) government services to the seed growers for seed cleaning, treatment, and bagging; and (4) government assistance in market promotion. All available improved seed was sold in both 1977 and 1978. In 1979 enough improved ICTA seed is available to sow 60,000 hectares in the lowlands (about 15 per cent of maize in this climatic zone).

For the highlands, where an ancient maize-oriented culture exists among thousands of small landholders, a totally different research strategy has developed. On-farm testing in the highlands began with experimental varieties developed by ICTA on its experiment stations, grown with the best farmers' traditional varieties as checks. These trials revealed that some traditional highland varieties were superior in yield and wide adaptation. Two years of trials at 50 farm sites gave support for the decision that three traditional Guatemalan varieties should be placed in seed increase and recommended to highland farmers.

Opaque-2 maize, containing higher quantities of lysine and tryptophan, has made sufficient progress in Guatemala that INCAP is now testing maize foods from these mutant maize varieties in home trials with hundreds of families. Two of the opaque varieties with modified endosperm will be widely tested in on-farm trials in 1979, using "normal" maize checks.

CIMMYT anticipates reducing its posted staff from two scientists to one in 1980.

Regional programs

A regional maize program represents one type of linkage between a group of collaborators and CIMMYT. In several parts of the world groups of maize-growing countries have entered into regional arrangements to improve their maize production. Regional groupings generally comprise neighboring countries in which maize is a major crop, grown under similar climatic conditions, exposed to similar diseases and insects, and therefore benefiting from continuous exchange of germ plasm and technology within the region.

Typically a regional program will sponsor: (1) periodic workshops among maize scientists to review one year's research and plan the following year; (2) maize trials for the region; (3) visits of local scientists to neighboring countries; (4) training within the region; and (5) consultation by CIMMYT scientists.

At the outset of 1979 CIMMYT scientists shared in maize improvement in the following regions:

Regional Maize Programs in 1979

Region and home base	Number of Cooperating countries	1979 Population (millions)	Approx. maize crop (tons)	CIMMYT assigned staff	Donor	Start of CIMMYT arrangement
Central America and Caribbean (Mexico)	13	34	2,200,000	2	IDB Switzerland	1976-76 1977
South and Southeast Asia (India)	11	1200	17,500,000	1	UNDP	1976
Andean region (Colombia and Ecuador)	5	71	2,800,000	3	Canada	1976

Central America and Caribbean Regional Program

Thirteen countries of Middle America have entered into a cooperative program for maize improvement. The participating nations now have a combined population of 34 million people still increasing at about 3 per cent a year. The food deficit for the region is substantial: these countries produce about three million tons of grain a year and import over 1.5 million tons; hence the grain deficit is about one-third of consumption.

Most people of the region are maize eaters. Maize represents about 80 per cent of local grain production.

Since 1974 CIMMYT has assigned two maize scientists to work with these governments, assisting maize scientists of the region and consulting with agricultural policy makers. The CIMMYT team helps governments plan their annual research programs, recommends the international trials

CIMMYT's Central American regional staff spend most of their time travelling between the national programs found in this region. Here CIMMYT staff attend a field day reviewing on-farm research activities of a former CIMMYT in-service trainee, Ing. Agr. Gilberto Araya.

shipped from Mexico, advises local policy makers on their research budgets and input requirements, and helps conduct workshops for maize scientists of the region.

The team also helps to plan and promote on-farm trials for experimental varieties and organizes training courses for production agronomists. The two CIMMYT scientists were awarded certificates of recognition in 1978 by the ministers of agriculture of this region for their contributions to agricultural growth.

In 1978 the two regional scientists gave seven months to consultation and training. A total of 97 young maize scientists from this region have now completed the six-month training course in Mexico, and more senior local scientists have spent some weeks in Mexico as visiting scientists, participating in CIMMYT's research procedures.

In 1978 the participating governments planted 124 international maize trials at their experiment stations, and another 900 trials were planted on farmers' fields.

Two workshops were held in 1978 for scientists of the region.

The maize-bean project at Danli, Honduras—a mixed cropping project initiated by the government with financial help from the Inter-American Bank—has emerged as an outstanding production project of this region. Starting from average maize yields of 1.2 tons a hectare on 7,000 hectares (1974) the Danli project achieved average yields of 4.0 tons on 50,000 hectares in 1978. With the help of this project, Honduras moved from a maize deficit to a surplus in four years. Scientists from neighboring countries have been given CIMMYT travel grants to visit the Danli project.

Average national maize yields among participating Central American countries ranged from 0.9 to 1.7 tons per hectare in 1974 when CIMMYT's regional program began. The averages in the region have been slowly rising, and future progress will be judged by this indicator on farmers' fields.

South and Southeast Asia Regional Program

Eleven countries of South and Southeast Asia participate in a regional maize program. These countries have a combined population in excess of 1,200 million, increasing at 2.5 per cent a year (that means 30 million people added annually).

The region produces 255 million tons of grain a year, with rice, wheat and maize the principal crops in that order. A small percentage food deficit is met by imports—in 1977 the deficit was 10 million tons, smallest of the decade.

Maize production in this region has reached 17 million tons, at national yields ranging from 0.8 to 2.2 tons a hectare. India produces about a third of the regional maize with average yield of 1.1 tons. Production in the Philippines passed three million tons in 1977 and Thailand reached three million tons for the first time in 1978. The Philippines and Thailand have each increased their maize production by more than one million tons during the 1970's.

Since 1976 CIMMYT has maintained one breeder-agronomist, based in India, to assist in the exchange of germ plasm and ideas between countries.

CIMMYT's regional scientist consulted with 10 participating governments during 1978, plus Japan and South Korea. Other CIMMYT staff scientists from Mexico spent extended periods in this region during 1978 including the CIMMYT maize director (80 days), CIMMYT training agronomists (25 days), and the head of CIMMYT research stations (15 days).

Starting in January 1979 CIMMYT received 2-year funding from the Government of Canada (CIDA) to collaborate with the India National Maize Program through exchanges of visiting scientists, germ plasm, and consultative services.

India's national maize crop—grown under rainfed conditions—has fluctuated between 6-8 million tons during the 1970's. The crop is largely concentrated in the northern tier of states where the testing of new maize varieties on farmers' fields is now a widespread activity. CIMMYT has assisted this development by multiplying seed at the ICRISAT station in southern India during the off-season.

National maize coordinators for India, Thailand, and the Philippines provide leadership in circulating regional maize nurseries which are tested in collaborating countries.

India, Thailand, and other countries of the region have already attained a surplus in maize or are approaching that situation. Thailand is a major exporter of maize. CIMMYT sponsored with the Indian Council of Agricultural Research (ICAR) an international workshop on maize utilization, processing and marketing at New Delhi in the first half of 1979.

Andean Regional Program

Five Andean countries—Bolivia, Colombia, Ecuador, Peru and Venezuela—produce about 7 million tons of grain annually and import 4 million tons—hence their deficit of basic cereals exceeds one third of the regional requirements. Maize and rice are the largest local crops and wheat is the main import.

In 1979 the population of the region will pass 71 million, increasing at 2.9 per cent a year.

These five countries have entered into a cooperative maize improvement program to exchange maize technology, and CIMMYT has posted two maize scientists in Colombia based at CIAT and one in Ecuador to assist in regional activities which include: (1) workshops among regional scientists each year; (2) maize nurseries exchanged within the region, containing the best materials from participating countries plus experimental materials from CIMMYT; (3) a joint breeding program for floury maize (large soft kernels preferred in the highlands) assisted by a CIMMYT breeder at Santa Catalina station, Ecuador; (4) trials of experimental maize varieties on farmers' fields assisted by a regional agronomist and economist; (5) training for local maize scientists either within national programs or at CIMMYT-Mexico; and (6) consulting by regional scientists on problems holding back maize yields.

Forty-nine local maize scientists have now been trained in Mexico for one crop season (11 in 1978) and CIMMYT-CIAT staff assisted in organizing local training courses for maize agronomists in Colombia and Ecuador during 1978-79.

A workshop at the National Agrarian University, Peru in May 1978, drew nearly all maize scientists of the Andean region, as well as eight CIMMYT-CIAT staff members.

This CIMMYT breeder, works throughout the Andean region from his home base at CIAT in Cali, Colombia. Here, he stands beside the variety La Posta, a promising candidate for farmer acceptance in parts of the region.

The breeding program for highland floury maize has put together six gene pools for population improvement, five managed at Quito, Ecuador, and one at Cochabamba, Bolivia. One difficulty with floury maize is its multiple uses—each needing specific qualities--for choclo (roasting ears), tostado (parched corn), chicha (fermented beer), mote (hominy), or maize meal and flour. The diverse uses involve a variety of plant types, planting dates, maturity dates, grain color and flavor. Another difficulty is the almost total absence of chemical fertilizer applied to highland maize except to the plantings which will be sold as a cash crop of roasting ears. The present highlands gene pools represent the first region-wide effort to assist the sierra small holders with their preferred food.

Ecuador's maize crop of 250,000 tons is the second most important food crop, after rice, in the diet of 8 million people who are increasing at 3.2 per cent a year.

In June 1978 the Swiss Government made a grant of $109,000 to CIMMYT to finance two years of collaboration with the Ecuadorean National Maize Program. The principal activity under Swiss funding is "production research" by Ecuadorean economists and agronomists who are conducting on-farm trials. No expatriate staff are included in the plan, but CIMMYT's maize breeder and economist posted in Ecuador under the Andean regional program (Canadian financed) are assisting the production research.

CIMMYT staff members posted to this region spent over 250 man-days of travel and consultation with the five governments during 1978.

National maize yields in the Andes now range from 0.9 tons (Ecuador), to 1.2 tons (Bolivia and Colombia), to 1.4 tons (Venezuela), to 1.7 tons (Peru). The success of the regional program will be measured over years by the increase of these relatively low yield levels.

wheat improvement

INTRODUCTION TO THE WHEAT PROGRAM

World wheat production for the year ending mid-1979 is forecast to be 412 million metric tons, approximately equal to an all-time record high in 1977 of 415 million tons. (Source: U.S. Department of Agriculture, World Grain Situation, October 1978.)

Developing countries will produce about 87 million metric tons of wheat for the year ending mid-1979, a sizable drop from the record high in 1977.

Developing countries continue to import 30-35 million tons of wheat and wheat flour each year, representing a deficit of more than a quarter of the wheat they consume.

Stable resistance comes first

Stable resistance to the three rusts remains the first objective of the wheat scientist. Rust has been a threat to the wheat crop for thousands of years. Constant mutation of the rust pathogens provides new threats to wheat varieties, including the varieties previously considered resistant to the existing races of rust. The breeders must therefore give first attention to the development of new varieties which combine different sources of resistance to the three rusts, and thus provide replacements for today's commercial varieties when they are found susceptible.

The multiline, described elsewhere in this report, offers one option for slowing down a rust epidemic—probably one of the better ways to introduce a measure of stability for resistance. India in 1978 became the first country to approve for release to its farmers several of the new multilines based upon derivatives from the cross 8156.

Raising the yield ceiling

Raising the yield plateau is the second objective of the wheat scientist.

Semidwarf wheats distributed from Mexico in the 1960's raised the yield potential for wheat in the research station from 4 t/ha to the 7-8 ton range. Since that time the yield potential has gradually increased to the range of 8-9 tons. But in general a yield plateau has existed for a decade.

Although many of the benefits of the so-called "green revolution" in the developing countries are still to come, we are already asking ourselves where and how can we add another dimension to the present revolution in crop production. Although it is obvious that we must continue to expend most of our research effort and budget on the crops that feed the world today, we must also explore in a modest way other new approaches.

A major step in this direction is being made by the development of the new man-made crop triticale. The new species was created by producing a "sterile mule" plant by hybridizing wheat and rye and manipulating the chromosomes with chemicals to induce fertility. The new form possesses all of the genetic mechanism of two species, wheat and rye, in a single species. The genetic potential of this species in increasing food production and improving nutritional quality is indeed promising.

Triticale is not intended at present to replace wheat as a commercial crop, except under very special conditions where it greatly outyields wheat. On very acid soils, such as the highly leached laterites of Brazil, Kenya, Ethiopia, Tanzania, and the outer ranges of the Himalayas in northern India, Pakistan and Nepal, triticale will frequently yield twice as much as the best wheat. At present, under the best irrigated areas in Sonora, Mexico—the home of the Mexican dwarf wheats—triticale yields as much as the best wheat varieties. In the same area 10 years ago it yielded only 50 per cent as much as the best wheat.

About this report

In this report our staff has assembled a summary of recent activity.

In 1978 our international nurseries for bread wheat, durum wheat, barley, and triticale were shipped to 108 countries. These nurseries put new germ plasm on display and generate testing data to guide the worldwide wheat network in further breeding.

Fifty-eight young wheat scientists from developing countries were brought to Mexico in 1978 to work one cropping season with CIMMYT staff. They are now back in their home countries where they serve as part of the world network. Sixty visiting scientists came to CIMMYT to learn more about our program, help in varietal selection and explore new techniques for crop improvement.

Our Mexico wheat staff travelled to more than 60 countries in 1978 to observe the international wheat trials, to talk with farmers, to consult with policy makers, and to visit former trainees.

Highlights of these activities appear in the following pages.

N.E. Borlaug

BREAD WHEAT

Over the last fifteen years, the adoption of high yielding semidwarf bread wheat varieties (HYV's) in developing countries has been remarkably fast when compared to any other crop and any other time period. By 1976-77 at least 29 million hectares in the developing world—more than half in the Indian Sub-Continent—were seeded to varieties containing semidwarf germ plasm developed by CIMMYT and collaborating national programs. Much of this HYV wheat is grown under irrigated conditions. Future increases of land seeded to HYV will come through their expansion into rainfed production areas primarily in regions of North and West Africa, the Near East, Latin America, and the Sub-Continent.

The central objective of the bread wheat program continues to be the development of disease resistant germ plasm with high yield potential and wide adaptation. Breeders believe that wide adaptation can best be obtained by a combination of the following characteristics:

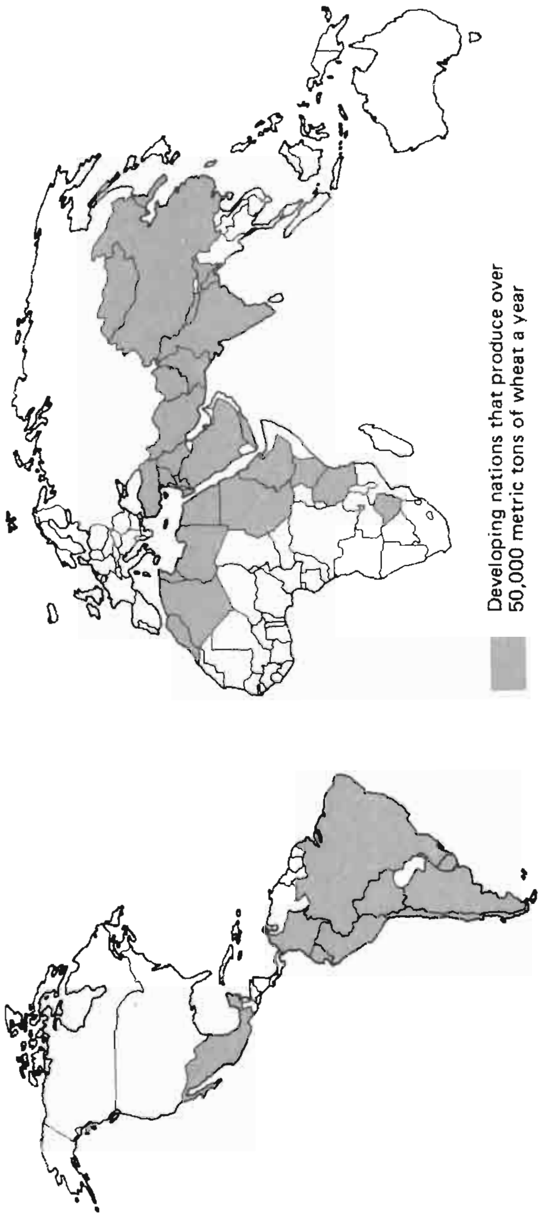
(1) High yield potential across different climates
(2) Semidwarf character
(3) Broad disease resistance
(4) Day length insensitivity.

Wheat research in Mexico is conducted in two cycles each year, one a winter crop at Cd. Obregon (40 m altitude, 27°N latitude); the other a summer crop at Toluca (2,640 m elevation and 19°N latitude). The movement of successive generations between these contrasting climates, each characterized by endemic rust attacks, enables breeders to select day length insensitive, widely adapted lines with high levels of rust resistance.

To ensure heavier pressure from diseases, CIMMYT supplements the natural presence of pathogens with artificial inoculation.

This approach cuts in half the time needed to develop a new variety, and selection in alternate segregating generations under contrasting environments leads to adapted types which may be grown under widely differing conditions.

Finally, bread wheats which prove superior in the Mexico trials are subjected to worldwide testing in over 100 countries across many environments. This testing process serves both to distribute new germ plasm to the national programs and feeds


Developing nations that produce over
50,000 metric tons of wheat a year

information to a worldwide network of scientists about disease resistance and wide adaptation.

The bread wheat program made 8,000 crosses in 1978 and evaluated more than 40,000 segregating lines at each of two alternating sites in Mexico: Cd. Obregon and Toluca.

Breeders have experienced a yield plateau in wheat for the last decade. Still CIMMYT-derived varieties which possess new genetic resistance to diseases and improved quality for bread making are being released by national programs.

Yield testing of advanced lines

At Cd. Obregon, along with the segregating lines, more than I,700 advanced lines were evaluated for yield, grain color, plant height, and rust reactions to select high yielding germ plasm for the International Bread Wheat Screening Nursery (IBWSN). From this material 465 lines were selected to make up the 12th IBWSN sent out in 1978 to 180 locations throughout the world. These lines represent about one quarter of the lines developed in bread wheat. The remainder are also tested by CIMMYT regional staff for adaptation and usefulness in those regions.

The IBWSN is designed to assess rapidly a large number of advanced generation lines of spring wheats under a wide range of latitudes, climates, day lengths, fertility conditions, water management and most specifically, disease conditions. The 95 best yielding entries in the 12th IBWSN will be tested in elite yield trials in four locations in Mexico during I978-79 for possible inclusion in future international yield trials.

The International Spring Wheat Yield Nursery (ISWYN) is designed to test the adaptation of groups of spring wheat varieties under a wide range of conditions. In 1978, the seed of 50 lines for replicated yield trials was sent to 95 countries requesting this nursery.

New variety releases

Twelve countries released CIMMYT-derived bread wheat varieties to their local farmers in 1978. These countries and the number of CIMMYT-related varieties released were:

- Algeria (5)
- Brazil (1)
- Chile (4)
- Ecuador (1)
- Guatemala (1)
- India (1)
- Iraq (1)
- Pakistan (1)
- Paraguay (1)
- Peru (1)
- South Africa (7)
- Spain (4)

Spring x winter crossing

CIMMYT, working in cooperation with Oregon State University (OSU), is attempting to transfer useful genes between spring wheats and winter wheats. These are two separate gene pools, and scientists believe that intercrossing can produce yield increases in both types. Crossing may improve other characteristics such as disease resistance, and drought tolerance. A wider range of maturity may also become available for both winter and spring wheats.

The climatic conditions at CIMMYT's Toluca station are severe enough during the winter to allow direct planting in November of winter types with natural vernalization. In January, spring types are planted bringing both winter and spring types to flowering in May when approximately 1,500 spring x winter crosses are made. The seed from the crosses is divided equally with OSU. Advanced lines selected from winter x spring crosses grown in Mexico and Oregon are distributed through international nurseries.

This spring x winter crossing program presently uses winter wheats from 10 European countries: Austria, France, German Federal Republic, Great Britain, Hungary, Netherlands, Poland, Rumania, USSR, and Yugoslavia. Additional winter parents come from Asia (Japan, Korea, Peoples Republic of China and Turkey), from South America (Argentina and Chile), and from the USA. The Russian winter variety Kavkaz has proved to be an excellent combiner with spring wheats.

Facultative wheats

Some wheat-producing areas of the world—-such as Argentina, North Africa and the higher areas of the Mideast—require spring wheats with greater cold tolerance to withstand late spring frosts. These are called facultative wheats.

Beginning in 1978 CIMMYT selected progeny from the winter x spring crossing program to be retested for cold tolerance in order to serve as facultative wheats. To the present time, CIMMYT has never developed a semidwarf facultative wheat.

8156 multiline

CIMMYT has long warned of the dangers in growing genetically similar wheat cultivars over large areas. Accordingly, CIMMYT breeders have been involved for eight years in an international program to develop a multiline composite variety based on cross 8156. A multiline cultivar is a mechanical mixture of agronomically similar plant types (resembling each other in plant height, maturity period and grain appearance) but differing genetically in rust resistance. Cross 8156 was made by Dr. Borlaug in 1955 while working in the Mexican

National Wheat Program. Progenies from this cross were used as parents to produce a long series of Mexican semidwarf wheats. This variety has been in commercial use on millions of hectares in the sub-continent for more than ten years.

It is not possible for the CIMMYT bread wheat program to produce multiline composite cultivars for individual countries because suitable components must be selected locally. Therefore, CIMMYT produces possible components for multiline composites and sends them to interested nations for agronomic and pathological evaluation.

The 6th International Multiline (8156) Nursery was distributed to 30 locations in regions of 8156 adaptation. Some of the very best yielding components of this nursery were assembled as a Multiline (8156) Yield Trial and sent to one location each in India, Pakistan, Egypt and Algeria.

India multilines

In 1978 India approved for release three multiline composites based on the 8156 genotype. Each composite contains from 6 to 9 component lines. CIMMYT-derived components were used as parts of two of the newly released multiline composites; Indian colleagues developed the other components. Plans called for 20,000 kg of multiline seed to be increased for sale in India for the winter season 1978-79.

Disease resistance

Breeding for disease resistance, especially to the three rusts, is an integral part of the CIMMYT breeding program. Various locations in Mexico known for the presence of wheat debilitating diseases are used as sites for the selection of lines exhibiting resistance. Starting in 1967, the IBWSN served to identify lines that were broadly resistant to disease. Since 1970 many more international and regional disease nurseries have come into existence. These nurseries broaden the base for identifying germ plasm resistant to wheat diseases.

Breeding for aluminum toxicity resistance

There are areas of actual or potential wheat production, for example, in Brazil and East Africa, which have acid soils and aluminum toxicity problems. A program was initiated in 1973 to transfer resistance to aluminum toxicity into high yielding disease resistant semidwarf wheat types. The resistance now available is mainly in tall, low-yielding, poor agronomic wheat types. One exception is Alondra "S" which is a high yielding semidwarf from the CIMMYT program which although it does not carry aluminum toxicity resistance, performs well in these soils. This variety is being widely crossed by Brazilian breeders. To avoid the problems inherent in narrowing the genetic base of subsequent progeny, breeders have selected 286 semidwarf types with some tolerance to aluminum toxicity. These are being intercrossed and advanced lines from this material will become available from the CIMMYT program in 1980.

Through a program of "shuttle breeding", CIMMYT and several Brazilian research organizations (EMBRAPA, FECOTRIGO, and OCEPAR) are developing improved materials at an accelerated pace by planting alternately in Brazil and Mexico in the same year. This has allowed selection for aluminum toxicity in one cycle and for superior agronomic types in the other cycle.

In 1978 CIMMYT is receiving help in its aluminum toxicity studies from Dr. C.F.Konzak of Washington State University, USA. He is testing under laboratory conditions a large number of CIMMYT breeding materials for aluminum toxicity resistance.

Wheat for the humid tropics

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

While CIMMYT believes that other crops, maize in particular, are probably better suited to such environments, CIMMYT has carried out some breeding to develop lines which are able to tiller more adequately and resist the common fungus disease, *Helminthosporium.*

In 1977-78, 2,470 lines were evaluated for resistance or tolerance to *Helminthosporium.* A severe epidemic developed and destroyed most of the lines in this nursery. Some 131 lines showing promising resistance were retained and distributed to 50 locations in the world plagued by this disease. The results of this international testing under varying environments will identify those lines with superior resistance to

Helminthosporium and these can used as parents in the breeding program. These lines also may be multiplied and released in those areas where this disease is a problem. Levels of resistance are still somewhat inadequate but attempts are being made to pyramid resistance from different sources.

Wheats with early maturity

Early maturing wheat varieties are needed in certain areas to fit rotation patterns with other crops.

Although early maturing varieties like Inia 66 and Sonalika have shown broad adaptability, they have been susceptible to various diseases. In 1978 Chinese and Korean germ plasm were crossed with the main CIMMYT material. From the advanced CIMMYT material 234 lines were identified in 1978 to be as early as Inia 66. In 1979 these lines will be evaluated for yield and the best lines will be distributed through the international nurseries to appropriate areas.

Selected spring bread wheat varieties bred by CIMMYT-INIA or predecessors, released in Mexico, 1950-78

Year of Mexican release	Variety name	Year of cross	Yield potential kg/ha*	Plant ht cm	Grain Color	Stem rust	Leaf rust	Stripe rust	Septoria
					Disease rating in Mexico 1978**				
1950	Yaqui 50	1945	3500	115	Red	TMS	20MS	10MS	MR
1960	Nainari 60	1958	4000	110	Red	10MS	5R	0	–
1962	Pitic 62	1956	5870	105	Red	100S	60S	80S	MR
1962	Penjamo 62	1956	5870	100	Red	50MS	0	80S	MR
1964	Sonora 64	1957	5580	85	Red	20MS	70S	80S	S
1964	Lerma Rojo 64	1958	6000	100	Red	30MR	80S	80S	S
1966	INIA 66	1962	7000	100	Red	5MR	100S	80S	S
1966	Siete Cerros 66	1957	7000	100	Amber	TMS	60S	100S	S
1970	Yecora 70	1966	7500	75	Amber	TR	100S	100S	S
1971	Cajeme 71	1966	7000	75	Red	TR	100S	100S	S
1971	Tanori 71	1968	7000	90	Red	20MR	80S	60S	S
1973	Jupateco 73	1969	7500	95	Red	TMR	80S	60S	S
1973	Torim 73	1967	7000	75	Amber	TMR	20MS	40S	S
1975	Cocoraque 75	1969	7000	90	Red	TR	TR	20MR	S
1975	Salamanca 75	1967	7000	90	Red	TMR	20MS	20MS	S
1975	Zaragoza 75	1964	8000	90	Red	0	30MS	80S	S
1976	Nacozari 76	1969	7500***	90	Amber	0	TMR	10MR	S
1976	Pavon 76	1970	7500***	100	Amber	0	TMR	10MR	MS
1977	Pima 77	1964	7500***	90	Amber	5MR	TMR	30MS-MS	S
1977	Hermosillo 77	1972	7500***	85	Red	5MR	5MR	TR	S
1977	Jauhara 77	1969	7500***	90	Red	5MR	TR	TR	S

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

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

*** Yield of varieties released in 1976 and 1977 has ranged 7500-9500 kg/ha in different seasons and trials, but the conservative minimum of 7500 kg/ha as given here for all five releases.

DURUM WHEAT

Durum wheat is grown extensively in the Mediterranean region, the Mideast, India, the Andean countries, Argentina, Chile, USSR, Canada, and USA. Semolina (durum wheat flour) is generally used for macaroni, spaghetti and other pasta products; and for flat-unleavened bread in the Mideast countries, couscous in North Africa, chapatis in India, bulgur in Turkey and mote in the Andean countries. Worldwide, durum is grown on about 30 million hectares which produce an estimated 20 million metric tons of grain.

Although some attempts to reduce the plant height of durums in Mexico started in the early 1960's, CIMMYT did not start a durum program per se until 1968. Data from research on experiment stations as well as on farmers' fields in the irrigated northwest area of Mexico indicate that durum yields have reached the same levels of the best bread wheats. The problem of sterility of dwarf and semidwarf durums has been diminished significantly and higher head fertility of new developed lines now is maintained in both the summer and winter plantings.

The incorporation of adequate levels of resistance or tolerance to the most prevalent diseases is a primary effort in the development of new durum lines. Significant progress is being made by intensive testing in many countries. Seven different types of durum nurseries are sent from Mexico to collaborators in 79 countries. Two nurseries—the International Durum Screening Nursery (IDSN) and the International Durum Yield Nursery (IDYN)—are important in the testing networks to measure the performance and adaptation of current varieties and new lines.

Cultivars evolved from the international durum testing program, such as Jori 69, Cocorit 71, Mexicali 75, Amal 72, Dicle 74, Gediz, Maghrebi 72, Quilafen, are grown commercially in various parts of the world. Also some advanced lines—Loon "S", Scarcies "S", Harlequin"S", Bittern "S", Guillemot "S" and Kranich "S"—look very promising at locations in North Africa and the Mideast.

Higher yields

In 1977-78, 510 new durum lines with checks of bread wheat, triticale and durum were planted in 17 yield trials at Cd. Obregon, Sonora, Mexico. In these trials, 30 durum lines outyielded the best checks by 5-14 per cent despite unusually hot weather that affected all cereal grains. Although the average yield of the five top yielding durum lines grown at Cd. Obregon has diminished during the last two seasons, due to adverse weather conditions, average yields in 1977-78 were still higher than the average yields of 1975-1976. The best lines outyielded durum, bread wheat and triticale checks by as much as 19 per cent during the last growing season of 1977-1978. Also elite durum yield trials (EDYT) planted at CIMMYT headquarters, El Batan, in summer 1978 outyielded by 25.4 per cent the EDYT planted in 1977 at the same location.

Durum varieties released in Mexico between 1940 and 1978.

Year of Mexican release	Variety name	Year of cross	Yield potential* kg/ha	Plant ht.* cm	Disease reaction** Stem rust	Leaf rust	Stripe rust	Test weight kg/hl	*** Pigment ppm
1941	Barrigon-Yaqui		4000	130	0	TS	70S	75	4.5
1960	Tehuacan 60	1954	4200	150	0	10MR	20MS	81	5.5
1965	Oviachic 65	1960	7000	90	0-40MS	30S	5MR	81	7.2
1967	Chapala 67	1961	7000	85	0	10MS	10MR	83	4.0
1969	Jori C 69	1963	7700	85	0	TR	5MS	81	3.7
1971	Cocorit 71	1965	8300	85	0	5MR	5MS	81	3.6
1975	Mexicali 75	1969	8600	90	0	TR	5MR	78	5.8

* Measured at CIANO experiment station, under good agronomic practices.
** In Mexico, 1975. R=resistant, MR=moderately resistant, MS=moderately susceptible, S=susceptible. Figures before letters indicate percentage of infection.
*** Carotinoids.

EDYT data from the nurseries planted during 1970-78 at various locations around the world indicate an average annual yield increase of 11.2 per cent per year.

Disease resistance

The durum program in Mexico continues to search for new sources of resistance to the most destructive diseases of durum wheat, such as leaf rust, stem rust, stripe rust, powdery mildew and *Septoria.* Year after year lines with good resistance to these diseases are identified from IDYN data, and from other nurseries operated by CIMMYT's sister institution, ICARDA. Also, the USDA World Durum Collection is periodically screened to identify disease resistant strains.

These resistant materials then are crossed with other parental types containing desirable breeding characteristics.

Developing better agronomic type

Durum materials of short stiff straw are being developed for areas which are irrigated and highly fertilized. Emphasis is also given to developing medium and tall lines with strong straw for moisture-short rainfed areas where such types perform better because of superior ability to compete with weeds during the growing season. Drought tolerant materials from Russia, India, and North Africa are being utilized in crosses to develop lines with greater drought tolerance.

Some cold tolerant materials are being developed for areas where hazards of frost damage exist. In 1977-78, new crosses were made with materials from the durum world collection that suffered the least damage when grown under -11^{o}C temperature at the Toluca station.

Improving head type and fertility

Durum wheat lines with semi-lax, highly-fertile heads reduce the possibilities of headrotting diseases such as head-scab. Some fertile durum lines included in the 8th EDYT nursery distributed in 1978 have exceeded the fertility of the checks Mexicali 75 (durum) and Jupateco 73 (bread wheat) by nearly 14 per cent in trials planted at El Batan and Cd. Obregon. Breeders are continuing to search for lines with higher fertility.

Semolina and macaroni quality

To be readily marketable, durum wheats must have a high grain test weight, large size grains and a good macaroni color (largely determined by carotene content). CIMMYT's cereal quality laboratory routinely screens new high yielding lines for test weights and carotene content to help select parents which do not lose their carotene content during macaroni processing. Carotene content in CIMMYT lines compares favorably with the best Italian macaroni durums.

TRITICALE

CIMMYT continues its work on the man-made crop triticale, a hybrid cross of wheat and rye. CIMMYT's program is directed primarily toward the improvement of "hexaploid" type spring triticales (durum-rye cross). The objective is to develop a high yielding grain crop for those areas of developing countries where triticales outperform other cereals.

From the beginning of the program, attention has been focused on the problems of sterility, lodging, seed shrivelling, disease susceptibility, undesirable height, and late maturity. Notable progress has been made in ameliorating each of these problems. Today, new improved lines of triticale are at the threshold of commercial use in a number of developing countries. Kenya, Brazil, Chile, India and Portugal —all with active triticale research programs—are on the verge of releasing commercial varieties. These countries may soon join a number of mainly temperate zone nations—Mexico, Argentina, Australia, Bulgaria, Canada, Peoples Republic of China, Hungary, South Africa, Spain, Soviet Union, and the United States—which already have released triticale varieties for commercial use.

Four spring triticales, developed in collaboration with the CIMMYT program, have been released in 1978 for commercial production in the United States, Canada, Bulgaria and Australia. They are Siskiyou, Beagle, Welsh, and Mexitol.

It is in temperate zone countries where triticales have first been adopted. Worldwide, roughly 160,000 ha are in triticale production, with 95 per cent occurring in developed countries. There are several reasons why this has happened:

(1) Most of the semi-tropical countries satisfy part of their demand for wheat through imports, and their milling and bread making industries are not sufficiently familiar with triticale to risk using it as a substitute for imported wheat.

(2) Most developing countries do not have sufficient research personnel or familiarity with the crop to finance the necessary research in agronomy and utilization, or to develop a strong extension effort. Many organizations are taking a "let's wait and see" attitude.

Yield performance

The preliminary summary of results for the 71 sites reporting on the 14th International Spring Wheat Yield Nursery

(ISWYN) show that the mean yield of the triticale variety Mapache used as a check in these trials slightly outyielded the mean yield of Pavon, the best bread wheat variety. The mean test weight of the Mapache grain (weight of one hectoliter of grain) was, however, considerably lower than that of the Pavon grain (65 kg/hl compared to 79 kg/hl). Still, triticale may have the potential of surpassing the yield of bread wheats. Future improvements in grain plumpness will also result in an increase in yield.

In term of yielding ability, triticale has come of age. Today, the best triticale lines often yield as well as the best bread wheats. Triticale has the greatest comparative advantage over wheat in acid soils with aluminium toxicities (campos cerrados, Brazil) and cool highland production areas (Himalayan and East African highlands).

Grain quality

Abnormal endosperm development resulting in a shrivelled seed with a deep crease has been a persistent problem in the improvement of triticale. This is reflected in the lower test weight which results in lower levels of flour extraction compared to bread wheats. Camel, a triticale strain resulting from the cross of Armadillo with the bread wheat variety INIA 66, has been used extensively to improve grain characteristics in triticale. Recent new strains, called Panda, have demonstrated grain test weight ranging between 71 and 79 kg/hl which represent the highest test weights achieved for triticales (standard for the U.S. bread wheat industry is 76 kg/hl). Unfortunately, Panda lines are quite tall, have weak straw and are of low yield potential. A crossing program involving Panda and high yielding, well adapted triticale strains was started in 1976 resulting during 1978 in the distribution of over 250 lines with test weights above 73.5 kg/hl in international triticale nurseries.

Nutritional and industrial quality

Protein quality levels of triticale grain, in terms of lysine, have tended to stabilize at levels superior to bread wheats. Industrially, the new triticale strains can be used to make all the commercial products which are made from bread wheats. A good loaf of bread can be made with 100 per cent triticale flour by adjusting the mixing and fermentation times. Most triticales will produce a higher loaf-volume if mixed with 40 per cent bread wheat flour. The trend toward increasing test weights in the new triticale strains has resulted in a remarkable increase in the per cent of flour extraction. In general the newer strains give about 65 per cent flour, and in certain cases, up to 71 per cent flour which is comparable with wheats.

CIMMYT began breeding work in 1978 on two problems which prejudice the acceptability of triticale as a commercial crop: sprouting in the head under wet harvest conditions and damage to seed in storage. Both spoil the grain quality for commercial use. Sources of resistance to pre-harvest sprouting are being identified. A chemical method has also been used to identify strains lacking the needed enzyme to resist the sprouting of seed.

Many triticale strains tend to have soft kernels with a deep crease which attracts storage grain insects to feed and multiply. In contrast, wheat varieties suffer lower losses. Recently, CIMMYT cereal technologists have identified triticale strains with improved baking quality. These triticales have harder grain texture which may show lower damage to the grain during storage.

Disease resistance

The resistance to stem rust and stripe rust in the Mexican triticales has been well established but data from international testing indicate that resistance to leaf rust is considerably less stable. However, good sources of resistance to leaf rust are present in the triticale program.

Experimental plots are inoculated regularly with a mixture of field collections of various disease pathogens, especially rusts, to provide uniformly severe conditions for selection.

As yet, disease and insects are not serious problems to the triticale crop. However, this situation could change as the area under commercial production of triticale increases.

Broadening adaptation in triticale

The practice of growing two crop cycles a year in Mexico under very different agroclimatic conditions has significantly improved the adaptation of Mexican triticales. This alternation of environments permits the identification of strains which are light insensitive, resistant to diseases and with high yield potential. Several triticale strains like Mapache, Beagle, Bison, Rahum and Bacum can be classified in the broadly adapted class.

Acid soils

Triticale appears to have an advantage in adaptation over the high yielding wheats in certain acidic tropical soils characterized by heavy rainfall and often by aluminum and copper toxicities. Triticales have outperformed wheat and other cereals under such soil environments in Brazil, East Africa and the Himalayas.

Mountain areas

Certain triticale strains are also quite well adapted to cultivation under cool growth temperatures found in high elevations of tropical mountain areas. The plant vigor and yield of some triticale strains under low evening temperatures is excellent. Triticales have also shown higher tolerance than wheat to frost during the early vegetative period.

Diversification of germ plasm

To introduce fertility, all strains of triticale developed in Mexico have been crossed with the line Armadillo. This has resulted in a narrowing of the germ plasm base with accompanying disadvantages. CIMMYT now employs three approaches to increase variability in newer strains. These are: inter-crossing triticale with bread wheat, durum, and rye species; creation of new primary triticales; and crosses of the Mexican spring triticales with winter germ plasm from Europe and North America. As Mexican conditions do not permit a good selection for winter hardiness, such selection is being made in Oregon, Canada and several European locations. The segregating populations between these types are showing a widening range of variability for all characters.

Forage triticales

The crosses between spring x winter triticales are producing several segregates which have the vigor and rapid growth habits of spring types. Under experimental cuttings, these strains are showing an excellent ability to regenerate and produce more green forage. Some of these materials are being distributed for further grazing tests in national programs, particularly Argentina.

International nurseries

In 1978 CIMMYT sent 11 types of triticale nurseries to 83 countries for testing in 400 locations. Nurseries include both spring and winter triticales and represent both segregating populations and advanced lines.

The increase in the amount of material sent out coincides with an increase in the number of selections and information received from cooperators.

National programs

Based on research reports received from collaborators it appears that triticales show greatest competitive advantage in three regions of developing countries:

(1) The Hill Areas of India, Pakistan, and Nepal.

(2) The East African Highlands, from Ethiopia to South Africa.
(3) The Southern Cone countries of South America, particularly Brazil, and in Colombia to the north.

Latin America

Latin America, Brazil, Chile and Mexico have active programs for triticale testing. Brazil has found superior performance of triticales over wheats in trials on the acid and aluminum toxic soils of Rio Grande do Sul. At the Cruz Alta experiment station trials in 1978, triticale yields were considerably greater than the best bread wheats even when diseases and insects were controlled at optimum experimental levels.

Excellent triticale research is conducted in Chile by the National Institute of Agricultural Research (INIA) and by the Catholic University, but no triticale varieties have been released. The major concern is that local millers are not ready to accept the crop for milling and baking in competition with imported wheats.

Mexico's National Institute for Agricultural Research (INIA) named a National Coordinator for Triticale Research in 1978. The main variety in production is Rahum, and to a lesser extent, Bacum and Mapache. Much of the grain from the roughly 1,000 hectares planted to triticale in Mexico is used as animal feed.

Argentina is the country in Latin America with the most land in triticale production. An estimated 20,000 ha are producing forage for cattle. The varieties in use are 6TA-203 and Rosner, both of Canadian origin.

Africa

In the East African region, Kenya has the most active triticale testing program, centered at Njoro plant breeding station. Triticale strains have consistently produced 20-40 per cent more grain than the best wheats. Triticale grain is being produced for quality and baking research and for distribution to growers. Varieties under seed increase include Bacum (from Mexico), 6TA-204 (Canada), and an INIA-Armadillo derivative (Mexico). Selections made in Kenya are also performing well in the research stations of other East African countries including Rwanda, Burundi, Zambia, Malawi, and Madagascar.

Progress on the Development of High Yielding Triticale Strains at CIMMYT since 1967

Year in advanced trials	Identity	Sonora Nursery* Yield kg/ha	Test wt kg/hl	Plant ht cm	I T Y N ** Year	Yield kg/ha	No. of Locations
1967-68	Bronco X224	2356	64.4	150	1969-70	2578	39
1968-69	Arm. T909	3100	65.8	125	1970-71	3272	17
1969-70	Badger PM122	4492	68.5	125	1971-72	3274	34
1970-71	Arm.X208-14Y	5490	65.4	125	1972-73	3506	25
1971-72	Cinnamon	5550	66.8	100	1972-73	3409	25
1972-73	Maya IIxArm	6300	70.0	90	1973-74	4200	47
1973-74	Yoreme	7000	71.0	90	1973-74	4400	47
1974-75	Beagle	7500	68.0	110	1974-75	4480	45
1975-76	Mapache	8000	69.0	111	1975-76	4483	60
1976-77	KLA-M2A	7802	71.9	100	NA		

* Northwest Mexico
** Average at all locations in the International Triticale Yield Nursery

At this Nepalese experiment station triticales yield up to 50 per cent better than the best bread wheats. Farmers use the triticale for making chapatis.

Asia

Triticales have shown their suitability for cultivation in the Hills areas bordering the Himalayas in Pakistan, India and Nepal.

Experiments in the mountain valleys of Nepal, particularly on low pH soils, have consistently shown better grain yields and growth by 50 per cent or more over wheat. Triticale varieties such as Beagle, Rahum, Bacum and F.S. 1897—all from CIMMYT—are well suited. The taller varieties, such as Beagle, are favored because of greater amounts of straw for thatching.

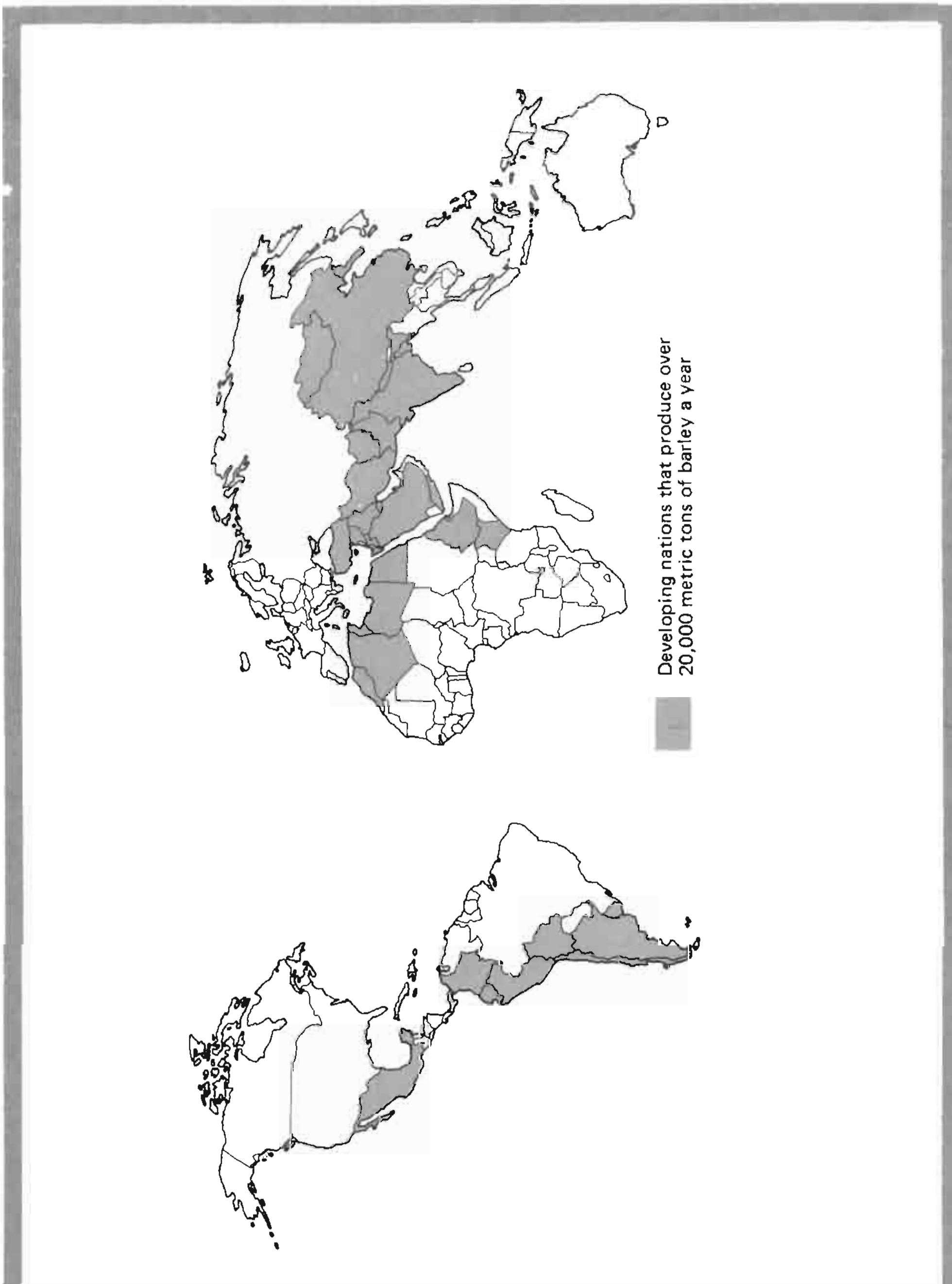
BARLEY

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

Although improved varieties have been developed for livestock feed and barley malt, most barleys eaten by human populations have been low yielding and susceptible to disease, and the tough hulls around the barley grain, while useful in livestock varieties and for making barley malt, must be removed before the grain is eaten by humans. The removal of this hull reduces grain weight as well as nutrient levels.

Since 1972 CIMMYT has assembled breeding sources for nearly all characters needed to develop high yielding varieties for direct human consumption. CIMMYT breeding is focused on developing widely adapted varieties that are resistant to diseases and lodging and have good nutritional quality. The program is interested also in developing good hull-less types, as well as earlier maturing lines.

New entries of germ plasm from regional and national programs have enriched CIMMYT's germ plasm base during the past two cycles, particularly from the Andean region and ICARDA (Syria).


Developing nations that produce over
20,000 metric tons of barley a year

Wider adaptation

By growing two generations a year at two locations in Mexico, which differ in latitude, environmental conditions and disease populations, CIMMYT breeders have been able to identify light insensitive materials which exhibit wide adaptation. At Cd. Obregon the crop can express its maximum yield potential and every line tested is simultaneously increased in small multiplication plots. With the seed obtained from these plots, the International Barley Observation Nursery (IBON) is assembled. In 1978 this nursery contained 354 lines and was sent to more than 70 locations around the world.

Lodging resistance

The search continues for barley lines which carry good lodging resistance under both irrigated and dryland conditions. New genotypes with good straw strength and well developed root systems which anchor themselves strongly in the soil have been developed. Some of these lines can stand high dosages of fertilizer, but they are still too short in plant height to be grown under dryland drought-stress conditions.

Disease resistance

During the last two cycles CIMMYT has placed greater emphasis on disease resistance. For example, in Colombia, Ecuador, Peru, and Chile, the barley yellow dwarf virus has become a major disease problem. A new race of stripe rust is also devastating the barley crop in Colombia and Ecuador and has moved south to Peru and Bolivia. Screening has been a priority activity.

A series of advanced lines have been screened to identify lines which carry genetic resistance to diseases such as leaf rust, powdery mildew, bacterial stripe and barley yellow dwarf. Considerable work lies ahead to develop greater resistance to these diseases.

Quality

After a number of years of breeding to improve grain quality in CIMMYT experimental lines, the problem of grain shrivelling in lines carrying the high lysine mutant gene, Hiproly, has been solved. The gene is now incorporated in barley lines which show a well developed endosperm. These genotypes are now used as parents in the crossing blocks.

Hull-less grain

Many crosses have been made to incorporate the hull-less (naked) character into the breeding material used at CIMMYT. This character is now spread widely throughout our breeding material. Advanced lines carrying the hull-less character have been evaluated in preliminary yield trials grown at Cd. Obregon. The hull-less line "Bichi" outyielded all the barley checks and even some wheat and triticale checks when grown with only three irrigations and fertilized with 80 kg N/ha and 60 kg P/ha. These results, which should be interpreted with caution, nevertheless demonstrate that the yield potential of hull-less barley is improving.

The problem of grain damage in hull-less barleys during the threshing process resulting in lower germination rates when the seed is planted in the succeeding cycle is also under study. More than 100 lines were selected from the World Barley Collection where the seed embryo had greater protection within the endosperm. These lines are being grown in small plots in the 1978/79 season at Cd. Obregon for subsequent threshing to see if the position of the embryo in the endosperm is a feature that can confer resistance to embryo rupturing.

Spring x winter crosses

The need for winter hardiness for certain developing countries led CIMMYT to begin a spring x winter crossing program in 1976-77 at Toluca. Lines were screened for winter hardiness and selections were used as progenitors to make crosses with improved lines in the spring crossing block. The F_1 seed was sown at the Cd. Obregon station during the 1977-78 winter cycle and 567 crosses were later sent to countries like Turkey, Korea and Chile for evaluation.

International testing

Barleys selected from preliminary yield trials in Mexico have been tested on an international basis through the Elite Barley Yield Trials (EBYT) which began in 1975-76. These trials normally contained 24 lines from the CIMMYT program and one local check. In order to make fair comparisons, the lines are divided into covered grain types and hull-less types. The average yield of the top five hull-less lines at 14 locations in the 1977-78 international yield trials was 2653 kg/ha. The average yield of the top five covered grain type lines in similar trials at 19 locations was 3022 kg/ha.

A decision was made to consolidate the yield nurseries (e.g. naked vs covered types, early vs normal types) into one yield nursery to be called The International Barley Yield Trial (IBYT). This nursery was distributed for the first time in 1978 and contained 20 lines and varieties from different collaborating programs around the world, four lines from CIMMYT, and one local check. Cooperators will continue to have access to other CIMMYT advanced material through the International Barley Observation Nursery (IBON).

DEVELOPMENT OF NEW GERM PLASM

In conventional breeding programs, experimental lines are evaluated simultaneously for a number of desirable characteristics. Lines which carry only a single character useful to the breeder, but intermixed with undesirable characters, are often rejected. One breeding unit at CIMMYT is making painstaking transfers of single genes into lines with good agronomic type. Once modified to possess several useful characters these lines can be used as parents within the conventional breeding program.

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

Protein improvement

The development of higher protein bread wheat is an important effort of the special breeding unit. For several years varieties of higher protein content or quality have been crossed with varieties of good agronomic characteristics to transfer desirable genes.

Slowly CIMMYT breeders have been able to develop lines which retained higher protein levels. Traditional agronomic deficiencies such as tall plant height, late maturity, photoperiod sensitivity and susceptibility to rust attack have been overcome. Progress has been made in improving the grain type of high protein lines. However infertility problems still persist, particulary with the shorter plant lines.

Some early maturing higher protein lines with good agronomic characteristics and acceptable fertility levels are now being used in the conventional bread wheat program.

Rust resistance

Work continued in 1978 to improve the agronomic characteristics of the lines Yaqui 50, Bonza 55, Samaca, Andes 56, Eagle, Africa-Mayo 48, Chris, Tezanos Pinto Precoz, and Era which have long exhibited stable resistance to stem rust but are too tall for use with heavy fertilization.

This breeder is making painstaking transfers of single genes for disease resistance, dwarfism, etc. into lines with good agronomic characters and pyramiding the useful genes. Once modified to possess useful characters these lines can be used as parents within conventional breeding programs.

Sources of dwarfing have been incorporated into these varieties to reduce plant height. Breeders are also attempting to transfer into these lines genes for leaf rust resistance. In another project, dominant genes for leaf rust resistance normally present in tall, late maturing varieties are being transferred into semidwarf, early maturing varieties. High yielding varieties like INIA 66, Yecora 55, Cajeme 71, Potam 70 and Zaragoza 75 are being crossed with the varieties Agatha and RL 6040, each with a dominant gene for resistance to leaf rust.

In the 1978-79 cycle, breeders are optimistic that they will be able to select offspring exhibiting both the good agronomic type and leaf rust resistance characteristic of their separate parents. These new lines will then be promising candidates for use in the conventional bread wheat program.

New sources of dwarfing

Much of the original work to introduce new and multiple sources of dwarfing into high yielding tall varieties has been accomplished. A number of varieties now contain single, double and triple gene sources for dwarfism. The varieties CIANO 67 and Sta. Elena, both high yielding, now are triple and double gene semidwarf wheats. Hisumi, a very short (45-55 cm) winter wheat has been backcrossed with the spring bread wheat, Jupateco, for several generations. The dwarfing genes of Hisumi have now been transferred to Jupateco 73.

Work is continuing to increase the genetic dwarfing sources in the high yielding varieties Huamantla Rojo, Nainari 60, Lerma Rojo 64A, Pitic 62, and Penjamo 62. All possess genetic deficiencies along with salient features (such as yield potential and good grain type) which make them difficult to handle in their present form in the conventional breeding program.

Genes for dwarfism and rust resistance are being pyramided into these varieties. The 1978-79 cycle produced lines with the desired combination of characters for dwarfism and rust resistance.

The special breeding unit is also completing its efforts to introduce additional dwarfing genes in the newer semidwarf high yielding varieties, using genes from the varieties S.948.A1, Hisumi and Norin 10.

More spikelets per head, more grains per spikelet

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

Various experimental lines from one cross containing the variety Morocco are producing 8 grains per spikelet on the best developed plants (3-5 are the normal number in most bread wheat). These plants are about 70 cm tall, early maturing, have good disease resistance and excellent fertility.

Another cross containing the winter wheat Tetrastichón in its pedigree has a head twice as long as most spring wheats, giving 27-30 spikelets per head. Lines from this cross show acceptable resistance to rust and good plant type, although grain filling characteristics are poor.

Breeders have been making crosses to combine these two characters—more spikelets per head and more grains per spikelet. One such cross successfully combined the characters of the Morocco and Tetrastichón varieties producing lines with 7-9 grains per spikelet and 26-30 spikelets per head.

New crosses with disease resistant varieties have produced segregating lines with good disease resistance and good grain type. As advanced uniform lines are developed with the host of desirable characteristics needed to become a high yielding variety, replicated yield trials will be carried out to determine if these materials do in fact offer yield improvements per unit area over existing high yielding bread wheats.

Tolerance to aluminum toxicity

Over the last several years breeders have been attempting to introduce dwarfing genes into tall, native, low yielding, weak strawed Brazilian wheat varieties which have shown a tolerance to aluminum toxicity to see if tolerance to toxicity would be diminished as plant height was shortened. By 1978 several cycles of crossing and selection had been completed with the resulting progeny tested in Brazil's acid soils. Several lines containing dwarfing genes continued to show tolerance to aluminum toxicity.

In another approach triticale x bread wheat crosses are used in an attempt to transfer triticale's tolerance to aluminum toxicity into wheat. Some of the segregating lines from these crosses with a wheat phenotype were tested in Brazil in 1978 and showed much improved aluminum toxicity tolerance over normal Mexican high yielding varieties grown under these acid soil conditions.

Wide crosses (intergeneric crosses)

In 1978 wide crosses continued between wheat x barley and also wheat and some species of the grasses *Agropyron, Elymus and Aegilops.* Crosses are made in the field. Female plants usually receive chemical treatment to achieve fertilization and embryos are removed from their endosperms and raised on an artificial medium in the laboratory and later in a greenhouse.

In 1978 wheat x barley crosses were made producing progeny which appear to be classic hybrids which carry the complete complement of chromosomes of both parents. The F_1 offspring are sterile and are maintained under greenhouse conditions. These offspring are increased by cloning to maintain the hybrid population and to submit some offspring to chemical treatment in attempts to double the number of chromosomes and thus possibly obtain fertile hybrids.

Other F_1 fertile plants that are partial hybrids (do not contain the full complement of parental chromosomes) are raised during their first generation in the greenhouse. Subsequent generations are grown under field conditions. These offspring phenotypically are the same as their female parent.

The objective of intergeneric crossing is to create a bridge whereby useful characters can be transferred from one plant genus to another.

AGRONOMY - PHYSIOLOGY

Agronomy

CIMMYT has long advocated the importance of agronomy research, oriented by farmer circumstances, to improve the productivity of small grain farming. Center scientists have argued that such research must be carried out in national programs, under local conditions.

CIMMYT staff assigned to regional and national programs are heavily involved in production-oriented agronomy research with national collaborators.

At headquarters in Mexico the training programs work with in-service trainees to develop research methodologies capable of increasing on-farm agricultural productivity.

In addition some agronomy research is carried out in Mexico to support the breeding efforts at different experiment stations.

Weed control

Agronomic studies continued at El Batan and Toluca stations in 1978 for more effective weed control programs for breeding nurseries. The trials do not relate to farmers' requirements, as the conditions encountered in breeding nurseries and farmers' fields are completely different.

Breeding nurseries are planted with wide spacing and thus herbicides which control weeds by dwarfing their growth temporarily until the crop gains a competitive advantage are not useful. Short weeds that would not normally be a problem in a commercial crop become important in a nursery. Because of the range in maturity of the nursery, hormone type herbicides cannot normally be used.

Three main trials were conducted at the El Batan station using three chemical herbicides. Two main trials were conducted at the Toluca station. These trials will be repeated before results are published.

Physiology

During 1978 scientists in this unit worked on five topics: (1) assessment of yield potential of new advanced lines and varieties; (2) the effect of solar radiation on yield potential; (3) the yield behavior of varietal mixtures; (4) selection methodology for high yield potential; and (5) row spacing and density effects on the yield of distinctive genotypes.

Assessment of yield potential

As in previous seasons, new advanced lines from the bread wheat, durum, and triticale programs were grown under optimum agronomic conditions to compare yield potential with check varieties. Trials conducted in 1977-78 at Cd. Obregon were affected by unusually high temperatures.

One interesting feature of these trials was the superiority of the durum wheats over bread wheats and triticale. Seven of eleven durums included in the yield potential trial were among the ten highest yielders.

Yield trials over the past three years with bread wheats show that the yield potential of new varieties and lines has advanced approximately one per cent each year.

Agronomy work in Mexico serves two purposes: it supports production training programs and its supports breeding efforts at experiment stations used by CIMMYT. Staff assigned to national and regional programs are also heavily involved in production-oriented agronomy research with national collaborators. Here, a CIMMYT agronomist works with 1978 wheat production trainees.

Radiation effects on yield

Research conducted in recent years in the high yielding environment in the Yaqui Valley around Cd. Obregon has demonstrated that the component most limiting yield potential is the number of grains that set per unit area.

In 1977-78 an intensive study was conducted on the effects of shading on the variety Yecora 70. Contrary to initial expectations, shading affected all stems and not just the late tillers as had been hypothesized. The number of spikelets containing grain was reduced markedly by shade. More sterile spikelets were found at the base of the spike in shade treatments. A full review of this work and its implications will be published in 1979.

Selection methodology for high yield potential

Early segregating populations grown at CIMMYT and in many national breeding programs are sown with considerable space between plants to aid the scientist in his appraisals of disease resistance and other individual characteristics.

Numerous studies have shown that there is little, if any, relationship between the yield of widely spaced individual plants and their yield under the competitive conditions prevailing at commercial densities.

In 1976 CIMMYT initiated a study of superior selection criteria which could be used with segregating populations. In two advanced generations, F_4 and F_5, yield was most highly correlated with leaf permeability measured on F_2 plants approximately three weeks after flowering (i.e. measuring size of pores in the leaves). Further work was initiated to test the practicality of using leaf permeability as a selection criterion in early segregating generations.

Another procedure under evaluation involved interplot competition in yield tests. For practical reasons, yield trials of advanced lines at CIMMYT and in many national programs are harvested without removing the edges of the plots. At question is the error that is introduced into the yield data when using this procedure.

In 1977-78 two trials were conducted to investigate this issue. The effect of border areas did cause notable differences in the apparent yield of some cultivars. When the height of the cultivars in the trial was variable, the taller cultivars moved up in yield rankings from the net to the whole plot while the shorter cultivars moved down. This stresses the need to group cultivars in the yield trials according to their height.

Row spacing and density studies

Studies on row spacing generally show that there is a wide range of spacings where maximum yields are obtained —from very close rows (10-15 cm) up to 45 cm or more spacing between rows.

In 1978 a study was conducted using 12 different wheat genotypes in a trial using row spacings of 10 cm, 20 cm, and 30 cm. The object was to investigate whether some of the newer short, erect-leaved and compact lines need closer spacings to achieve their optimum yield. The results of this trial showed that closer spacing (highest yields obtained at 10 cm spacing) benefits very short lines with a very compact habit and lines with very erect leaves.

As with row spacing, studies on seeding densities have generally shown that maximum yields may be obtained from a wide range of densities—as low as 10 kg/ha seed up 200 kg/ha or more. The effect of four seed rates (50, 100, 200 and 300 kg/ha) on six contrasting genotypes was studied in 1977-78. Overall, no significant difference in yield because of seeding densities was observed although lodging is likely to be a greater problem at higher densities as there are larger numbers of stems per unit area, and these stems are likely to be weaker. One advantage of high seed rates is better weed competition.

It would appear that there is no advantage in using very high seed rates, unless weeds are a problem, and in this case, high densities should be considered only for varieties with lodging resistance.

Conclusion of physiology work

The wheat physiology program ended in 1978. Work will no longer continue on selection criteria and limiting factors for high yield potential. However, considerable data from past experiments have not been analyzed. When data analysis is completed, the results of this work will be published.

PATHOLOGY

Stable resistance to the wheat diseases remains a primary objective of CIMMYT wheat scientists.

Rust has been a threat to the wheat crop for thousands of years. Constant mutation of rust pathogens provides new threats to wheat varieties, including varieties previously considered resistant to rusts. Stable rust resistance in the long term is unlikely to be achieved in pure-line varieties and the wheat scientists must continue to give attention to the development of new varieties which combine new sources of resistance to rust.

CIMMYT wheat pathologists provide support information to wheat, barley and triticale breeders. The pathology group is responsible for artificially inoculating nurseries to impart heavy disease pressure for selection of resistant lines.

Pathologists also receive materials from national collaborators which are evaluated for resistance to different virulent populations present at six sites in Mexico. This information assists national programs to evaluate the disease resistance of local varieties to disease strains not normally a problem in their area.

CIMMYT pathologists are involved in many different activities. One important area of responsibility is the in-service training program in pathology. In 1978, six trainees from as many countries spent seven months working to strengthen their abilities in pathology research side by side with CIMMYT pathologists.

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

Greenhouse studies

Wheat pathologists conduct greenhouse work to monitor changes in different virulent types of leaf and stem rust. The objective of the project is to monitor the races of rust to signal possible mutations which would lead to new disease outbreaks to which CIMMYT lines might be susceptible.

Training activities

This group is also responsible for pathology training for in-service training participants. In 1978, six trainees from as many countries worked seven months with CIMMYT pathologists to practice the techniques used in pathology research at CIMMYT.

Consulting services to national programs

Wheat pathologists also provide consulting services to national programs. Nurseries are assembled and sent to national collaborators for evaluation under local disease situations. CIMMYT staff then visit these disease observation nurseries and work hand-in-hand with national scientists to evaluate the disease resistance of the experimental lines.

Special research projects

Special projects are in progress to identify new genes or combinations of genes which impart resistance to leaf rust, *Septoria* spp., barley yellow dwarf and *Helminthosporium.* Pathologists are evaluating materials from the world germ plasm collection and from the CIMMYT breeding program. In addition a collection of wild wheats and near-relatives of wheat, sent from the Mideast, is being subjected to heavy leaf rust disease attack in Mexico. CIMMYT hopes to discover new sources of genetic resistance to leaf rust in this material.

INTERNATIONAL WHEAT TESTING

In 1978 nearly 300 collaborating scientists in 108 nations requested over 1,600 trials of wheat, triticale, and barley nurseries from CIMMYT. The total weight of the experimental seed shipped by air, was 9.3 metric tons, representing 31 different nurseries and 500,000 packets of seed. A nursery consists of a set of varieties or lines, sometimes as many as 700 entries. The two largest nursery categories for wheat, barley and triticale are the screening and yield nurseries.

Collaborators are free to use any of the materials included in a nursery. When directly released as a commercial variety CIMMYT requests that the origin of the germ plasm be recognized. Varieties originating from the international nurseries and released for commercial production cannot be protected under patents or plant breeder rights. CIMMYT believes that network germ plasm must be open for use by everyone that can benefit from it.

Screening nurseries

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

The objectives of screening nurseries are:

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

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

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

Yield nurseries

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

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

Bread Wheat, Durum, Triticale and Barley Nurseries Distributed by The International Nurseries Program 1978.

	Bread wheat	Durum	Triti-cale	Barley
Latin America	**172**	**74**	**108**	**64**
Argentina	24	16	9	3
Bolivia	10	6	2	8
Brazil	40	3	23	8
Chile	16	9	16	8
Colombia	4	1	5	—
Costa Rica	3	—	2	1
Dominican Republic	4	—	2	—
Ecuador	8	4	8	7
El Salvador	2	—	—	—
Guatemala	6	1	4	2
Guyana	3	—	3	—
Haiti	1	—	—	—
Honduras	3	2	1	2
Jamaica	1	—	1	—
Mexico	15	22	17	12
Nicaragua	3	—	—	—
Paraguay	5	—	3	3
Peru	13	7	8	10
Trinidad	3	—	—	—
Uruguay	5	2	3	—
Venezuela	3	1	1	—
Africa	**117**	**69**	**67**	**55**
Algeria	11	14	5	4
Burundi	1	—	1	—
Cameroon	1	1	1	2
Centr.Afr.Emp.	1	—	—	—
Egypt	8	6	4	4
Ethiopia	6	3	7	4
Ghana	1	1	1	1
Kenya	5	6	7	6
Lesotho	4	—	2	—
Liberia	1	—	—	—
Libya	3	2	2	2
Malagasy	1	—	—	—
Malawi	2	—	1	—
Mali	2	—	—	—
Morocco	2	3	1	1
Mozambique	2	—	—	1
Niger	1	—	—	—
Nigeria	4	2	2	3
Rhodesia	4	—	3	4
Rwanda	1	—	1	—
Senegal	1	1	1	1
Somalia	3	4	1	—
South Africa	14	6	7	10
Sudan	12	7	7	7
Tanzania	6	—	3	—
Tchad	2	3	2	—
Tunisia	8	9	3	4
Upper Volta	1	—	—	—
Zaire	2	—	1	—
Zambia	7	1	4	1
Mideast	**72**	**64**	**55**	**42**
Cyprus	3	4	2	4
Iran	11	2	5	4
Iraq	6	5	2	3
Israel	8	7	9	4
Jordan	7	11	6	6
Quatar	1	—	—	—
Saudi Arabia	3	1	1	1

	Bread wheat	Durum	Triti-cale	Barley
Syria	14	18	17	11
Turkey	11	13	8	6
North Yemen	6	3	5	3
South Yemen	2	—	—	—
East Asia	**88**	**52**	**73**	**52**
Afghanistan	8	4	2	3
Bangladesh	5	2	3	2
China	4	2	3	2
India	23	24	23	17
Indonesia	2	—	1	—
Japan	2	—	5	2
North Korea	1	2	1	5
South Korea	5	1	1	—
Nepal	9	2	7	6
Pakistan	15	13	17	11
Philippines	6	1	7	—
Sri Lanka	3	—	1	2
Thailand	3	1	2	2
Vietnam	2	—	—	—
Oceania	**18**	**9**	**7**	**1**
Australia	9	6	5	—
New Caledonia	3	—	—	—
New Guinea	1	—	—	—
New Zealand	2	3	2	1
Tahiti	3	—	—	—
Europe	**78**	**69**	**50**	**19**
Albania	2	1	—	—
Austria	—	6	1	—
Belgium	2	—	—	—
Bulgaria	—	5	6	—
Czechoslovakia	4	—	—	—
England	4	—	1	—
Finland	1	—	—	1
France	6	7	6	—
Germany,DPR	1	—	2	1
Germany,F.Rep.	4	4	3	1
Greece	5	6	2	5
Hungary	3	1	7	—
Italy	5	10	—	3
Malta	—	1	—	—
Netherlands	4	1	2	1
Norway	3	—	1	2
Poland	7	1	3	—
Portugal	6	2	4	2
Rumania	3	6	—	—
Russia	1	1	1	—
Spain	9	12	2	2
Sweden	3	—	6	—
Switzerland	—	—	1	—
Yugoslavia	5	5	2	1
North America	**48**	**15**	**39**	**25**
Canada	13	1	13	10
U.S.A.	35	14	26	15
TOTALS:				
Countries	**103**	**67**	**85**	**59**
Locations	**593**	**352**	**399**	**258**

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

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

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

Operation of international nurseries

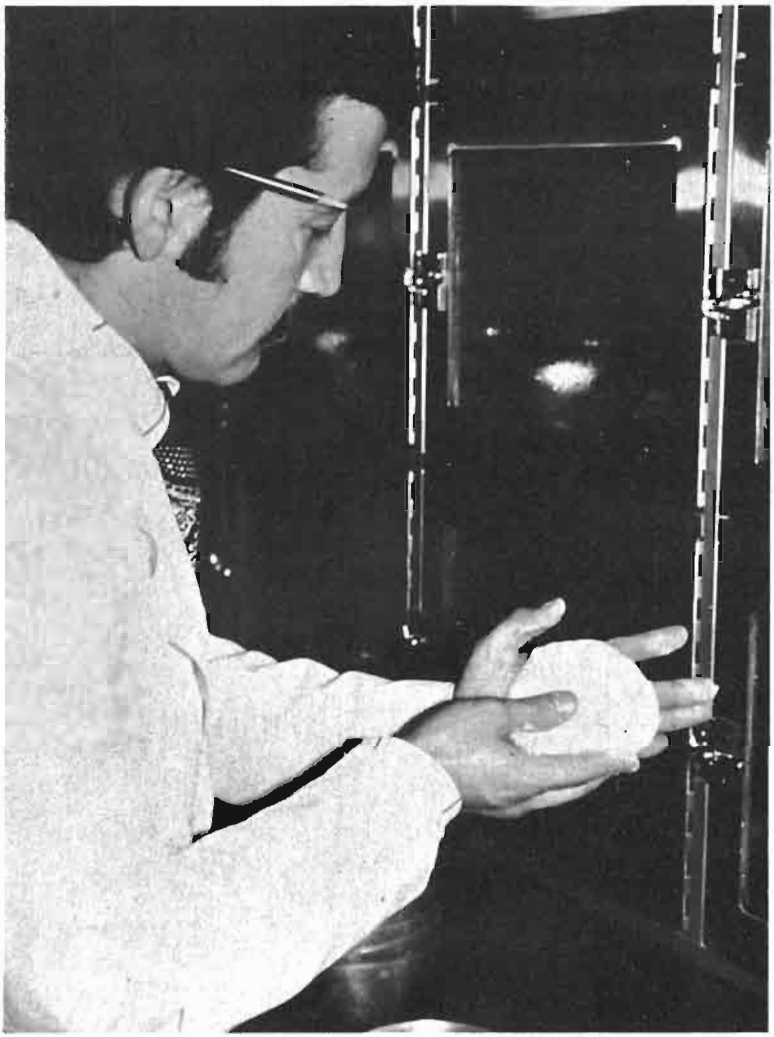
The operation of the international nurseries involves a series of coordinated activities which span the entire calendar year. Varieties sent by collaborators for possible testing in future international yield nurseries must be received at CIMMYT by September 15 to be tested in the following year. These lines are planted in November at Cd. Obregon where CIMMYT breeders select advanced lines and varieties for inclusion in the upcoming international testing cycle. Harvesting begins in April and is followed by seed handling, cleaning and packaging into sets. According to requests and seed availability the nurseries are sent to collaborators in August and September. Included with each trial are instructions for research design, data recording books, and seed handling certificates. The trials are then planted at locations around the world using uniform designs appropriate to the type of nursery being grown.

Collaborators, after harvest, complete their nursery observations and send their completed data books back to CIMMYT as soon as possible. At CIMMYT the data are analyzed on the computer using standardized programs and preliminary reports on the results of the nursery at each location are prepared and made available to collaborators for their future planning of breeding work. Then the cycle begins again.

MILLING AND BAKING LABORATORY

The milling and baking laboratory evaluates the grain of bread wheat, durum, and triticale lines for their suitability in making bread, tortillas, chapatis, cookies, spaghetti, and other products.

In 1978 the laboratory tested 20,000 samples from early generation bread wheat lines (F_3 and F_4) for gluten strength by the use of the micro-Pelshenke test. By screening early generations for seed type, advanced materials have increased in test weight (weight of grain per unit volume). Very few advanced lines are now discarded because of low grain test weight.



Promising materials coming out of the breeding programs are tested for their milling and baking qualities. Good industrial characteristics are as crucial to any new variety as are yield potential, disease resistance, and agronomic type.

About 1,200 advanced lines and varieties of bread wheat were evaluated in 1978 for milling, protein, and baking qualities. A number of lines with good baking quality were selected from this material.

In durum wheats the laboratory screened 7,000 individual plants for pigment content, and 960 advanced lines were evaluated for spaghetti-making quality. Several advanced durum lines were found with better spaghetti cooking quality than Mexicali, Mexico's leading durum. Several lines from the special protein improvement project had protein levels up to 17 per cent in flour and good baking quality.

In triticale 390 lines that have good yield and test weights were evaluated for milling and baking and for quality in cookie-making. Almost all the triticale lines tested had a flour yield higher than 60 per cent, and some higher than 70 (good bread wheats have flour yields of 70 per cent). Baking tests were conducted with triticale flour and a high number of triticale lines had bread loaf volumes above 700 cc. Some lines had loaf volumes up to 800 cc which compare favorably with Hermosillo, a good quality wheat for bread-making, which has a loaf volume of 860 cc. Many triticale lines provide flour that is better for cookies than the soft bread wheat normally used for making this product.

Two trainees from Ecuador and India spent an average of 3 months each in 1978 learning techniques in the milling and baking laboratory. The laboratory also received two visiting scientists from Argentina.

1978 WHEAT TRAINING PROGRAM

In-service

The 1978 wheat in-service training cycle—the largest in CIMMYT's wheat program history—included 58 agricultural officers from 29 countries. These trainees, while all exposed to a general orientation to wheat agronomy, also specialized in either wheat pathology, breeding, production agronomy, industrial cereal technology or experiment station management.

Most trainees spent one cropping cycle in Mexico. The largest number take part in the production agronomy course which stresses techniques for on-farm research. Production trainees at CIMMYT do more than just develop and carry out a set of on-farm experiments during their stay in Mexico. In addition, they help evolve strategies for the organization of agronomic research. Components of this system include ways to develop short-term strategies for raising national production and reducing the gap between the yields obtained from on-station research and those experienced on farmers' fields. Trainees, working with wheat and economics program staff, are developing systems to identify, survey and process information affecting farmer circumstances, and through this, improve the focus of agricultural research.

Information generated from this off-station research and training program helps CIMMYT wheat breeders focus on agronomic management problems which will eventually determine the adaptation of the crop varieties they develop.

In recent years production agronomy training has been limited to a rainfed environment in the central plateau of Mexico. Beginning in late 1979, CIMMYT will reinstate its irrigated lands production agronomy training. The first cycle of the irrigated agronomy program will be located in the Yaqui valley near the CIANO station where systems of water management and wheat production will be explored.

The emphasis in the wheat training program is toward developing greater self-reliance in the trainee. In addition to a common orientation to wheat agronomy, trainees also specialize in either wheat pathology, breeding, production agronomy, industrial cereal technology or experiment station management. The 1978 cycle included 58 agricultural officers from 29 countries.

CIMMYT's wheat breeding and pathology training programs are modifying their orientation in recognition that experiment station conditions in collaborating national wheat programs are different to those encountered at CIMMYT. Hereafter trainees will work "off" as well as "on" stations. Breeding and pathology trainees are planting screening trials on farmers' fields to test—under rainfed conditions—germ plasm developed under "ideal " irrigated experiment station conditions.

Working away from the experiment station also means that trainees in breeding and pathology directly supervise land selection and preparation, seeding, input acquisition and application, weedings, inoculations, varietal selection, and harvesting. This new focus leads to greater awareness of the factors involved in designing and implementing breeding and pathology research, and thus results in increased self-reliance among CIMMYT trainee graduates.

Pre and Postdoctoral fellows

During 1978-79 CIMMYT is cooperating in the training of four master's candidates (1-Ecuador, 3-Mexico) in Mexico; four predoctoral fellows (3-Algeria, 1-Peru) in the USA; and eight postdoctoral fellows in wheat research (1-Egypt, 1-Ethiopia, 1-Morocco, 1-Poland, 1-Sierra Leone, 1-Syria, 1-Uganda, 1-USA).

Visiting scientists

Each year CIMMYT receives visiting scientists from traditional and non-traditional wheat growing areas of the world. These are usually senior scientists who spend 2-4 weeks participating in various field activities associated with the CIMMYT breeding program. The number of visiting wheat scientists travelling to CIMMYT each year has grown from 10 in 1975 to 42 in 1978.

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

In-country and regional training activities

The wheat training staff works with national research programs on the development of in-service training at the national level. Several staff have also participated in the organization and execution of short term production training courses in the Mideast and North African regions. CIMMYT strives to stimulate all national research programs to develop their national training capabilities and to take an active role in training national extension services. Such a link would help to improve the interchange of information between research and extension and would improve the development and transfer of technology from the experiment station to farmers' fields.

Origin of Wheat in-service trainees, 1966-78.

	1966-1978	1978		1966-1978	1978
Latin America	**134**	**16**	**Africa,South of the Sahara**	**48**	**8**
Argentina	12	0	Ethiopia	11	0
Bolivia	10	5	Kenya	7	0
Brazil	17	0	Malagasy	1	0
Chile	7	1	Malawi	1	1
Colombia	5	1	Mali	1	1
Dominican Republic	1	0	Nigeria	14	0
Ecuador	13	3	Rwanda	1	1
Guatemala	7	2	Somalia	1	0
Honduras	1	0	Tanzania	3	0
Mexico	42	2	Tchad	1	1
Panama	1	0	Zaire	2	1
Paraguay	4	0	Zambia	5	3
Peru	13	2			
Uruguay	1	0	**South, Southeast**		
			& East Asia	**101**	**18**
North Africa			Afghanistan	13	0
& Mideast	**174**	**15**	Bangladesh	20	3
Algeria	45	3	India	12	6
Cyprus	1	0	Nepal	11	4
Egypt	12	3	Pakistan	36	3
Iran	8	0	Philippines	1	1
Iraq	5	0	South Korea	8	1
Jordan	5	2			
Lebanon	4	0	**Other Countries**	**18**	**1**
Libya	4	0	France	1	0
Morocco	18	0	Hungary	2	1
Saudi Arabia	1	0	Poland	3	0
Sudan	3	0	Portugal	1	0
Syria	6	1	Rumania	2	0
Tunisia	24	1	Spain	2	0
Turkey	35	5	USA	4	0
Yemen	3	0	USSR	3	0
			TOTAL:		
			Countries	**56**	**26**
			Individuals	**475**	**58**

COOPERATIVE PROJECTS OUTSIDE MEXICO

In 1978 CIMMYT increased the number of wheat scientists posted outside Mexico. Staff members are stationed in national programs when a government requests them and an extra core grant covers the cost. CIMMYT also assigns staff to regional programs which are funded by the core operating budget.

During 1978 CIMMYT had three wheat scientists working with national wheat programs and five wheat scientists posted in regional assignments. CIMMYT staff assigned to national programs typically concentrate on improving wheat research on experiment stations and farmers' fields, and help to arrange additional training for local scientists. CIMMYT is reducing its assignments of staff to national programs as more staff are assigned to regional programs.

A regional assignment involves work in a group of neighboring countries where wheat is a major crop, grown under similar climatic conditions, threatened by similar diseases, and benefiting from continuous intra-regional exchanges of research information and new technology. Typically, a regional program will sponsor (1) regional workshops for cooperating scientists, (2) circulation of uniform disease and yield nursery trials, (3) exchange visits by local scientists to observe wheat research in neighboring countries, (4) increased training opportunities in the regions, and (5) improved consultation services by CIMMYT scientists.

Regional programs

At the beginning of 1979 CIMMYT wheat scientists were stationed in the following regional programs:

Wheat region & headquarters	Number of coop-erating countries	1978 popu-lation (millions)	Wheat crop (tons)	CIMMYT assigned staff 1978	Donor of restricted core funds	Year regional arrangement began
Mediterranean, Mideast & South Asia (Egypt & Turkey)	22	1040	69,000,000	2	Netherlands	1973
East Africa (Kenya)	14	106	1,000,000	1	Canada	1976
Andean Region (Ecuador)	5	69	330,000	1	Canada	1976
Southern Cone (Chile)	6	164	13,000,000	2	CIMMYT /Japan	1978

In 1979, existing regional programs will be further strengthened by the assignment of additional scientists to the East Africa and Mediterranean/Asia Regions.

Mediterranean and Asian Regional Program

The problems of wheat diseases continue to be the major activity for the two scientists assigned to the region. These CIMMYT staff, one headquartered in Turkey, and the other located in Egypt, cover a wheat-growing area which stretches from Morocco in the west to the Indian sub-continent in the east. This program operates in cooperation with ICARDA and FAO in part of this region.

In addition to normal regional program activities these scientists are working on two unique projects: a disease surveillance-warning system for the region and an in-service workshop series on wheat diseases and practical field-laboratory methods for screening and identification of resistant lines.

A regional disease detection nursery program extends throughout Western Asia and North Africa to assist national programs in gathering information on sources of disease resistance for breeding purposes by identifying new varieties with adequate levels of disease resistance. This information also is communicated to breeders at CIMMYT headquarters to help guide the breeding programs in Mexico.

The disease surveillance program is gathering information to help predict impending disease epidemics so that new varieties with genetic resistance can be identified and introduced before a new menacing pathogen becomes pandemic. Information is gathered through two different nurseries: The Regional Disease and Insect Screening Nursery (RDISN) and The Regional Disease Trap Nursery (RDTN).

The RDISN is primarily a genetic nursery in the sense that it is used principally in plant breeding efforts. It emphasizes the early detection and identification of resistance by screening at locations where new and diverse races of pathogens are present or evolving. All breeders are encouraged to place their newly evolved varieties in this nursery to test their depth and width of disease resistance. This nursery was sent to about 50 locations in 32 countries in 1978.

The RDTN is used for disease monitoring purposes. This nursery is composed of commercial varieties, with susceptible and resistant check varieties. This nursery was sent to 150 locations in 50 countries in 1978. Through this nursery (and the RDISN) the origin and spread of new races of rust pathogens from one zone to another are beginning to be mapped. This early warning system can give additional time to an area facing a high probability of future attack by a disease for which its wheat varieties are susceptible. It is possible to develop a surveillance system which could provide 3-5 years lead time between the detection of a new race and the time it becomes the dominant disease race in the area. This is sufficient time for breeders to develop new varieties with resistance to the new race and multiply seed for introduction in susceptible farming areas.

In 1978 a regional workshop was conducted in Turkey aimed at strengthening the ability of national programs to identify and screen lines for resistance to small grain cereal diseases, principally rusts. Sixteen participants from Turkey attended the workshop. In this workshop, lectures on theory were followed by practical field and laboratory applications. Methods of creating artificial epidemics to increase breeding selection pressure, field collection and scoring of disease, storage of rust spores, and analysis of survey data were practiced. At the end of the workshop, each participant received a complete set of pathology field research and rust spore storage equipment for his institute. These kits are provided courtesy of the Royal Government of The Netherlands.

Eastern and Southern Africa Regional Program

Wheat and other small grains are relatively new crops in Africa south of the Sahara. Fourteen countries of this region together produce approximately 1.4 million tons of wheat: Botswana, Burundi, Ethiopia, Kenya, Lesotho, Madagascar, Malawi, Mozambique, Rwanda, Somalia, Swaziland, Tanzania, Uganda, and Zambia. Almost all the wheat is grown in highland areas above 1,700 meters altitude.

Starting in 1976, CIMMYT assigned one wheat breeder to this region with headquarters at the Kenyan National Plant Breeding Station, Njoro, elevation 2,300 meters, about 200 kilometers northwest of Nairobi, near Nakuru.

Workshops on wheat diseases and pathology research methodologies were held in Zambia, Kenya and Madagascar. At the Zambia Workshop, attended by 25 scientists, discussions focused on regional developments in wheat research with particular emphasis on foliar diseases in rainfed wheat crops. Strategies to increase wheat under Zambian conditions were explored.

The first in-country wheat workshop was held in Madagascar. CIMMYT and CIP cooperated with FIFAMANOR, a Malagasy Norwegian crop improvement program for wheat and potatoes. As one part of the workshop participants from Madagascar reviewed experiments with wheat, triticale, barley, oats and durums. A firm basis was laid for increasing production of these highland small grain crops.

The Kenya Workshop on Wheat Rust Methodology in 1978 included 13 trainees from Kenya, Madagascar, Tanzania, and Zambia. As had occurred with this workshop when given in other locations, classroom lectures on theory were combined with practical activities in the laboratory and field. In the Kenya workshop field activities were given greater emphasis than was given in the similar workshop held in Turkey. At the end of the workshop each participant received a set of pathology field research and spore collecting and storage equipment for his institution.

Wheat is grown in Rwanda mainly above 1,700 meters. Pictured here is Mr. Iyamuramya, Rwanda Director of Agricultural Research, observing a triticale nursery. Triticale performs well in the cool, acid soils of Rwanda, where it outyields wheat.

Njoro station in Kenya continues to produce vital information for breeders in the Near East and at CIMMYT with its summer nursery service. Seeds of promising and resistant lines of wheat, barley, and triticale are selected in Kenya and returned to collaborating scientists for further crossing. Exchange of material and data from the Kenya summer nurseries have also started between South America and the East Africa Region. This summer nursery permits a number of wheat research institutes to benefit from a second growing cycle each year.

The African Cooperative Wheat Yield Trial and Screening Nursery continued to distribute seed to cooperating African countries. A large number of seed requests in 1978 for superior Kenyan varieties testifies to the excellent work done in the national program of Kenya.

A new CIMMYT regional program in North and West Africa slated to begin in 1979 will form an important link between different parts of Africa which will add strength to wheat improvement efforts in this continent.

Andean Regional Program

Five countries of the Andean Region (Bolivia, Colombia, Ecuador, Peru and Venezuela) produced about 300,000 tons of wheat in 1978 and 375,000 tons of barley. Total wheat imports in the region continue to climb, reaching approximately 2.25 million tons in 1978.

Beginning in 1976, CIMMYT assigned one wheat scientist to Ecuador to work with national programs in the region.

Production of small grains in the Andean countries in 1978 was adversely affected by poor rainfall throughout most of the region. Barley production was also damaged by the continuing problem of a new race of stripe rust which first appeared in Colombia in late 1975 and by March 1978 had spread to southern Peru eliminating nearly all commercial barley varieties in Colombia, Ecuador and Peru.

In May, 1978, a regional wheat disease workshop held in Quito was attended by 75 scientists representing almost every country in Latin America. Stripe rust was the main topic of the conference. Methods of transferring improved production technology for wheat and barley and the potential of triticale in the Andean region were also discussed.

In October 1978, three regional nurseries were distributed throughout Latin America. These are disease observation nurseries for wheat and barley and a trap nursery, all similar to those distributed by the Mediterranean and Mideast regional program. Material for these nurseries comes from countries of the region as well as from other parts of Latin America and Africa.

Eight Andean region wheat scientists participated in CIMMYT's in-service training program: four in plant breeding and pathology, three in wheat production, and one in experiment station management. Eight visiting scientists from the region spent 3 weeks in Mexico selecting along with CIMMYT staff new germ plasm for their area and becoming better acquainted with the CIMMYT organization and staff.

Exchange visits within the region between neighboring scientists continued. In October 1978, scientists from three countries met in Lima to visit the Peruvian National Wheat Research Program. The visit lasted 10 days and allowed visiting scientists to become better acquainted with other programs in their region.

Consulting by CIMMYT scientists from Mexico continued to play an important role; seven CIMMYT wheat scientists visited the region in 1978.

Southern Cone Regional Program

CIMMYT's fourth regional wheat program, covering areas of six Southern Cone countries of South America—Argentina, Bolivia (lowland area), Brazil, Chile, Paraguay, and Uruguay—began in October, 1978, with the assignment of a regional agronomist who was joined in early 1979 by a CIMMYT breeder.

The new regional program is working cooperatively with IICA, the Inter-American Institute of Agricultural Sciences. CIMMYT staff are headquartered at Chile's National Institute of Agricultural Research (INIA) in Santiago.

The proposed program in this region has many of the same elements found in other regional programs. Special emphasis in the Southern Cone is being placed on soil-fertilizer problems related to wheat, barley and triticale production. Ways to handle problem soils, such as those suffering from aluminum toxicity and high phosphorus fixation tendencies, are a major focus of the program.

In breeding, the emphasis will be on bringing the scientific strength of the region together to develop and introduce more disease resistant varieties, particularly to barley yellow dwarf.

Regional yield trials and screening nurseries will be established to improve the introduction of new genetic material into national programs.

National Programs

The following countries participated in cooperative arrangements with CIMMYT at the beginning of 1979:

Country	Start of CIMMYT Arrangement	Population 1979 (millions)	Assigned CIMMYT Staff 1978	Approximate Wheat Crop (tons)	Donor*
Pakistan	1965	77	1	9,000,000	USAID/Ford
Algeria	1971	19	2	1,500,000	Ford
India	1979	635	0	30,000,000	Canada

*CIMMYT requires 'extra core funds' for support of each national arrangement.

Algerian National Program

Wheat production in Algeria since the record harvest of 2.9 million tons of 1976 has declined, mainly due to highly unfavorable climatic conditions. In 1978 Algerian wheat production was about 1.5 million tons.

Starting in 1971 CIMMYT assigned a team of wheat scientists to collaborate with the Algerian National Cereals Program. In 1978, two CIMMYT scientists were still working there. By mutual agreement with the Government of Algeria, the assignment of CIMMYT scientists to the national wheat program will be phased out. The Mediterranean/Asian regional wheat program will continue to support research efforts in Algeria in collaboration with ICARDA.

Training has been a major element of Algerian activities. By 1979, forty-five Algerian scientists had spent one crop cycle in Mexico in the CIMMYT in-service training program. Post graduate training which began in 1975 is expected to produce 17 scientists with advanced degrees for national wheat research.

By 1978, the Algerian government considered that its biggest wheat production problem centered around potential yields versus farmers' actual yields. Discussions between Algerian and CIMMYT scientists led to an intensified program of farm demonstrations beginning in 1978 on improved production practices for seed bed preparation, weed control, fertilizer strategies and varietal selection.

In 1978, the Algerian government requested assistance from CIMMYT in analyzing socio-economic factors affecting small grain production in Algeria. This program will start in 1979.

Pakistan National Program

Wheat is the most important cereal crop to Pakistan's 77 million people. After a record harvest of over nine million tons of wheat in 1977, a severe rust epidemic spread across Pakistan in 1978, severely damaging most commercial varieties being used.

CIMMYT has a long history of collaboration with agricultural scientists in Pakistan. A CIMMYT wheat scientist was first posted to Pakistan in 1965, and other staff members have served there including one wheat agronomist in 1979.

The wheat program in Pakistan has released more than a dozen new varieties during the past decade. High yielding wheat varieties are now sown on over 75 per cent of Pakistan's wheat land. The average yield of wheat in farmers' fields has risen nearly 30 per cent since 1970.

Since 1966, Pakistan has sent 36 young agricultural scientists to CIMMYT's in-service training program. In 1978, three scientists attended the program.

economics program

INTRODUCTION TO ECONOMICS PROGRAM

CIMMYT's Economic Program entered its eighth year in 1979. From the beginning, this program has sought new ways in which research on the farmer and his markets could facilitate the development and diffusion of improved agricultural technology. While its objective remains unchanged, the program's activities have evolved during the 1970's, concentrating ever more on developing analytical tools to help guide the design of agricultural research programs and accenting ever more collaboration with biological scientists. The activities described below are interrelated but will be singled out for separate comment.

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

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

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

As a part of our contribution to training we produced a manual to illustrate the formulation of recommendations for farmers. This manual, written for agronomists, illustrates all steps in deriving "economic" recommendations starting with agronomic data, blending in the relevant economic data, and then developing practical recommendations. First published in 1976, it is now available in English, Spanish, Turkish, and Arabic with the French version to follow in 1979.

With mounting interest in the procedures that we were developing, we were encouraged to offer a training program for other economists. In 1979 six economists from developing countries will join us as visiting scientists to acquaint themselves with the ideas that guide collaborative research with biological scientists. Their program will contain roughly equal parts of work on crops and on procedures.

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

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

Most of our work is motivated by the realization that few farmers in developing countries are following the recommendations of researchers and extension workers. Explanations for this difference between practice and recommendations abound.

Some claim that farmers are at fault, arguing that preferences based on traditionalism lead farmers to reject unfamiliar technologies. Some point to extension, arguing that the utility of improved technologies has not been demonstrated to farmers. Others claim that inadequate credit limits farmers' ability to adopt improved technologies. Some emphasize that inputs are not available in a timely way and at appropriate prices. Finally, but less frequently encountered, some contend that recommended technologies are often not appropriate for farmers.

Certainly each of these explanations has been valid for some time and place. However, a number of recent experiences have shown even the poorest farmers—presumably among the most tradition-bound and usually among those with least access to inputs, information, and markets—taking up certain technologies while rejecting others. These experiences suggest that more attention should be given to the adequacy of recommended technologies which, in turn, implies that more attention be given to the research systems which develop technologies.

In CIMMYT's case this all raises the question of what we can contribute to the development of technologies likely to be used by farmers. CIMMYT is most involved in producing intermediate products—elements of new technology, training, and procedures—which national programs apply in forging technologies. In the economics program our immediate concern is with the research procedures used in national programs. We believe that these must focus squarely on the representative farmer, and that requires a better knowledge of farmer circumstances as a guide to subsequent research.

CIMMYT encourages a better understanding of farmers through on-farm research—a program of studies at the farm level—conducted by local agronomists and economists, working together. These studies rely partly on interviews with farmers, and partly on developing and testing new technology on farmers' fields. Resulting data provides authoritative guidelines to experiment stations, to policy makers, and to CIMMYT.

In brief: development of new technology begins and ends with farmers. It begins with on-farm research which establishes the critical natural and economic circumstances which influence the behavior of farmers. It continues with recommendations which are consistent with those circumstances. It goes on by assessing reactions to the improved technologies and ways to improve them further. This is the process, based squarely on the farmer as its principal client, which we believe is most likely to lead to the development and diffusion of improved agricultural technologies.

D. L. Winkelmann

TRAINING

The Economics Staff at CIMMYT headquarters contributes to training in fours ways: by participating in the instruction of maize and wheat trainees in Mexico; by helping the regional maize and wheat programs with training undertaken within the regions; by preparing materials of special interest to agricultural officers (see manuals below); and by a program of doctoral fellows and visiting economists (also described below).

Economists share in planning farmer interviews and on-farm experiments which are carried out by the maize trainees in Veracruz State, Mexico, and by wheat trainees on the central plateau of Mexico. This is the type of research which CIMMYT hopes trainees will continue when they return to their home countries. It rests on our belief that factors which are important to farmer decision making must be reflected in research to develop improved technologies.

Manuals for agricultural researchers

CIMMYT's newest economics manual, a booklet of about 100 pages, will describe our procedures for undertaking research aimed at developing improved technologies. The manual will be released in late 1979 to serve the needs of biological scientists and economists charged with forging new agricultural technology. It is based on our experiences with national maize and wheat programs in several countries where the procedures described have been developed and refined.

The manual is divided into four parts. Part I gives the reason why collaborative research under farmers' circumstances is a necessary step in planning national crop research programs. Part II describes the kinds of information a scientist needs to know about farmers' circumstances, and how some of this information can be quickly gathered from farmers and merchants. Part III gives the procedures for a scientific survey of farmers to produce more precise data than by informal methods. Part IV shows how the findings on farmer circumstances can help in planning crop improvement research.

This manual will be a sequel to CIMMYT's Economics Manual No. 1 (1976), entitled, "From Agronomic Data to Farm Recommendations", which deals with the problems of converting research data into recommendations for farmers.

Doctoral fellows and visiting scientists

One postdoctoral fellow is working with the program in 1979. He holds a doctorate in anthropology and an M.S. in human nutrition. He will work in Ecuador where he will assess the need to incorporate information on diets into the design of research on agricultural technologies. A pre-doctoral fellow is conducting thesis research in the Veracruz State, Mexico. His work, done in conjunction with the maize training program, examines the procedures for undertaking collaborative research and for training maize production specialists.

The program will receive several visiting scientists during 1979 for two to five-month periods. The scientists, all from developing countries, will collaborate in production research programs on returning home. While in Mexico they will participate with the maize or wheat training programs in on-farm experimentation, will conduct interviews and surveys with farmers, and will attend wide ranging seminars on topics relating to the development of improved technologies. One visiting scientist will also work with the Eastern African regional program in developing indigenous competence in collaborative research.

Predoctoral fellow Larry Harrington is conducting his thesis research in Veracruz State, Mexico, in conjunction with the maize training program. He is involved in survey work designed to orient production research priorities.

Management seminars for agricultural decision makers

In 1977 the CIMMYT Trustees authorized a three-year project to organize a series of management seminars for agricultural decision makers from developing countries. The economics program was asked to provide leadership for the project, enlisting the skills of outside specialists and involving the CIMMYT maize and wheat staffs in the preparation and presentation of the seminars.

The purpose of the seminars is to assemble experienced policy makers, scientists, and managers whose activities affect national agricultural production to discuss the role of public policy in the development and adoption of improved agricultural technologies. By examining several "case studies" which will require the participants to formulate appropriate public policies affecting agriculture, the seminar will emphasize the importance of considering farmer circumstances, agronomic, economic, and political factors in the formulation of effective agricultural policy. The workshop will provide a vehicle whereby participants of diverse backgrounds can share their experiences and perspectives on policy issues related to the development and adoption of improved agricultural technologies.

The first workshop, to be held in mid 1979, will consist of a curriculum of 6 cases to be studied and discussed by 35-40 participants over a 3-day period. Each case study will present a specific decision making situation and will include background material and technical notes describing in detail the dimensions of each situation. Participants will utilize the background material, technical notes and their own experience to formulate solutions to the problem posed by the case. In addition, the workshop will feature presentations by prominent figures in international agriculture.

Because of the experimental nature of the project, several options will be tested in 1979 related to case materials, mixture of participants, length of seminar, discussion leaders, and course locations.

COOPERATIVE PROJECTS OUTSIDE MEXICO

Regional programs

CIMMYT's regional economists work with maize and wheat scientists in national programs where they encourage the kind of collaborative research aimed at the development of technologies useful to representative farmers. This involves bringing local economists together with the biological scientists, consulting on the organization of micro-level research, providing financial support to such work where necessary, and cooperating in drawing inferences for the orientation of biological research and for policy.

Economics staff serving in four regions have helped to establish many collaborative research programs. These programs are recasting their research to conform with the results of such collaborative efforts and their on-farm activities are showing new solutions to the problems of representative farmers.

East African Regional Program

After reviewing the results of several studies carried out with CIMMYT support, the Government of Kenya has opened eight positions in its agricultural research service for economists. Most will be assigned to agricultural research stations where they will cooperate with biological scientists in research establishing the needs of representative farmers and in orienting research on improved technologies in terms of those needs.

After two collaborative ventures in Tanzania involving economists and members of the national maize program, the Agricultural University at Morogoro added programs on on-farm surveys and research, the Ministry of Agriculture approved additional studies in new areas in southern Tanzania, and the Ministry asked for help in building capacity to do this kind of research in all of the agricultural research institutes of the country. Beyond that, two important development assistance agencies have incorporated the approach in their proposals for agricultural service programs.

Zambia completed its first demonstration of collaborative research focused on identifying farmer needs in 1978 with help from Mount Makulu research station near Lusaka and has asked CIMMYT to work with two newly hired graduates on expansion of this work.

The regional economist has also participated in several workshops featuring training for young professionals from the region.

Andean Regional Program

An economist was posted to the Andean Region in late 1977 for cooperative work in Colombia, Ecuador, Peru and Bolivia. His work has concentrated on floury maize, a dominant crop in the highlands; on wheat, a secondary crop in the farming system of that area; and on tropical maize in the coastal and Amazon basin areas. Working with indigenous economists and national crops programs, six surveys were completed by the beginning of 1979. In one study in Peru, the importance of the maize-potato rotation led to a joint national program for CIMMYT/CIP work. In Ecuador, the importance of the maize-bean association led to a joint national program involving CIMMYT/CIAT work. A set of on-farm trials were initiated in three different Andean locations in Peru. These will be used to evaluate and, where necessary, reorient research undertaken in experimental stations for new technology. The same approach has been utilized in Ecuador where it has also served as a framework for a local training course in production research with floury maize as a basic crop.

In both Ecuador and Peru national meetings of maize scientists have used the resulting on-farm experiments to motivate discussion on methods and on the direction of future work.

Central American Regional Program

The regional economist assigned to Central America in 1978 has concentrated on production studies now under way in Panama, El Salvador, and Costa Rica. The Panama program emphasizes on-farm research in an area producing maize, beans, and dairy products and integrates the participation of national and international institutions. Work in El Salvador also focuses on area-specific production research programs. One consequence of this work is that the national research program has decided to extend the approach to the entire country, assigning the responsibility to a full-time team formed by 14 extensionists and eight researchers representing different disciplines. Efforts in Costa Rica are based on two years of on-farm trials. Micro-level surveys were added, target farmer groups identified, and experiments shifted to conform with new impressions of research problems.

Workshops in Panama and El Salvador, involving CIMMYT staff from other regions and from the maize training program, have strengthened the thrust of work there. In all cases former CIMMYT trainees have participated in the work.

South Asian Regional Program

The regional economist, newly posted in 1978, has opened research in India and Bangladesh. In the north of India he is working with biological scientists from the G.B. Pant University of Agriculture and Technology in surveys and on-farm trials. This is part of an on-going program for developing triticales for the Himalayan hills. These hills, stretching from Afghanistan to Nepal, are populated by small farmers and dominated by conditions where triticale seems to offer marked advantages over wheat. This work, as well as methods for collaboration among regional scientists, was the subject of a regional triticale workshop held in April, 1979.

Also in India he has been heavily involved in on-farm research projects in two Indian states (Uttar Pradesh and Bihar). Each project aims at improving maize technology. Both are being conducted by local researchers.

In Bangladesh the regional economist is helping in the development of priorities and programs for the national integrated wheat research and extension system.

supporting services

EXPERIMENT STATIONS

CIMMYT conducted research at seven stations in Mexico during 1978. Three belong to Mexico's National Agricultural Research Institute (INIA), and four belong to CIMMYT. Some characteristics of these stations are:

Station	Altitude (m)	Latitude (°N)	Hectares Used by CIMMYT		Crop Season
CIANO–INIA	39	27	165	(wheat*)	Nov–May
				(maize)	Jun–Dec
Los Mochis–INIA**	40	26	2	(wheat)	Dec–May
Rio Bravo–INIA**	30	26	1	(wheat*)	Dec–May
El Batan–CIMMYT Headquarters	2,240	19	26	(maize)	Apr–Dec
			28	(wheat*)	May–Nov
			4	(sorghum)	Apr–Oct
Atizapan–CIMMYT	2,640	19	48	(wheat*)	May–Nov
			5	(wheat*)	Dec–May
			14	(maize)	Apr–Dec
			1	(potatoes***)	Mar–Dec
Poza Rica–CIMMYT	60	20	41	(maize,	Dec–May
			4	sorghum***)	Jun–Nov
			1	(wheat)	Nov–May
Tlaltizapan–CIMMYT	940	18	31	(maize,	Dec–May
			1	sorghum***)	Jun–Dec

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

At El Batan station the final arrangements were made for the transfer from the Mexican Ministry of Agriculture and Water Resources of 13 hectares of land adjacent to our main entrance, bringing the total area of El Batan station to 78 hectares. Work was started in 1978 on the development of the new area and will be completed before the 1979 planting season. This land purchase has provided a better drainage outlet, in addition to increasing the area devoted to field research.

At Toluca station work continued on a new drainage and irrigation scheme.

At Poza Rica the river defenses again proved their worth when a bad flood occurred in September, 1978, causing only minor damage to the station.

The head and assistant head spent 78 days as consultants to Ecuador, Tanzania and India.

Training

Two training courses in experiment station management were given in 1978 to sixteen agricultural officers from 11 countries. Many short term visitors from developing countries were also received.

Training in experiment station management is being requested more and more by national collaborators. In 1978, sixteen agricultural officers from 11 countries participated in this practical problem-oriented training program.

LABORATORY SERVICES

CIMMYT maintains laboratories to evaluate the quality of the materials generated by the maize, wheat, triticale and barley programs. The laboratories also provide services to CIMMYT agronomy, experiment stations and training programs.

Protein quality laboratory

Cereal grains have nutritional deficiencies mainly due to the low quality of their protein. CIMMYT scientists are involved in developing genetic material with improved nutritional quality as well as high yield potential. In 1978 the protein laboratory analyzed 15,000 maize samples of different populations with high lysine and desirable grain characteristics.

The low quality of the protein in normal maize kernels is due to the low content of lysine and tryptophan, two essential amino acids which are highly correlated with protein quality of the endosperm. Screening for high quality protein maize is performed to determine tryptophan with a procedure that permits approximately 320 determinations per day. Lysine is determined after high tryptophan materials are

Technicians in the protein quality laboratory analyze thousands of maize samples each year. Laboratory data is essential for guiding the breeding program in maize nutritional improvement. This interdisciplinary effort has accelerated the development of high protein quality, normal looking, hard endosperm materials.

identified. The protein content is estimated in all samples. Levels of all amino acids are determined only on the most outstanding materials selected for protein quality as well as superior agronomic characteristics.

Preliminary evaluations of floury 1-opaque-2 materials are also conducted. This analysis has accelerated the conversion of highland floury pools grown mainly in the Andean region of South America to opaque-2 types with improved nutritional quality for future testing and possible introduction as improved varieties.

Approximately 3,200 triticale, 1,500 wheat and 400 barley samples were analyzed in the preliminary laboratory evaluations for protein quality. The most promising materials are also analyzed for lysine content. Complete amino acid analysis is performed only with the most superior materials of high yield potential.

Biological evaluation

Samples of extremely promising material evaluated at CIMMYT for protein quality are also sent to the National Institute on Animal Research in Mexico and the Danish Agricultural Experimental Laboratory in Denmark where final tests for nutritional quality are performed by feeding trials with laboratory animals.

Training

During 1978, five visiting scientists from Colombia, Egypt, India and Peru spent one to three months each at CIMMYT to become acquainted with analytical techniques and laboratory organization. CIMMYT's biochemists also continued to advise a network of national programs on laboratory programs and equipment.

Soils and plant nutrition laboratory

This laboratory performs chemical analysis on samples of soil, water, plant tissue, and grain. During 1978 the laboratory analyzed 1,755 soil samples to provide information to CIMMYT scientists about the nutrient content and availability in CIMMYT experiment station soils and at off-station sites where agronomy and training programs carry out research trials.

Samples are analyzed, as needed, for pH, organic matter, total nitrogen, calcium, magnesium, potassium, phosphorus, iron, manganese, copper, zinc, boron, nitrate, exchangeable acidity, electric conductivity, cation exchange capacity, and texture.

Irrigation water quality is analyzed for content levels of sodium, boron, and total soluble salts. Thirty-eight analyses were carried out in 1978. A monthly analysis of potable water quality is performed at CIMMYT experiment stations.

About 2,600 samples of vegetal tissue were analyzed to evaluate the effect on plant protein of different timings and levels of nitrogen fertilizer applications. Sugar levels were estimated to explore yield-limiting factors in relation to photosyntetic efficiency, light competition and plant height under optimum production conditions.

Another 652 samples of vegetal tissue were tested for iron analysis in order to evaluate the extraction levels of this nutrient under different sulfur treatments.

INFORMATION SERVICES

Thirty-seven new titles were published during 1978. In addition the general information booklet, *This is CIMMYT,* was revised and reissued.

The serial CIMMYT TODAY, continued with two issues published during the year. Articles in this serial treat broad aspects of CIMMYT's activities for the informed layman.

The pocket-size field book for identifying maize diseases was revised and reissued in 1978.

The Commonwealth Agricultural Bureau (UK) issued on behalf of CIMMYT, Volume 4 of the Maize Quality Protein Abstracts (MQPA), and Volume 4 of Triticale Abstracts (TA). About 650 maize scientists receive MQPA and about 400 scientists receive TA.

Mailing lists

In 1978, a questionnaire was sent out to the 4,700 listings on CIMMYT's general mailing list.

Eighty per cent asked to remain on the mailing list, which now includes approximately 4,000 addresses classified by interest: 23 per cent wheat specialists, 21 per cent maize specialists, 46 per cent general agriculturalists, 10 per cent libraries; by language: 60 per cent English, 40 per cent Spanish; by geographic area: 10 per cent Europe, 23 per cent North America, 40 per cent Latin America, 9 per cent Africa, 18 per cent Asia and the Pacific.

Audio visuals

The permanent exhibits in the administration building continued to grow; new displays were added in 1978. The exhibits depict CIMMYT's activities in increasing the world food supply.

A video taping capability was added to this program in 1978. Using portable, modestly priced equipment, the audio-visuals program produced 32 video tapes in 1978 for visitor services, training programs, and CIMMYT staff orientation. The development of video programs will continue in 1979 with many new productions programmed for the training programs and visitor services. Most of the tapes run 10-20 minutes. Audio-visual materials are also being developed using the slide/tape format for use by CIMMYT staff not located at El Batan headquarters to assist them in explaining CIMMYT program objectives and activities.

Visitors Services

In 1978 over 9,000 visitors from 70 countries visited CIMMYT headquarters. Many others visited experiment stations in Mexico where CIMMYT conducts research.

Eleven major conference events, each lasting 1-5 days, were handled by the Visitors Service. Over 750 campus tours and slide presentations were given during the year.

The Visitors Service staff continues to look for innovative and more effective ways to tell the CIMMYT story. In 1978 new visitor materials such as publications, audiovisual aids, slide presentations and tour aids were developed.

Library Services

CIMMYT's special library (2,384 volumes, 4,099 reprints, 760 serials) continued to offer service to the headquarters staff, postdoctoral fellows and trainees. The library also has access to the much larger Mexican National Agricultural Library Collection.

PUBLICATIONS ISSUED BY CIMMYT IN 1978

Title	Language	Pages	Press Run
Administration			
This is CIMMYT	English Spanish	32 31	6000 5000
CIMMYT Review 1978	English	138	7200
CIMMYT Today - Training	English Spanish	16 16	7500 7500
CIMMYT Today - Transforming Maize Farming in Zaire	English Spanish	20 20	5000 3000
Wheat			
CIMMYT Report on Wheat Improvement 1975	English	208	2000
CIMMYT Report on Wheat Improvement 1976	English	234	2000
Results of the Seventh International Durum Yield Nursery (IDYN) 1975-76 (IB31)	English	86	1000
Results of the Sixth International Triticale Yield Nursery (ITYN) 1974-75 (IB32)	English	68	1000
Results of the Seventh International Triticale Yield Nursery (ITYN) 1975-76 (IB33)	English	82	1000
Semidwarf Bread Wheats—names, parentage, pedigrees, origin. (IB34)	English Spanish	16 15	3000 2000
Results of the Eleventh International Spring Wheat Yield Nursery (ISWYN) 1974-75 (IB35)	English	95	1000
Results of the First International Barley Observation Nursery (IBON) 1973-74 (IB36)	English	7	1000
Results of the First Elite Barley Yield Trial (EBYT) 1975-76 (IB37)	English	25	1000
Instructions for the Management and Reporting of Results of all International Yield Nurseries and Screening Nurseries (IB38)	English	17	2000
Results of the Twelfth International Spring Wheat Yield Nursery (ISWYN) 1975-76 (IB39)	English	118	1000
Results of the Thirteenth International Spring Wheat Yield Nursery (ISWYN) 1976-77 (IB40)	English	103	1000
Results of the Eighth International Triticale Yield Nursery (ITYN) 1976-77 (IB41)	English	81	1000
Results of the Eighth International Durum Yield Nursery (IDYN) 1976-77 (IB42)	English	56	1000
Present Status of Wheat Improvement in CIMMYT (TR23)	English	11	500
Wheat Breeding and its Impact on World Food Supply (TR2)	English Spanish	36 40	500 500

Maize			
International Testing Program 1976. Addendum to Supplementary Report	English/ Spanish	72	500
International Testing 1977. Preliminary Report	English/ Spanish	133	500
International Testing 1977. Supplementary Report	English/ Spanish	124	500
International Testing 1977. Addendum to Supplementary Report	English/ Spanish	82	500
International Testing 1978. Preliminary Report	English/ Spanish	81	500
Maize Diseases - A Guide for Field Identification, 1978 (IB11) 2nd. ed.	English Spanish	93 93	7100 7200
Mejoramiento Integral del Maíz	Spanish	206	1000
Economics			
La adopción de la nueva tecnología de maíz en el Plan Puebla, México	Spanish	33	1500
Efecto de las políticas de importación de trigo sobre la producción y el consumo nacional	Spanish	7	500
El Trigo en Perú	Spanish	14	500
El Trigo en Colombia	Spanish	18	500
El Trigo en Ecuador	Spanish	25	500
El Trigo en Bolivia	Spanish	17	500
Miscellaneous			
Races of Maize in Brazil and Adjacent Areas	English	95	2000
Tractors—Basic Principles and Operation. Experiment Station Practical Training	English	40	60
Small Farm Grain Storage	English	300	500
De la Harina al Pan	Spanish	80	500

STATISTICAL SERVICES

During 1978 the number of experiments analyzed and reports produced doubled over 1977 activity.

Maize international testing results continued to be analyzed and summarized by the same basic computer programs used in 1975-77, although there have been many improvements in efficiency. In 1978 one maize progeny trial (IPTT) went out with 144 entries instead of the usual 256, and the option to analyze any set of identical simple lattice designs of any size has therefore been introduced.

Wheat international yield nurseries, for which computer programs were introduced at the end of 1977, have had initial difficulties ironed out and the analysis of the nurseries data is well in hand. During 1978 a backlog of other recent nursery results was also analyzed, so that reporting on these nurseries is now up to date.

Maize germ plasm inventory management by computer continues to run smoothly and the backlog from previous years has been cleared. Owing to computer software problems we do not yet have a working version of EXIR (germ plasm bank management system) available at El Batan, and it is hoped this can be achieved during 1979.

Considerable progress was achieved in 1978 on computer programs to automate the derivation of wheat pedigree listings and development of logbooks and field tags. The F_2 to F_7 files of names are now on the computer and F_1 field books are currently being produced for the 1979 season. In the next cycle it is hoped to obtain information on pedigrees in the crossing blocks themselves, when another computer program (already working) will automatically derive the F_1 names from pairs of crossing block names. This computer system simplifies the task of pedigree records and reduces the probability of errors compared to the past practice of handwritten records.

Apart from the wheat selection field books mentioned above, all the field logbooks sent to collaborators in the international testing programs are now produced by the computer at El Batan. A program has been written which will produce randomizations for randomized blocks, split-plots, and various lattice designs in a form suitable for direct printing.

The computer programs mentioned in the 1977 CIMMYT report for the wheat program screening nurseries have now been superseded, as it was found that the many and varied demands for presentation of the data necessitated a complete overhaul. The new programs, recently delivered are now in operation, and have been developed for CIMMYT by Laboratory for Information Science in Agriculture (LISA), at Colorado State University.

Outside the international testing work, computer programs have been written or adapted which provide facilities for the component types of experimental design, for multivariate regression, and for data plotting. Work is currently under way on a package for the summarization of simple survey data for the economics program. Statistical advice on the design and analysis of research has been provided for wheat and maize physiologists, breeders, agronomists and pathologists.

In the routine handling of international testing results, two further steps appear desirable: 1) a merging of the handling of the wheat screening and yield trials, where the requirements are very similar but inputs different, and 2) a fresh look at the programs for international maize progeny and experimental variety trials to increase flexibility of data input and improve the selection options.

Once the backlog is eliminated in wheat screening nurseries and the pedigrees are completely up-to-date, it is hoped that there will be time to examine the fine detail of the mass of results which have been processed during the past three years, with a view to improving field techniques, finding suitable transformations to permit analysis of further variables, and to investigate whether the CIMMYT research designs used in breeding are achieving their objectives.

SPECIAL REPORT: CIMMYT Priorities for Regional Programs

CIMMYT, with concurrence of its Board of Trustees, began in 1973 to post staff members to regional assignments to improve the efficiency of CIMMYT services to national programs and to encourage cooperation among national agricultural scientists within a region.

A region includes a number of countries, usually geographically contiguous, which possess similar production environments and face similar production problems. Such countries agree to strengthen through regional cooperation the exchange of germ plasm and scientific information among themselves, thus improving their utilization of scarce research resources with the common goal of accelerating wheat and/or maize-related research in their respective countries.

Typically, regionally assigned CIMMYT staff members help a regional program to distribute new germ plasm to collaborators through regional nurseries, organize workshops and field tours for regional scientists, improve and coordinate training opportunities inside and outside the region, and identify problems and coordinate visits of CIMMYT and other scientists to the region for consultation assistance.

CIMMYT has used the following criteria in deciding to assign staff to work with regional programs:

(1) the importance of maize or wheat production and consumption in the region;

(2) similarities of production conditions and constraints facing farmers in the region;

(3) existence of national research capacities in maize and wheat production and improvement;

(4) interest of national programs within the region in inter-country cooperation and exchange of scientific information as well as improved germ plasm.

Wherever possible CIMMYT seeks logistical support for its regionally assigned staff from sister international institutes or collaborating national institutes.

CIMMYT views the staff posted to regional programs as integral members of on-going CIMMYT research programs responsible directly to the Directors of Maize, Wheat or Economics programs.

Regional assignments are financed as core CIMMYT activities. These staff play a key role in problem identification to guide the efforts of the headquarters programs. Regional staff also have the central responsibility for encouraging agronomic research by national programs both on experiment stations and on farmers' fields.

Regional Maize Programs

CIMMYT now operates three regional maize programs and three more are proposed. The 1978 activities of the ongoing programs are described in the Maize Section of this Report.

(1) Central American and Caribbean Regional Maize Program (initiated 1974)

The Inter-American Development Bank (IDB) expressed interest in supporting maize improvement in Latin America at three levels—at CIMMYT headquarters, in one region of Latin America, and through bilateral grants to several countries.

CIMMYT recommended the Central American and Caribbean Region because:

(a) Maize is the No. 1 cereal crop of the region, producing 3.5 million metric tons of maize on two million hectares. The region suffers a food deficit, for which it annually imports 1.5 million tons of grain, mostly wheat.

(b) CIMMYT already had improved maize germ plasm suitable for use in this region and a system of regional testing had already begun. CIMMYT and its predecessor agency had longer experience in Central America than any other region of Latin America.

(c) More young maize scientists from this region had been trained at CIMMYT than from any other part of the Hemisphere.

(d) The region had reasonably stable governments, both politically and economically.

(e) Countries of the region had been engaged since 1954 in a cooperative arrangement for crop improvement known as PCCMCA (Programa Cooperativo Centroamericano para Mejoramiento de Cultivos Alimenticios). This program had established the needed inter-governmental channels for cooperation but still required additional access to new technology to achieve scientific goals.

The IDB accepted this reasoning and provided support to a regional program for the initial period October 1974 through December 1976. Since January 1977 the program has continued with support from the Government of Switzerland. Regional staff are stationed at CIMMYT headquarters.

(2) Asian Regional Maize Program (initiated 1976)

A regional maize program in South and Southeast Asia began in 1976 with support from the UN Development Programme (UNDP), for the following reasons:

(a) CIMMYT and its predecessor agency had 20 years' experience with the Asian region through the Asian corn program, supported by the Rockefeller Foundation during 1954-76.

(b) South and Southeast Asia produced a large maize crop (17 million tons).

(c) Several countries of the region had outstanding maize scientists and were thus ready to contribute and to receive services under regional cooperation.

(d) South Asia had the largest continuing food deficit of any region in the world, and projections by IFPRI (International Food Policy Research Institute) indicated this deficit was likely to grow during the 1980's.

UNDP accepted this explanation; it financed the program with an initial grant for 1976-79, and subsequently extended its support for five more years, 1979-84. CIMMYT regional staff are stationed at and receive logistic support from ICRISAT.

(3) Andean Regional Maize Program (initiated 1976)

In 1976 CIAT Trustees proposed that CIMMYT and CIAT should work together for a joint maize program in the Andean region. CIMMYT Trustees concurred. The Canadian International Development Agency (CIDA) agreed to finance the program for three years, 1976-79.

CIMMYT's reasons for recommending this regional maize program in 1976 were:

(a) Maize was the largest food crop in the region, and the region had a large food deficit.

(b) Highland maize had received little attention from maize researchers, and research on floury maize, which is widely grown above 2000 meters elevation, had been especially neglected.

(c) CIMMYT had trained younger scientists from the Andean region and there were sufficient scientists with adequate qualifications in research to make a viable regional program.

(d) Prior existence of the Andean Pact and Andean Common Market suggested favorable relationships which would facilitate regional cooperation.

CIDA-Canada found this justification acceptable and financed the Andean project. CIMMYT regional staff receive their logistical support from CIAT.

(4) Future Maize Regional Programs

CIMMYT Trustees have approved the initiation of three additional regional maize programs over the next few years:

Tropical East Africa region—12 countries, 156 million people, annual maize production of about 8 million tons.

Tropical West Africa region—13 countries, 132 million people, annual maize production of 4 million tons; this program will be in collaboration with IITA.

North Africa-Mideast region—5 countries, 143 million people, annual maize production of 5 million tons.

Before each of these three new activities is begun, the regions again will be reviewed using criteria similar to those listed for the programs already operating.

Regional Wheat Programs

Setting priorities for regional wheat programs follows a process similar to maize but the groupings of countries are not the same, and selection of areas is strongly influenced by the prevalent wheat diseases which are common to a number of countries. The wheat program now has four operating regional activities and proposes two more. Each will be described. (More detailed descriptions of 1978 activities are found in this Report under the Wheat Section).

(1) Mediterranean and Mideast Regional Wheat Program (initiated 1973)

A wheat pathologist in India (1967-73) achieved wide recognition for his work in organizing, jointly with Indian scientists, an early warning system against attacks by new races of rust. (A warning system can give several years in which to replace varieties which become susceptible to a new race of disease, thus safeguarding against epidemics).

The Ford Foundation offered in 1973 to place this employee on the CIMMYT payroll, and to transfer his post from India to the Mideast, where he could work over a much larger area, providing services to many more governments. CIMMYT agreed for the following reasons:

(a) The wind-borne pathogens for wheat rust travel over vast areas between India in the east and Morocco in the west, and south to Kenya and Tanzania in East Africa. CIMMYT believed that one warning system could provide services to all these countries through the posting of regional pathologists to work with local scientists.

(b) This region produces about 70 million tons of wheat per year, and is thus the most important wheat-growing region among developing countries.

(c) Most countries of the region already had 5-10 years of experience in growing international nurseries, and this was the area in which semidwarf wheats gained their widest recognition.

(d) CIMMYT had trained young scientists from this region, and there were more experienced scientists to give leadership to a regional program.

(e) When governments were consulted, CIMMYT found widespread interest in a cooperative regional program for a wheat disease warning system.

On this basis the Ford Foundation provided initial funding. This regional program is operated cooperatively with ICARDA.

(2) Tropical East Africa Regional Wheat Program (initiated 1976)

CIMMYT, in collaboration with the Government of Kenya and ALAD (Arid Lands Agricultural Development Program), initiated in the early 1970's a summer nursery for wheat research at Njoro, Kenya. This program was initially financed by the Government of Kenya. The summer nursery gave breeders in countries of the Mediterranean-Mideast an opportunity to grow two cycles of breeding materials a year—one in the winter season in their home country and one in the summer season in Kenya.

CIMMYT proposed that the summer nursery in Kenya be converted to a regional wheat program for tropical East Africa for the following considerations:

(a) Twelve countries of the Mediterranean-Mideast region had already used the summer nursery in Kenya, and wanted the service continued.

(b) Wheat and barley were important crops among 14 countries in tropical East and Central Africa, where over one million tons of the two cereals are produced.

(c) This region had a large food deficit and imported 500,000 to one million tons of cereal grains a year, most of it wheat or wheat flour.

(d) East Africa was experienced in agricultural cooperation through EAAFRO (East Africa Agricultural and Forestry Research Organization) headquartered at Nairobi, Kenya. But the East Africa Community was dissolved in 1976 and EAAFRO separated into national programs. There was need for an initiative to revive agricultural cooperation.

(e) The Canadian Government had provided bilateral assistance for wheat research in several countries (Kenya, Tanzania, Zambia) but there was no longer a regional service to move the benefits of these research activities to neighboring countries.

(f) The East African countries were "hot spots" for stem rust. If international materials were tested regularly in East Africa, this could become an important location for identifying resistance to this major disease.

(g) Tropical East Africa required an early warning system against the spread of new races of wheat disease, and such a warning system could best be managed through regional cooperation.

Based on these factors, the Canadian Government (CIDA) agreed to finance the program for an initial three years, 1976-79. ILRAD provides logistical support for the CIMMYT regional staff.

(3) Andean Regional Wheat Program (initiated 1976)

Five countries of the Andean Pact (Bolivia, Colombia, Ecuador, Peru, Venezuela) engage in many forms of economic cooperation and share some similarities in climate and agricultural problems.

CIMMYT helped initiate a regional wheat-barley-triticale program for this region in 1976, for these reasons:

(a) Although the Andean countries produced only 300,000 tons of wheat, and 300,000 tons of barley, they imported almost four million tons of cereal grains a year, about half of it wheat or wheat flour.

(b) The Andean region was a "hot spot" for stripe rust. CIMMYT believed that this regional program could test all the international materials for resistance to stripe rust, and thus help to identify sources of resistance, an assistance both to the region and to the world network.

(c) Barley yellow dwarf was another severe disease of the Andean region, and the international testing of barley materials here would have benefits similar to those for wheat.

(d) There were enough trained scientists in the region to provide leadership for a cooperative program.

(e) When CIMMYT surveyed the attitude of governments toward a regional wheat program, it found all Andean countries ready to participate.

Several obstacles to a program were also recognized: first, that wheat is the No. 2 crop of the region, after maize, and therefore receives less attention; second, that the U.S. Government had been selling surplus wheat at preferential prices causing the Andean governments to make less effort to improve their wheat crop.

Nevertheless, the Canadian Government (CIDA) and CIMMYT agreed to proceed with the program under Canadian financing. Ecuador's National Agricultural Research Institute provides logistical support for the CIMMYT regional staff.

(4) Southern Cone Regional Wheat Program (initiated 1978)

The Southern Cone region of South America (Argentina, Brazil, Chile, Uruguay, and Paraguay) is an area in which many common agricultural problems exist, but there has been a minimum of joint effort. CIMMYT believed agricultural cooperation between scientists could be attained, even if close political ties do not exist between governments.

CIMMYT recommended this regional wheat program, starting in October 1978, based on the following considerations:

(a) Wheat was the first ranking food crop of the region (15 million tons a year).

(b) The region had a body of well-trained scientists, many of whom have been visiting scientists at CIMMYT.

(c) There had been no regional nursery trials for wheat, and probably none would have started until an external organization took the initiative.

(d) Argentina had the possibility to become the largest exporter of wheat in the developing world, and thus contribute to world food security.

(e) Brazil had more than 20 million hectares of potential wheat land with acid soils. It is possible to compensate for this problem through breeding for acid tolerant varieties.

(f) The Southern Cone was one of the most promising areas for introduction of triticale. (See Wheat Section of this Report.)

Based on these justifications, CIMMYT initiated a regional wheat activity in 1978 with core funds, and anticipates it will produce viable cooperation between regional scientists. Chile's National Research Institute provides logistical support for CIMMYT regional staff.

(5) Future Regional Wheat Programs

CIMMYT Trustees have approved the initiation of two additional regional wheat programs over the next few years:

South Asia region—5 countries, 830 million people, annual wheat production of 42 million tons.

North and West Africa region—8 countries, 55 million people, annual wheat production of 4 million tons.

These activities will be reviewed using criteria similar to those listed under the maize program above, before a new activity begins.

Economics Regional Programs

Economics focuses the bulk of its attention on work with national programs to develop procedures to improve the evolution of more effective agricultural technologies. To be effective in developing and testing these procedures requires that CIMMYT economists establish close working relationships at the national level. Early in the life of the program this was done from headquarters in Mexico. The demands for these services soon vastly exceeded existing staff capacity. CIMMYT decided that additions to staff could be more effective if deployed close to the national programs with which they were to work. Regional staff are better able to establish close working relationships with biological scientists and economists as well as to reduce their travel costs, broadly defined.

In choosing regions several criteria are considered. We look for a roughly contiguous grouping of countries where maize and/or wheat are important, where there is support for the idea of collaboration among biological scientists and economists, and where a single language is serviceable.

By 1979 CIMMYT economists were serving four regions: East Africa, the Andean countries, Central America, and South Asia. (See Economics Section of this Report.) While the region covered by these economists differs in some cases from those of the maize and wheat programs, each of the four is based with a regional staff member from one of CIMMYT's other programs.

CIMMYT's regional economists participate in national research projects which bring biological scientists and economists together for purposes of developing improved technologies and to generate information useful to national policy formation. Training is another important function of regional economists. Finally, they contribute to CIMMYT's knowledge on developing and diffusing procedures to produce useful technologies.

1978 CIMMYT INCOME AND EXPENDITURES

(Excerpt from CIMMYT Auditors Report 1978*)

	Thousand US$
Core unrestricted income	**8,175**
Australia	143
Canadian International Development Agency	1,118
Denmark	180
Federal Republic of Germany	100
Ford Foundation	100
Inter-American Development Bank	2,850
International Bank for Reconstruction and Development	100
Rockefeller Foundation	400
United Kingdom	384
U.S. Agency for International Development	2,800
Core restricted income	**3,905**
Canadian International Development Agency	691
Andean Region and East Africa	
Federal Republic of Germany	8
Collaborative Research	
Japan	300
Wheat Pathology	
Netherlands	360
Wheat Disease Surveillance	
Switzerland	243
Central America and Caribbean and Andean Regions	
United Nations Development Programme	2,303
Quality Protein Maize and East Africa Economics	
Extra core grants and cooperative projects income	**1,361**
Canadian International Development Agency	150
Triticale Research and Training, Peru and Zambia Training	
Federal Republic of Germany	32
Training	
Ford Foundation	248
North Africa, Pakistan, Egypt and Training	
International Development Research Centre/ICRISAT	64
Sorghum Project	
International Potato Center (CIP)	62
Regional Research, Mexico	
Norwegian Agency for International Development	87
Training	
Rockefeller Foundation	37
Fellowships and Seminar	
U.S. Agency for International Development	493
Pakistan, Guatemala, Tanzania, Zaire, Nepal and Training	
Zaire Government	162
National Maize Program	
Training and miscellaneous grants	26
Earned income (not included elsewhere)	**105**
TOTAL INCOME	**13,546**

* Figures adjusted during 1979 due to default of a donor pledge.

	Thousand US$
Core operating expenses	**12,687**
Wheat Program	2,809
Maize Program	2,550
Economics	587
Laboratory Services	450
Experiment Station Services	1,380
Statistical Services	197
Training and Conferences	1,688
Information Services	510
General Administration	1,207
Plant Operations	1,229
Capital Acquisitions	80
Extra core grant and cooperative project expenses	**1,225**
Additions to working capital and reserves	**255**
TOTAL APPLICATION OF FUNDS IN 1978	**14,167**
Use of carry-over funds	**(621)**
TOTAL APPLICATION OF 1978 INCOME	**13,546**

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