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introduction

Between August 1974 and April 1975, the staff of this center conducted a program review. About 40 senior staff members comprised a panel which examined the research plots in the second cycle of 1974. Field visits required 4 days. Seminars were then held in the conference room to discuss questions of research method. When significant differences of opinion were found, a smaller staff group was designated to produce a staff study.

Out of this 8-month process came a summary of activities presented in this booklet. Seven topics which received extra study by small groups are summarized in the back as special reports.

This publications serves as a record of CIMMYT's accountability to its donors, for the year under review.

The report understates CIMMYT's indebtedness to its collaborators including:

First, the world-wide network of maize and wheat scientists who conduct the international trials.

Second, about 80 governments of Asia, Africa, and Latin America whose search for better foodcrop technology is the driving force in our work.

Finally, the constant support of the Mexican Ministry of Agriculture, the Mexican faculties of agriculture, and Mexican farm groups who share with us their seeds, their research facilities, their private farmlands, and their production experience —all to benefit food producers outside of Mexico.

Haldore Hanson, *Director General*
El Batan, Mexico, April 1975

maize improvement

MAIZE SUMMARY

Changes in organization. In 1974 the maize program completed its first full year under a new organization and set of procedures introduced in 1973. The new system stresses an interdisciplinary team. It provides better descriptions and use of the germ plasm at each stage of development, improvement, and testing. It enables multi-location testing to guide the selection process for wider adaptation. The new procedures will move elite varieties more rapidly to national programs.

Germ plasm bank. The 12,000 entries in the maize bank are being evaluated systematically to select useful materials for improving the gene pools.

The supervisor of the bank completed more crosses between maize and tripsacum, a wild relative of maize that may contribute desirable traits.

Backup and advanced units for developing superior families. Breeders, agronomists, and protection staff are now integrated in the process of evaluation and recombination.

Disease and insects. The plant protection staff is making disease-insect readings at every step of breeding and selection.

In studies of storage insects, hardness of the kernel was closely related to resistance to the maize weevil. In another study, maize weevils did less damage in the field to ears that had tight husks extending past the tip.

Physiology. Four series of studies were continued in 1974 to learn what limits the present tropical maize yields, and to provide guidance to the breeders on how to break the yield barriers.

Protein improvement. Research continued on how to improve the quality of protein in maize (by doubling quantities of two amino acids, lysine and tryptophan) with the opaque-2 gene introduced into most of the advanced populations. Little opaque-2 maize is yet grown commercially (only in the USA, Brazil, and Colombia, and in these countries only as hybrids). But CIMMYT is cooperating with nine national programs in Asia, Africa, and Latin America where open-pollinated varieties are under development.

International testing. Elite maize materials were sent to 39 countries for 238 trials during 1974.

Training. Forty-seven trainees from 23 countries received in-service training in Mexico. These courses last 6 to 7 months. Courses are offered for researchers, production agronomists, and laboratory technicians.

Many other categories of personnel visited for training or experience during 1974 including 12 master's degree candidates, 8 Ph.D. candidates in the USA, 2 Ph.D. candidates doing thesis research at CIMMYT, 11 postdoctoral fellows, 15 visiting scientists for 1 month or longer, and 25 short-term visiting scientists (1 to 4 weeks each).

Outreach activities. The staff devoted almost 900 man-days of consultation to governments in Asia, Africa, and Latin America. Ten staff members

were resident in five national programs during the year (Egypt, Nepal, Pakistan, Tanzania, and Zaire).

Sorghum. Work on cold-tolerant sorghum continued. This work is intended to serve cool climatic areas. New breeding materials arrived from Ethiopia and USA. Breeding progress was reported for wider adaptation, genetic resistance to disease and insects, and protein improvement. An international trial was grown in 13 countries outside Mexico.

NEW ORGANIZATION AND PROCEDURES

In 1974 CIMMYT completed its first full year under a reorganized maize program. The purpose of changes made in 1973 was to achieve completely interdisciplinary staff work at headquarters and to employ agronomic trials, disease-insect ratings, and other testing more systematically in selecting superior materials (Fig. 1). The streamlined process was expected to produce elite experimental varieties fitted to the needs of national programs in the shortest time, the first by 1976. The flow of improved materials thereafter should be continuous.

The changes involve: (1) Greater flow of new germ plasm from the bank and of introductions from other countries to the germ plasm pools in Mexico. (2) More multi-location testing within Mexico and outside

At harvest, the critical decision: which ears to save.

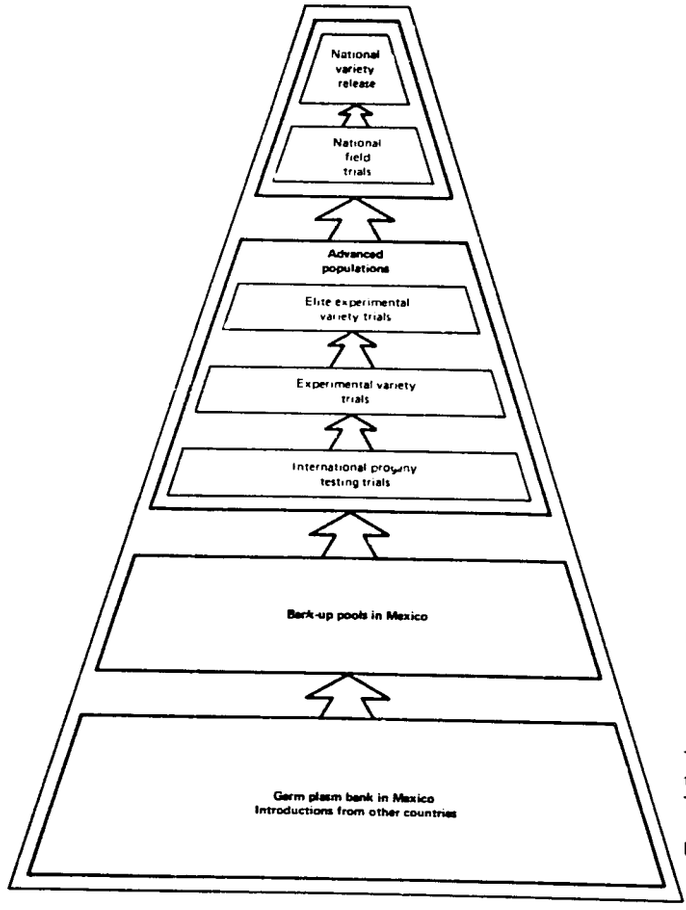


Fig. 1. Stages in the development of maize varieties at CIMMYT.

Based on **trials in farmers fields** and on international trials in competition with their best local varieties, **national agencies release new varieties.**

In the **advanced unit,** all families in all populations (250 families per population) are grown in the **International Progeny Testing Trials** in Mexico and five other locations. Ten superior families from each population become **experimental varieties.** About 100 best performing families in each population are intercrossed and regenerated to form the 250 families in each population in the next IPTT. In addition, any families advanced from the back-up pools are integrated at this time. The experimental varieties are tested at 25 to 30 locations and the best one or two varieties in each population become **elite experimental varieties.** Elite experimental varieties are tested at 100 to 125 locations. The best performing elites in each country are moved into national demonstration trials and considered for possible national release.

In the **back-up unit** materials are classified into 34 pools. There are 14 pools for the highland tropics, 12 pools for the lowland tropics and 8 pools for the temperate zone. Two cycles are grown a year. Superior families move to the advanced unit.

The **germ plasm bank** contains 12,000 accessions (varieties, lines, wild types) which are being classified according to economic characteristics. The best accessions are integrated into the appropriate back-up pools.

Introductions from other countries move directly to the back-up pools.

Mexico, thus moving new materials from the research station to the national programs as soon as supporting information can be generated. (3) Yield trials and disease-insect readings every second season in Mexico for all pools and populations undergoing improvement. (4) Integration of geneticists, agronomists, and plant protection staff in every step of plant improvement, from the testing of raw germ plasm in the bank up to the trials of elite experimental varieties at 100 or more sites outside Mexico.

To futher these purposes, the staff activities are organized into five units:

—Bank unit (maintains and tests unproven germ plasm).
—Back-up unit (handles the basic pools undergoing improvement).
—Advanced unit (tests improved populations, superior progeny, assembles experimental varieties).
—International testing unit (distributes advanced materials outside Mexico and analyzes the results of trials).
—Training unit.

Of the two seasons for tropical lowland and temperate maize in Mexico, the summer season is devoted to evaluation (testing for yield, disease-insect tolerance, and plant characters) and the winter season devoted to recombination (crossing). In this way, no year can go by without evidence whether each pool, each population, each progeny has improved in those characters or which it is being measured. Because highland maizes can be grown only once a year, they must be evaluated in one year and recombined in the next.

The new system calls for wider testing of germ plasm outside Mexico, and increased travel by CIMMYT senior staff in order to observe the international trials and to participate in planning workshops of national and regional programs.

GERM PLASM BANK AND MAIZE—TRIPSACUM CROSSES

The Mexico collection of 12,000 accessions of maize is the largest in the world. It was assembled by the government of Mexico during the 1940's and 1950's. The germ plasm bank fills many requests each year from institutions outside Mexico. In 1974 the bank made 45 shipments of seed to 22 countries. Since CIMMYT was created in 1966, the bank has shipped seed to 80 countries.

The principal service function of the bank unit is to provide breeders with a continuous flow of selected and classified germ plasm. To fulfill this function, the bank unit gathers new accessions, repropagates seed to maintain viability, conducts trials to classify the bank entries, and makes crosses between maize and its relatives to generate new germ plasm.

Propagation In 1974 the bank added 388 new accessions, and propagated 983 accessions to obtain additional viable seed. Thus about 8 percent of the

world collection was re-grown and observed during the year. Seed of 284 accessions which was repropagated in Peru in 1973 was received and incorporated in the inventory.

Tripsacum garden

Since 1972 the maize bank has maintained a tripsacum garden at Tlaltizapan. Tripsacum is a wild relative of maize found widely in Mexico, Guatemala, Honduras, and the southwestern USA. Tripsacum possesses a reservoir of potentially useful genes for breeding maize. The Mexico tripsacum garden contains all known species of this member of the grass family, and is open for experimental use by scientists outside CIMMYT.

Table 1. **The backup unit: Classification of gene pools.**

Type [a]	Maturity	Grain Color	Grain Texture	Pool No.
Tropical highland	early	white	flint	1
Tropical highland	early	white	dent	2
Tropical highland	early	white	floury	3
Tropical highland	early	yellow	flint	4
Tropical highland	early	yellow	dent	5
Tropical highland	intermediate	white	flint	6 [b]
Tropical highland	intermediate	white	dent	7
Tropical highland	intermediate	white	floury	8
Tropical highland	intermediate	yellow	flint	9
Tropical highland	intermediate	yellow	dent	10
Tropical highland	late	white	flint	11
Tropical highland	late	white	dent	12
Tropical highland	late	yellow	flint	13
Tropical highland	late	yellow	dent	14
Tropical lowland	early	white	flint	15
Tropical lowland	early	white	dent	16
Tropical lowland	early	yellow	flint	17
Tropical lowland	early	yellow	dent	18
Tropical lowland	intermediate	white	flint	19
Tropical lowland	intermediate	white	dent	20
Tropical lowland	intermediate	yellow	flint	21
Tropical lowland	intermediate	yellow	dent	22
Tropical lowland	late	white	flint	23
Tropical lowland	late	white	dent	24
Tropical lowland	late	yellow	flint	25
Tropical lowland	late	yellow	dent	26
Temperate	early	white	flint	27
Temperate	early	white	dent	28 [b]
Temperate	early	yellow	flint	29 [b]
Temperate	early	yellow	dent	30 [b]
Temperate	intermediate	white	flint	31 [b]
Temperate	intermediate	white	dent	32
Temperate	intermediate	yellow	flint	33
Temperate	intermediate	yellow	dent	34

a/ Average temperature minimum in highland locations is generally less than 18°C; in lowland locations, more than 18°C.
b/ Pools not yet formed.

Table 2. **Agro-climatic characteristics considered in classifying maize gene pools.**

Maturity range	Altitude meters	Latitude	Temperature [a]	Days to silking	Duration of crop growth days
			Tropical-Subtropical lowland		
early	0-1600	0-30°N–S	25-28°C	Up to 50	90-100
medium	0-1600	0-30°N–S	25-28°C	50-60	100-110
late	0-1600	0-30°N–S	25-28°C	60 +	110-120
			Tropical highland		
early	1600 +	0-30°N–S	15-17°C	Up to 70	Less than 130
medium	1600 +	0-30°N–S	15-17°C	70-95	130-190
late	1600 +	0-30°N–S	15-17°C	95-120	190-240
			Temperate		
early	0-1600	30-40°N–S	20-22°C	Up to 60	100-120
medium	0-1600	30-40°N–S	20-22°C	60-75	120-150
late	0-1600	30-40°N–S	20-22°C	75 +	150 +

a/ Mean of main growing season.

Maize x tripsacum

In 1974 the supervisor of the maize bank made additional crosses between maize and tripsacum, as part of a long-range program to transfer desirable genes from tripsacum to maize. Some resulting hybrids have been replanted in the El Batan greenhouse. This breeding work cannot be evaluated on a year-to-year basis, but should be viewed as a continuing experiment for 5 years or more.

BREEDING AND SELECTION: THE NEW BACKUP AND ADVANCED UNITS

Classification of pools

Twenty-nine pools of germ plasm were defined in 1973 as the framework for work of the back-up unit. The classification of these pools was based upon climate, length of growing season, and grain type (Table 1). The characteristics of the various climates and growing seasons which are used to classify pools are shown in Table 2. This classification of pools should permit a systematic flow of materials undergoing improvement into the more advanced steps of selection.

Development of back-up pools

In 1974, tropical and temperate pools were planted twice in Mexico at research stations appropriate for each climatic grouping. Highland pools can be planted only once a year because highland stations have several months of cold weather.

In each planting, the families making up each back-up pool are both recombined (crossed) in isolation and evaluated. For recombination, one row of each family is grown and the plants are detasseled so they are in effect female plants. The seed planted in the row next to each family is a even mixture of seed from all the families. This is the

Status of development of back-up pools and advanced populations at end of 1974. √ Pool formed. √√Pool generating families. ○Families with normal protein. ⊕Families with quality protein but soft endosperm. ●Families with quality protein and hard endosperm. Each pool formed and each population represented in the International Progeny Testing Trials (IPTT) has a quality protein "sidecar" which is being improved simultaneously.

	EARLY				INTERMEDIATE				LATE			
		Advanced pops.				Advanced pops.				Advanced pops.		
	Back up pool	IPTT	Exp. var.	Elite Exp. var.	Back up pool	IPTT	Exp. var.	Elite Exp. var.	Back up pool	IPTT	Exp. var.	Elite Exp. var.
TROPICAL LOWLAND												
Yellow flint	√				√√	○	○		√√	○	○●	
Yellow dent	√				√√	○	○		√√	○	○	
White flint	√				√√	○	○		√√	○	○●	
White dent	√				√√	○	○		√√	○⊕	○⊕	
TROPICAL HIGHLAND												
Yellow flint	√		○		√		○		√			
Yellow dent	√		○		√		○⊕		√			
White flint	√		○						√			
White dent	√		○		√		○⊕		√			
White floury	√		○		√		○					
TEMPERATE												
Yellow flint					√	○	○					
Yellow dent		○	○		√	○	○					
White flint	√											
White dent					√	○	○					

pollinator row and the pollen that it produces is representative of the pollen of all the families in the pool. Thus all the resulting ears within a pool are half-sibs.

New germ plasm is introduced to the pools from the germ plasm bank and the introduction nursery. The introduction nursery consists of newly arrived materials gathered from national programs outside Mexico. The materials selected for incorporation should have desirable characters such as insect resistance or disease resistance. Plants grown from seed introduced from the bank or the introduction nursery are detasseled and handled like the pool families. Thus their characteristics can be evaluated without danger that pollen from a undesirable introduction might contaminate the pool. In 1974 few families were introduced from the bank, but more than 1000 families were selected from the introduction nursery and added to the pools.

At the end of each season, the best half-sib families are identified based upon a weighted criteria for all characters under evaluation. The characters are yield and yield components, disease and insect reaction, and desirable agronomic characteristics.

Two or three ears are chosen from each selected family to make up the seed for the next cycle. The content of each pool changes in each season since recombinations involves selection for quality within the pool and the addition of new germ plasm from outside the pool.

Seed from the best ears (superior families) is also tested in yield trials and companion nurseries (high density, insect, and disease) and the best performing families (perhaps 10%) will be transferred to the advanced populations. The movement of superior families from the back-up unit to the advanced unit constitutes the bridge between the two units. The germ plasm moved to the advanced unit is not, however, removed from the back-up unit. Thus the quality of the pools is not depleted.

The pools at the start of 1974 contained 500 to 6000 families each or a total of about 30,000 families. This was far too many. The staff believes that after proper recombination, no more than 500 families will be enough to represent the genetic variability in each pool.

Fast maturing maize varieties are a critical need for farmers in many areas of the world.

The advanced unit

The improvement process continues in the advanced unit (Fig. 1) with

several significant differences from the backup unit: (1) Family structure is now full-sib rather than half-sib; (2) crosses with unproved germ plasm are no longer made; evaluation takes place in one season and recombination in the next; (3) selection for the desired characteristics is more intense, half the 250 families are selected in each evaluation phase; (4) testing each season is at more sites, with cooperating national programs; (5) about 10 superior families are finally identified to make an experimental variety and these families are recombined and the seed increased, to be tested as variety in at least 25 sites world-wide; (6) outstanding experimental varieties are designated, after trial, to be "elite" experimental varieties and these are tested at 100 or more sites. Each national program is encouraged to use the varieties in their

Advanced populations 1974.

Name	Maturity	Grain color	Grain texture
Tropical lowland			
Tuxpeño 1	late	white	dent
Mezcla tropical blanco	late	white	dent
Braquíticos	late	white	dent
Tuxpeño Caribe - 1	late	white	dent
Tuxpeño x La Posta o_2	late	white	soft dent
La posta	late	white	dent
AED x Tuxp. P.B.	late	white	dent
Tuxpeño Caribe - 2	late	white	dent
(Ant. 2 D x AED) Kitale II	late	white	dent
Amarillo Dentado - 2	late	yellow	dent
Cogollero	late	yellow	dent
Amarillo Cristalino - 1	late	yellow	flint
Mix. 1 x Col. Gpo. 1 ETO	intermediate	white	dent
Blanco Cristalino - 1	intermediate	white	flint
White H.E. o_2	intermediate	white	flint
Ant. x Ver. 181	intermediate	yellow	dent
IDRN	intermediate	yellow	dent
Mezcla Amarilla	intermediate	yellow	flint
(Ver. 181 x Ant. Gpo. 2)x(Venz. 1)o_2	intermediate	yellow	flint
Compuesto K (H.E.) o_2	intermediate	yellow	flint
Yellow H.E. o_2	intermediate	yellow	flint
Temperate			
Blancos Pakistan	intermediate	white	dent
Amarillo Subtropical	intermediate	yellow	dent
Blanco Subtropical	intermediate	yellow	dent
ETO x Illinois	intermediate	yellow	dent
Amarillos Pakistan	intermediate	yellow	dent
Compuesto de Hungría	intermediate	yellow	dent

breeding program, to organize on-farm testing and, finally, to recommend for commercial use those varieties which it finds suitable.

1974 work of the advanced unit

During 1974 advanced populations were planted two seasons in Mexico. Observations in these trials caused the staff to merge five populations with other similar materials; and three new populations were created from superior families moving up from the backup pools.

Superior progeny were selected in 1974 to develop the new set of 250 full-sib families to be tested in 23 international progeny trials in 1975.

Ninety-three experimental varieties were assembled in 1974 for international testing in 1975, and the required seed for the international trials was increased during the winter season of 1974/75.

The 1974 yield trials showed ample variability in populations of the advanced unit. One yield trial within a single population (Tuxpeño 1) produced yields ranging from 2.5 to 7.5 tons per hectare in the lowland tropics. This population could show a rapid rise in average yields through additional selection.

PLANT PROTECTION

The pathologists and entomologists have now integrated their services into the bank unit, backup unit, advanced unit, and training unit. Disease and insects are now considered at all levels of maize population improvement.

Mass rearing of insects

One special assignment of the entomologist is the mass rearing of insects for deliberately infesting CIMMYT's experimental fields with harmful pests. CIMMYT produces 10 generations a year of two insects harmful to the corn plant in Mexico, including two species of stem borers, and one species of fall armyworm. CIMMYT's mass rearing of insects in 1974 was hindered by the problem of sterility among the pests, but this factor is expected to be eliminated in 1975 by starting with freshly introduced egg masses.

Evidence is accumulating that as the advanced maize populations are subjected to greater pressure from insects, the surviving plants are showing greater genetic resistance to insect damage.

Storage insects

Whether the farmer produces high yields or low yields, much of the maize he harvests never reaches his table or the market because storage insects consume a significant proportion of the crop. For this reason, CIMMYT entomologists are searching for ways to make maize less vulnerable to storage insects.

In one study, the susceptibility of grain from 15 advanced unit

populations was compared. The populations differed widely in susceptibility to storage insects. Also, some evidence was found that quality protein lines that are being bred for hard endosperm are less damaged by storage insects than opaque-2 lines that have soft endosperm.

Another study related chemical and physical factors of maize kernels to infestation by the maize weevil, *Sitophilus zeamais.* Hardness of the kernel was most closely related to resistance to the insect. But low levels of reducing sugars, high fat content, and high protein content also increased resistance of the kernels.

The relation of kernel characteristics to egg laying (oviposition) by the maize weevil was examined by confining individual adult weevils with individual kernels of a variety and then counting the oviposition holes in each kernel. More kernels had no eggs laid in them than would have been expected by chance. These kernels may have characters that make them resistant to oviposition. They have been planted in a preliminary attempt to see if resistant lines can be obtained.

In addition to kernel characteristics, the husk that covers the ear can influence damage by storage insects. CIMMYT entomologists rated maize

In the search for maize with better drought tolerance, physiologists measure water loss through stomates during drought stress.

ears in the field on a 1 to 5 scale at the time of kernel filling. Ears that had a tight-fitting husk extending beyond the tip of the ear and that had no bird or stem borer damage were rated "1". Then 20 adult maize weevils were confined in a bag placed over each ear. At harvest, ears that had been rated "1" or "2" had no damage at all. Grain that is not infested before harvest should have less insect damage in storage than grain that is infested. Moreover, in areas where maize ears are stored in the husk, good husks may continue to protect the grain in storage.

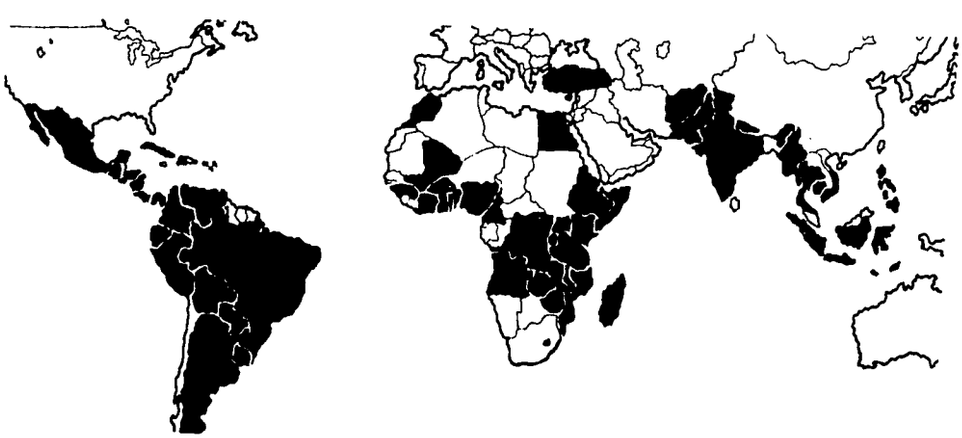
COMPANION NURSERIES

The yield nurseries of the back-up pools and the advanced populations are used to evaluate such characteristics as height, maturity, incidence of foliar diseases and yield under good management. Companion nurseries are used to evaluate resistance under uniform and severe attacks of insects and disease pathogens. In addition, a companion nursery is used to test the performance of advanced populations in thick plantings. Each nursery is unreplicated.

For the insect-resistance nursery, budworms and stem borers are multiplied in the laboratory. Half of each row in the field is infested, first with budworms and then with stem borers. The other half of the row is treated with insecticide. Each row represents one of the 250 families making up each advanced population. During the growing season each row is rated several times for insect damage.

In the disease-resistance nursery one-half of each row is inoculated with stalk rot pathogens and the entire row is inoculated with ear rot pathogens. The families are evaluated at the end of the season for stalk rots and ear rots. To get a high incidence of stunt disease under

Developing countries (FAO class II) in which maize is an important crop.

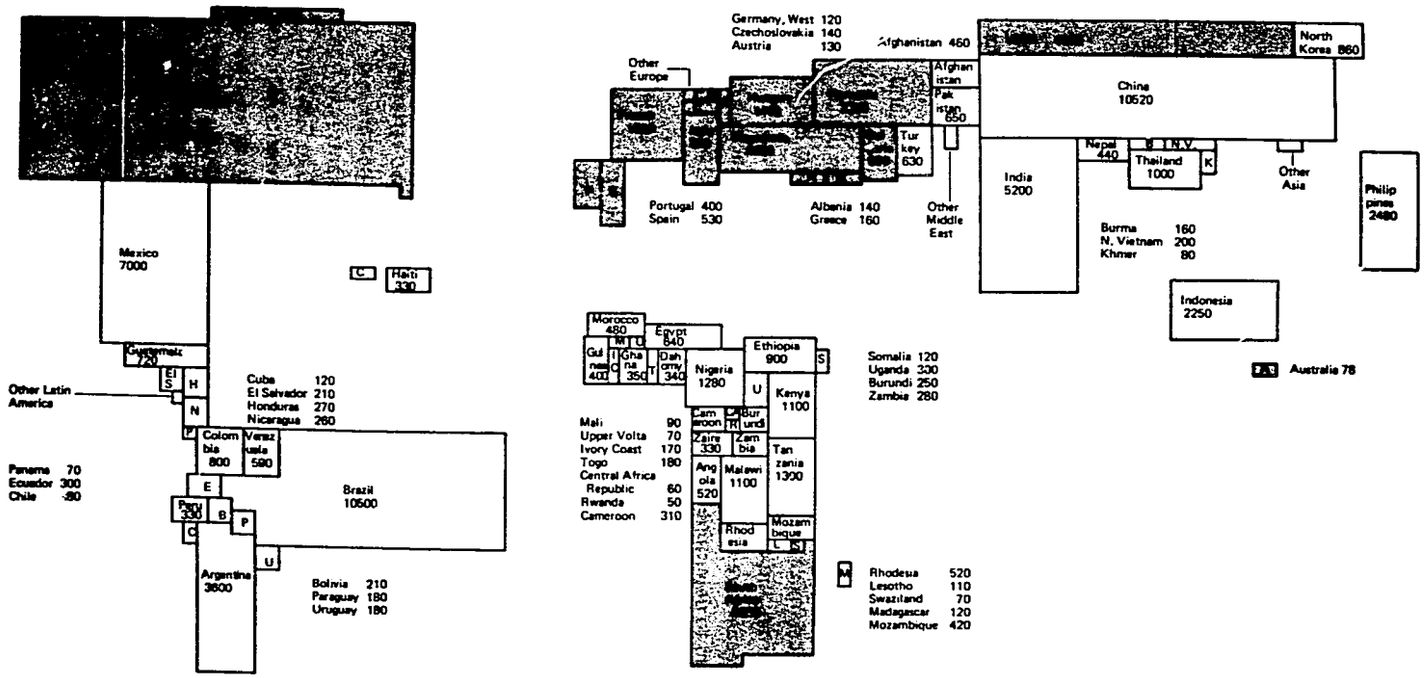


Maize trainees learn how to place irrigation siphons in experiment fields.

natural conditions, insect and disease nurseries are planted before the yield trials and the high density nursery. These early plantings tend to attract large numbers of insects that are vectors of stunt.

The high-density nursery is planted at 80,000 plants per hectare compared with the 53,300 plants per hectare used in the yield trials. Families with shorter plants have a higher optimum planting density than tall plants because short plants are less affected by lodging and barrenness at high densities than tall plants. Thus the high-density nurseries provide added information about the yield potential of short families.

For the back-up pools, insect and disease companion nurseries are grown about every third season. Results from the companions nurseries of the back-up pools are used along with results from yield trials, in deciding which families should move to the advanced populations.



Maize area by countries: The size of each country is proportional to its maize producing area circa 1972 (data in thousands of hectares). Unshaded nations are developing countries (FAO class II) or countries that have a per capita gross national product under US$600.

For the advanced populations, all families are included in companion nurseries in one crop season in every year. Thus data on the performance of every family in each advanced population is available each year from the insect, disease, and high-density nurseries.

AGRONOMY – PHYSIOLOGY

Maize agronomists service trials by the germ plasm bank, the back-up unit, and the advanced unit. Agronomy trials in Mexico are conducted jointly with the training program. These include variety trials and comparisons of the response of improved and unimproved varieties to high and low levels of management.

The physiologists are continuing their studies of maize plant growth to help define for the breeders the selection criteria for improved plants of the future.

Factors limiting yield

Studies on plant growth indicate that in both highland varieties and lowland (tropical) varieties, the sink size (capacity to store dry matter in the grain) currently limits yield. The incidence of barren plants when tropical maize is grown under higher plant density was identified as an important limitation of the storage capacity of the crop.

The breeders are now crossing the U.S. corn belt material to tropical germ plasm to determine whether the growth pattern of U.S. temperate zone maize is transferable genetically.

Families that show the lowest frequency of barren plants under high populations are being selected in trials in Mexico. The first of these selections made in 1974 have been included in the subsequent winter nurseries.

Increasing grain storage in the plants

In addition to factors limiting yields, the physiologists are studying ways to manipulate grain storage in the plant.

To investigate the effect of plant population density at various plant developmental stages on the components of grain yield, two varieties were planted at 33,000, 66,000, and 133,000 plants per hectare and later thinned at three growth stages. As the density of plants rose from 33,000 to 133,000, the ears per plant decreased from 1.5 to 0.87 and the grains per plant from 680 to 303. The thinning treatments indicated that populations density had little influence up to 62 days after sowing, but grain yield was greatly influenced by density from 62 days up to anthesis. The evidence from this and other related studies suggests that there are variety differences which could be exploited. Consequently this investigation is being pursued, but with shading treatments instead of varying plant densities, to give better experimental control of the light environment.

Complementary studies include observations of the development of

the lateral inflorescences and of the number of spikelets that are initiated and the number that survive to anthesis, in five experimental varieties.

Weather and the advanced-unit populations

To study the adaptation to climate of improved populations of maize, they are planted monthly at two sites in Mexico so that their response to weather factors can be measured. The effectiveness of this information in aiding the identification of the most suitable materials for national programs relies on the collection and the standardizing of weather data at all test sites. Characterization of regional environments in terms of moisture available for crop growth from weather data will also be useful in drought studies.

Drought stress and crop water requirements

The physiologists are attempting to identify materials that are adapted to environments of limiting water by analyzing yield data from international varietal trials. If contrasting materials are identified, the probable plant processes involved can be examined.

In anticipation of these studies a trial was conducted during the 1973 summer season at El Batan to establish probable procedures. Five maize genotypes were used in the experiment to measure differences between genotypes in drought response. A genotype in which stomata (pores in the leaves) remain open in periods of low moisture, thus allowing

A short break in the field work is a good time for the staff and trainees to trade ideas about maize improvement.

diffusion of carbon dioxide for photosynthesis and of water vapor for cooling the leaf, will consume more water, but may be a superior genotype (in terms of dry matter accumulation) in a short period of drought. By contrast, a genotype that closes its stomata during a period of low moisture will lose less moisture through transpiration, and may come out of a prolonged period of drought with less damage, and resume its growth more readily.

The resistance to water movement from the soil to the atmosphere and their relationships to the status of water in the plant were also investigated.

These studies are being conducted at Tlaltizapan. Total water use by the crop is being measured and related to weather data. Such data should also permit prediction of drought stress-days from meteorological data. The effects of drought stress-days and the status of water in the plant, at various developmental stages, on the growth and yield of the crop is also being examined.

Genotypes which show themselves superior in drought tolerance by these studies will require further examination for the kind of root structure, as well as the behavior of the stomata under moisture stress.

PROTEIN IMPROVEMENT

Most maize protein is inferior to animal protein. A commercial maize crop may contain 9 to 11 percent total protein. The limiting amino acids are lysine (typically 2% of protein) and tryptophan (typically 0.5% of protein). Ideally, the amounts of both these amino acids should be doubled to support normal body growth and maintenance.

The quality of maize protein can be improved by the use of the opaque-2 mutant gene (the name comes from the odd appearance of the kernel). Opaque-2 maize contains approximately 4 percent lysine and 1 percent tryptophan and thus might solve the problem of inferior quality of protein in maize. But ordinary opaque-2 maize has serious

Quality protein experimental maize varieties: Yields at six locations and average of 14 locations. 1974.

Experimental variety	Yield, t/ha						
	Avg. 14 locations	Tocumen, Panama	Nepalgunj, Nepal	Quevedo Ecuador	Suwan, Thailand	Tlaltizapan, Mexico	Legon, Ghana
W.H.E. o_2 [a]	3.2	2.6	3.3	3.8	5.2	4.6	3.4
Tuxpeño x La Posta o_2	3.2	3.0	2.6	3.7	5.0	4.8	4.1
Compuesto K (H.E.) o_2 [a]	3.1	2.4	2.6	3.8	5.0	4.4	3.9
Y.H.E. o_2 [a]	3.1	3.5	2.6	3.6	5.2	4.0	2.4
(Ver. 181 x Ant. Gpo. 2) Ven 1 o_2	2.7	2.6	2.5	3.2	4.6	3.7	4.4
Avg. six checks	3.9	3.4	2.9	5.1	5.9	6.0	4.0

a/ Hard endosperm.

defects: (1) Yield drops slightly because the opaque-2 maize contains a soft endosperm which weighs less than the endosperm of normal maize, (2) most consumers of maize are reluctant to accept opaque-2 maize as food because of its apperance, (3) Fusarium, ear rots, and insects cause greater damage to the soft endosperm both in the field and in storage.

Since the later 1960's, the breeders have been selecting opaque-2 populations for hard endosperm, normal appearance, resistance to ear rots, and higher tolerance to stored grain insects. In 1972 the first maize population combining opaque-2 gene with hard endosperm (at that time 85% of the kernels were hard) was distributed for testing. In 1974 work continued on conversion of all the advanced populations to opaque-2 and their testing internationally.

Trials in 1974 indicated that some opaque-2 populations now equal

Visitors to the Poza Rica station get a look at new experimental varieties.

normal maize in yields in each climatic zone (that is, in the tropics, in the temperate zone, and at high altitudes).

In 1974 little opaque-2 corn was grown commercially anywhere in the world. U.S.A., Brazil, and Colombia have released opaque-2 hybrid varieties to farmers.

CIMMYT is cooperating with national programs interested in developing open-pollinated varieties with the opaque-2 gene for their nutritional value. These developments involve Argentina, Ecuador, and Guatemala, in Latin America; Ghana, Tanzania, and Zaire, in Africa; and Nepal, Pakistan, and Philippines, in Asia.

None of these national efforts has reached the point where the governments can promote opaque-2 as a change of crop and food, but that time is approaching.

Maize international trials 1974 and 1975.

Region & country	1974 Progeny trials (actual number of trials)	1974 Exp. variety trials (actual number of trials)	1975 Progeny trials (prepared number of trials)	1975 Exp. variety trials (prepared number of trials)
Central America and Caribbean	*23*	*15*	*27*	*43*
Barbados	0	2	0	0
Belize	0	1	0	1
Costa Rica	2	2	4	4
Dominican Rep.	2	0	0	4
El Salvador	2	1	4	8
Guatemala	6	1	7	6
Haiti	0	1	0	4
Honduras	5	2	5	4
Jamaica	0	1	0	3
Nicaragua	3	1	4	4
Panama	3	3	3	4
South America	*17*	*16*	*16*	*43*
Argentina	0	1	0	2
Bolivia	0	2	0	14
Brazil	0	5	0	6
Chile	0	0	0	1
Colombia	14	4	2	9
Ecuador	3	2	4	4
Peru	0	2	5	5
Venezuela	0	0	5	2
Asia	*44*	*16*	*27*	*29*
Bangladesh	0	0	0	2
India	17	5	12	5
Indonesia	2	0	0	1
Khmer	0	0	0	1
Malaysia	0	1	0	0
Nepal	7	3	0	7

continued

INTERNATIONAL TRIALS

During 1974 CIMMYT conducted two series of international trials, one for superior progenies developed for advanced unit populations and grown in 154 separate trials in 22 countries; the other for experimental varieties, grown in 84 separate trials in 35 countries.

Progenies tested internationally in 1974 were those identified in Mexico in the 1973/74 winter season.

Only one experimental variety trial was grown in 1974. This was a pooling of 30 lowland tropical materials from CIMMYT's Poza Rica station, tested against six local check varieties.

CIMMYT maize staff increased its international travel by 25 percent to 875 man-days in 1974 compared with 700 man-days a year earlier. The observations they brought back included the following:

Maize international trials, *continued*

Region & country	1974 Progeny trials (actual number of trials)	1974 Exp. variety trials (actual number of trials)	1975 Progeny trials (prepared number of trials)	1975 Exp. variety trials (prepared number of trials)
Pakistan	11	2	6	4
Philippines	3	1	5	3
S. Vietnam	0	0	0	2
Thailand	4	4	4	3
Yemen	0	0	0	1
Mediterranean/Near East	*8*	*5*	*9*	*9*
Algeria	0	0	0	1
Egypt	5	2	5	4
Iran	0	3	1	2
Turkey	3	0	3	2
Tropical East Africa	*6*	*17*	*9*	*14*
Ethiopia	0	1	0	1
Kenya	1	2	0	4
Malawi	0	10	0	0
Mozambique	0	0	0	3
Tanzania	5	3	9	6
Zambia	0	1	0	0
Tropical West Africa	*5*	*9*	*11*	*15*
Central African Republic	0	0	0	1
Cape Verde	0	1	0	0
Ghana	0	2	0	3
Ivory Coast	0	1	5	4
Nigeria	5	3	6	3
Zaire	0	2	0	4
Other	*51*	*6*	*39*	*26*
Hungary	0	0	0	1
Yugoslavia	0	0	0	1
U.S.A.	1	0	0	0
Mexico	50	6	39	24
South Africa	0	0	0	1
Total	***154***	***84***	***138***	***180***

–CIMMYT's international testing strategy is sound. But many international trials are not useful unless the quality of planting and "reading" of the crop can be improved. Visits by CIMMYT staff on a regular schedule will help to improve the quality of trials.
–Airmail shipments of seed from Mexico are arriving too late for the planting season in many countries. This explains most non-return of data.
–Some CIMMYT maize is too late in maturity for the areas where sent, often by 2 weeks. CIMMYT is developing a maturity index for its international trials. From the index, a breeder should be able to tell how many days a variety requiring 55 days from planting to flowering at Poza Rica, Mexico, would have at New Delhi, India.

On the basis of data submitted by collaborators on the International Progeny Testing Trials, 1974 (IPTT), a series of experimental varieties, and the next cycle of progenies are being developed during the 1974/75 winter season at Poza Rica. The experimental varieties will be tested at 180 sites in 45 countries and the IPTT at 138 sites in 21 countries.

MAIZE TRAINING

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

–In-service training: generally 6 to 7 months residence in Mexico for those men holding a first degree in agriculture, and under age 35.
–Master's degree program.
–Predoctoral fellows: generally 1 year in Mexico to do their thesis research under CIMMYT supervision.

Maize in-service trainees 1971-74.

Region and country	1974	1971-1974	Region and country	1974	1971-1974
Latin America	*18*	*85*	Japan	0	3
Argentina	0	11	Nepal	2	5
Belize	2	2	Pakistan	4	8
Bolivia	2	4	Philippines	1	8
Brazil	1	3	Thailand	0	3
Colombia	2	5	*North Africa and*		
Costa Rica	0	1	*Near East*	*4*	*11*
Chile	0	2	Algeria	0	1
Dominican Republic	1	4	Egypt	3	6
Ecuador	3	6	Tunisia	0	1
El Salvador	1	10	Turkey	1	3
Guatemala	0	7	*Tropical*		
Guyana	0	1	*Africa*	*17*	*46*
Haiti	0	3	Cameroon	0	1
Honduras	2	9	Ethiopia	1	1
Mexico	2	4	Ghana	3	3
Nicaragua	0	3	Ivory Coast	1	2
Panama	0	3	Nigeria	4	8
Peru	1	3	Tanzania	4	15
Venezuela	1	4	Uganda	0	1
South and East Asia	*8*	*29*	Zaire	4	14
India	1	2	Other	0	1

—Postdoctoral fellows: two years' service as an associate on CIMMYT staff.
—Visiting scientists or short-term residents: mature scientists invited to spend a period of observation at CIMMYT; the term "visiting scientist" indicates those who remain from 1 month to 1 year; "short-term visitors" stay 1 to 4 weeks.

In-service training

The in-service maize program is only 4 years old, but has given training to 171 young scientists from developing countries, 47 of them in 1974.

In-service training in maize is designed to develop the skills in field and laboratory techniques needed for genetic improvement, give experience on an interdisciplinary team, and increase the participant's understanding of agricultural development.

One feature of maize training is the layout of agronomic trials on private farmer's fields. This work is performed by the trainees in Veracruz State during the spring season, under supervision of the maize training officer, in cooperation with agronomists of the Mexican extension service. The trainees manage the field days at which private farmers are invited to observe the measurement of yields.

The group of maize production trainees who began work at CIMMYT in November 1974 was reported by the training officers to be the strongest group ever recruited.

Other training

During 1974 the maize program was also involved in the training of degree candidates from 12 countries, two predoctoral fellows (Egypt and Ivory Coast), and 11 postdoctoral fellows from eight countries. Ten of the degree candidates were doing their coursework at the Escuela Nacional de Agricultura (Mexico), four at Kansas State University (USA), and five at Cornell University (USA). There were also 15 senior visiting scientists from nine countries and 25 short-term residents from 20 countries.

An unusual feature of academic training is the interdisciplinary Ph.D. program. Such programs are now under way between CIMMYT and Kansas State University and Cornell University. In each university four or five degree candidates from Asia, Africa, or Latin America are working on related topics for a Ph.D. thesis. For example, a breeder, a pathologist, an agronomist, and an economist may be studying closely related topics, sharing each other's research, but taking their academic studies in different departments. These teams of candidates will do their thesis research together in Mexico, but receive their degrees from Kansas State or Cornell.

OUTREACH ACTIVITIES FOR MAIZE

CIMMYT continued to help national maize programs strengthen their research and production activities. The maize staff spent about 875 man-days in 1974 consulting with governments of maize-producing countries in Asia, Africa, and Latin America. Consultation includes

E.W. Sprague, director of the maize program, underscores a point while sharing his experience with trainees.

participation in research workshops, where plans are made for the following year; observation of CIMMYT nursery materials grown by national programs; visits to commercial crops in farmers fields to analyze what is holding back production; meetings with national policymakers to discuss fertilizer supplies, maize prices, storage facilities, and other policy questions.

Experimental nurseries provided advanced populations for almost every maize-producing country in the developing world.

In-service training was provided for 47 trainees from 23 countries, and contacts were continued with more than 100 previous trainees who have returned to national programs.

Ten members of the maize staff were stationed in five national production programs during 1974: Egypt, Nepal, Pakistan, Tanzania, and Zaire.

The most important new development in outreach during 1974 was the beginning of regional services which are discussed in a special report elsewhere in this publication.

BREEDING SORGHUM FOR COLD TOLERANCE

Sorghum is the world's fifth ranking cereal grain, grown on all continents, and covering 41 million hectares.

CIMMYT's sorghum improvement program (in collaboration with the International Crops Research Institute for the Semi-Arid Tropics) stems from work begun in the late 1950's. Breeders thought sorghum would

prove more drought resistant than maize at elevations above 2000 meters in Mexico and other Latin American countries, but no sorghum previously tested in Mexico had set seed above 2000 meters apparently because of low nighttime temperatures.

CIMMYT's predecessor agency obtained sorghum seed from the highlands of East Africa (Ethiopia, Kenya) which set seed on the central plateau of Mexico but was excessively late in maturity. By crossing the East African lines with short duration materials from Texas, new lines were created which were satisfactory in Mexico above 2000 meters.

In 1973 CIMMYT recruited a postdoctoral fellow to work full time on cold-tolerant sorghum with the following objectives:

—Higher yield
—Field resistance to important diseases and insects
—Early maturity
—Wide adaptation and stability of production
—Higher protein quantity and quality
—Resistance to bird damage
—Diversity of agronomic types and kernel types

Over 2300 crosses were made in 1974, employing CIMMYT's working collection of 3500 families of sorghum.

By selecting the best progeny at six different sites in Mexico, under differing temperatures, moisture conditions, and disease-insect environments, it is expected that sorghum genotypes will be developed with wider adaptation.

Forty-four new sorghum families were introduced from the highlands of Ethiopia in 1974. These are being dwarfed to fit the shorter growing season in Mexico, and will then be used as donors in the breeding program if they provide new sources of cold-temperature tolerance.

Good sources of resistance to the three principal sorghum diseases under Mexican conditions (leaf blight, leaf rust, gray leaf spot) are now being incorporated into the CIMMYT breeding lines. Work is progressing on genetic resistance to three of the principal insect pests: fall armyworm, sorghum midge, and greenbug. Resistant materials from the USA have been obtained for the latter two insects.

An international sorghum trial, consisting of 37 selections, was grown at 13 locations around the world in 1974. Returns are not yet available.

For protein improvement, six lines of high lysine sorghum were obtained from Purdue University in 1974 and crosses were made between these and CIMMYT's best dwarf lines. High protein content, 15 to 18 percent in normal kernels, has been verified in the laboratory, but so far no cross has combined both high percentage of protein and high lysine. Results of protein work must be judged over a period of years.

One trainee from El Salvador completed his sorghum training course at El Batan in 1974. He made 200 crosses between sorghum lines from El Salvador and CIMMYT's advanced lines, and carried home a wide range of breeding materials.

wheat improvement

WHEAT SUMMARY

Spring bread wheats. By combining high yield potential with stability, CIMMYT is striving for spring wheats that yield well year after year in diverse environments. Wheats, such as Yaqui 50, which have been resistant to rusts for decades are being used as sources of stability in CIMMYT's massive spring wheat crossing program. To evaluate the stability and yield potential of new materials, tests are conducted in dozens of locations around the world. In 1974, out of 1700 advanced lines grown at the Ciudad Obregon station, the 400 best were selected for inclusion in the 8th International Bread Wheat Screening Nursery.

A second approach to yield stability, in addition to using stable varieties as parents, is the development of multiline varieties. A multiline variety is a mixture of seeds from lines that are almost genetically identical except that they have different genes for rust resistance. In 1974, 250 lines based on cross 8156 (Siete Cerros, Mexipak, etc.) were sent to 30 locations to enable breeders to determine which lines would be best for incorporation in a multiline variety at each location. At Ciudad Obregon, eight experimental multiline mixtures were planted in the first multiline yield trial in 1974.

Especially to help nations that do not have large crossing programs, CIMMYT distributes segregating F_2 crosses. In 1974 over 3000 F_1 crosses were grown and over half were discarded for undesirable characteristics. The remainder were classified for potential disease resistance based on the resistance of the parents, and the F_2 seed was sent to 75 locations.

About 400 varieties and lines selected for one or two special characteristics from the world's spring wheat germ plasm were sent to breeders in 40 locations in 1974. This "crossing block" is a mini-bank of germ plasm.

Several countries in the humid tropics are interested in growing wheat in their dry winter season. As a first step in selecting suitable parents, in 1974 CIMMYT began growing the crossing block and the bread wheat screening nursery at Poza Rica, Mexico, a hot, humid location.

Three new varieties derived from CIMMYT materials were released in Tunisia. Nine varieties selected from crosses with CIMMYT materials were released in India for different parts of the country.

Spring wheat x winter wheat. Crosses of spring wheat with winter wheats are made to transfer such characters as septoria resistance and cold tolerance from winter wheats into spring wheats and to transfer such characters as rust resistance and better bread-making quality from spring wheats into winter wheats. Large-scale crossing between these two types of wheat is possible at CIMMYT's Toluca station (2600 m. elevation). Nearly 3500 winter wheats were grown for crossing in 1974 at Toluca. So that the program can advance two crops a year, about 400 of the best winter wheats were artificially vernalized and grown at the Ciudad Obregon Station.

Seed of about 300 segregating F_2 spring x winter populations was sent to 75 locations for evaluation and selection in 1974.

The most advanced lines from spring x winter crosses reached the F_4 generation in 1974. Within 2 years yield testing will begin, however, two lines already show such good performance that they are being multiplied.

Durum wheats. Although short height is desirable in durums to reduce lodging which lowers yields, genes for shortness are linked with sterility. Cocorit 71, a one-gene dwarf durum, showed that the linkage could be broken. The linkage has also been broken in advanced generation two-gene and three-gene dwarf durums still under test. These dwarfs yield 15 to 20 percent more than Cocorit.

Seed from 3000 crosses of spring and winter durums was sent to breeders in major durum-growing countries. These crosses are made to increase the cold tolerance of durums.

As protection against drought or excessive heat late in the growing season, CIMMYT is attempting to develop strains with a rapid grain-filling period. Seed from early generation crosses involving germ plasm having such characteristics has been sent to breeders in North Africa and the Middle East for screening.

Triticale. Laboratory techniques necessary to produce fertile triticales were perfected during the last 2 years and as a result 84 new primary triticales (wheat x rye crosses) were created in 1974. CIMMYT now has 185 primary triticales.

The cold tolerance of spring triticale is being improved by crossing with winter wheat, winter rye, and winter triticale. Winter triticales resulting from this program are being developed at Oregon State University and the University of Guelph.

Based on an improved staining technique developed at CIMMYT, cytologists were able to show that wheat x rye crosses are resulting in plants with one to seven rye chromosomes. Knowledge of the number of rye chromosomes a triticale strain has is valuable in deciding which strains can be successfully crossed.

For several years breeders have been making selections to eliminate shrivelled grains in triticale. As a result, the test weight of triticales has improved rapidly. In 1974, 70 percent of the 600 lines in advanced yield trials had a test weight of 70 kg/hl. Four years ago the six best lines in the triticale program had a test weight of only 68 kg/hl.

Triticales continued to show good protein content. In 5500 lines analyzed by CIMMYT chemists during 1974, the average protein content was 13.5 percent and the average lysine content in the protein was 3.7 percent.

Forage trials in 1974 suggested that triticale could be grazed or cut for forage and then allowed to regrow to be harvested for grain with only a modest sacrifice in grain yield.

Tests of CIMMYT triticale lines at Purdue University revealed that over 100 are resistant to three races of Hessian fly, an important enemy of cereals.

The first triticale variety from CIMMYT material was released in Mexico under the name Yorene, for planting in 1975.

Barley. Since CIMMYT's barley breeding program began in 1972, developing disease resistance has received high priority. In 1974, the first group of CIMMYT-bred barley lines were sent for international testing for disease resistance.

To reduce lodging, breeders are using barleys from Japan and USA to strengthen stems, and varieties from Mexico to improve root crowns. For the first time in 1974, Indian mutant barleys that have strong crown roots and rather stiff stems were used in the breeding program.

The first barley yield trials were planted in 1974.

Crosses made with Riso mutant 1508 to raise the quality and quantity of barley protein reached their third selection cycle in 1974.

Physiology. Grain yields of individual plants are often used as selection criteria in early generations. Tests by physiologists in 1974 showed, however, that the harvest index (ratio of grain yield to dry weight of the plant) is a better indicator of crop yield than grain yield per plant.

Shading studies identified two periods when low sunlight is especially harmful to wheat yields. Studies of lodging in short wheats showed that even when plants are able to right themselves after partial lodging, yields may be severely lowered. Studies of drought resistance revealed that modern semi-dwarf Mexican wheats suffer no more under severe drought stress than varieties developed in areas where drought is severe hazard. In one drought experiment, two barley varieties yielded twice as much under stress as several bread wheats, durums, and triticales. Tests continued with erect-leaved plants which may be photosynthetically more efficient than the usual droopy leaved plants. Studies of wheat genotypes in hot and cool climates showed that a few consistently yield well in both climates.

Milling and baking laboratory. About 27,000 samples of bread wheat were tested for gluten strength and the pigment content of grain from 6000 durum plants was evaluated.

Wheat training. Thirty-four wheat researchers and production agronomists from 14 countries were trained in 1974.

International nursery trials. Over 1200 trials, more than ever before, were distributed to cereal researchers in 83 nations in 1974.

Outreach activities. CIMMYT wheat staff members consult each year with most wheat-growing countries in Asia, Africa, and Latin America. In 1973 the staff spend over 1200 man-days on consulting trips. In addition to travel from headquarters, CIMMYT had 11 wheat staff members in Turkey, Lebanon, Tunisia, Algeria, and Morocco.

BREAD WHEAT

The goal of the bread wheat program is to develop varieties that produce stable high yields in a wide range of environments. Stability is largely related to resistance to diseases and insensitivity to daylength. A wheat variety usually lasts at most 5 or 10 years before a new rust

Inoculation ensures that all wheat plants are exposed to a severe rust epidemic.

race develops that can overcome its resistance. A few varieties, however, have remained resistant for decades, although their yield potential is lower than present-day varieties. Yaqui 50 has been resistant to rusts for 25 years. Such varieties are being used as parents in the bread wheat program to introduce stable resistance to rusts into varieties that are already high yielding.

In the winter season, wheats are grown at sea level in Ciudad Obregon in northwest Mexico. In the summer, wheats are grown near Toluca, at 2600 m elevation. An early frost in Toluca in 1974 destroyed most of the summer experiments before they were harvested.

At Ciudad Obregon to screen lines for disease resistance, stem and leaf rust are artificially inoculated. In addition, a severe natural epidemic of stripe rust occurred this year.

Over 1700 advanced lines were yield tested at Ciudad Obregon. Based on yield, rust resistance, and agronomic type, 400 of the lines were selected for inclusion in the 8th International Bread Wheat Screening Nursery. Two lines, a selection from Kalyansona x Bluebird and a selection from Mengavi x 8156, were outstanding and are suitable for commercial release. The Kalyansona x Bluebird line is a three-gene dwarf that has the same yield potential as Yecora 70, 7 t/ha, but has better resistance to leaf rust. The Mengavi x 8156 line is a one-gene dwarf that has good resistance to stem rust and leaf rust, but is moderately susceptible to stripe rust. It has red seeds and it matures later than Siete Cerros.

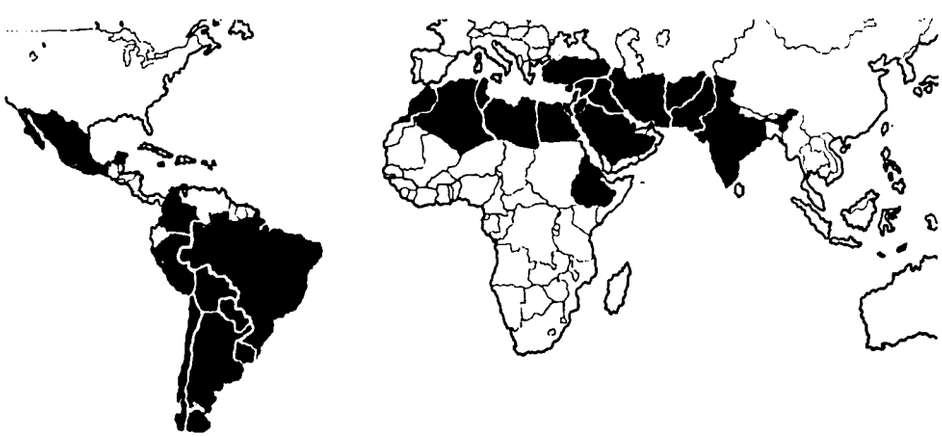
Spring x winter wheat program

CIMMYT crosses spring wheat with winter wheat to bring the strengths of winter wheats into spring wheats. Some of those strengths are genes for resistance to septoria disease, a high degree of drought tolerance and cold tolerance, and an expanded range of maturities. These characteristics are vital for raising yields in dryland areas. At the same time, spring wheats have features that would be desirable in winter wheats: greater nitrogen response, rust resistance, and better bread-making quality.

CIMMYT is developing spring wheats with characters transferred from winter wheats. Collaborating scientists in winter wheat areas are using CIMMYT's crosses to develop winter wheats with characters transferred from spring wheats.

The large-scale spring x winter crossing program was made possible by the discovery in 1972 that at CIMMYT's high altitude station (2600 m) near Toluca, winter and spring varieties could be planted in such a way that they would flower at the same time. Winter wheats are seeded in November and cold weather that occurs in the following 6 weeks is sufficient to induce flowering later. The spring wheats are planted after the middle of January when they are safe from frost damage.

Developing countries (FAO class II) in which wheat is an important crop.



Under this planting schedule both types flower in May and June and numerous crosses can be made.

In the 1973/74 season nearly 3500 winter wheats from USA, Europe, Chile, Argentina, and USSR were planted at Toluca along with spring wheats. So that the program can advance two crops a year, about 400 of the best winter wheats were artificially vernalized and planted at Ciudad Obregon station.

In 1973/74 over 1000 F_1 spring x winter wheat crosses were planted at Toluca but all were killed because of an early frost in September. Nevertheless agronomic evaluation could be made and reserve seed will permit planting of the best lines in 1975. At Ciudad Obregon about 500 F_1 spring x winter crosses were planted and 40 percent were discarded because of disease susceptibility or extreme lateness. The rest were harvested and sent as F_2 segregating populations to 75 locations worldwide for evaluation and selection.

All seed of new F_1 spring x winter crosses is shared equally with breeders at Oregon State University who exploit it in their winter wheat program. In 1975 winter wheat breeders in Turkey will also get an equal share of the F_1 seed.

In Mexico advanced lines from the spring x winter crosses are only in the F_4 generation. Some of these lines have 12 or 13 spikelets. If all those spikelets produce grain, the yields from these lines will be above normal. By 1976, the agronomic characteristics, disease resistance, and yield performance can be fully tested. Two sister lines called Canario "S" already show such good potential yield performance that they are being multiplied for possible commercial release.

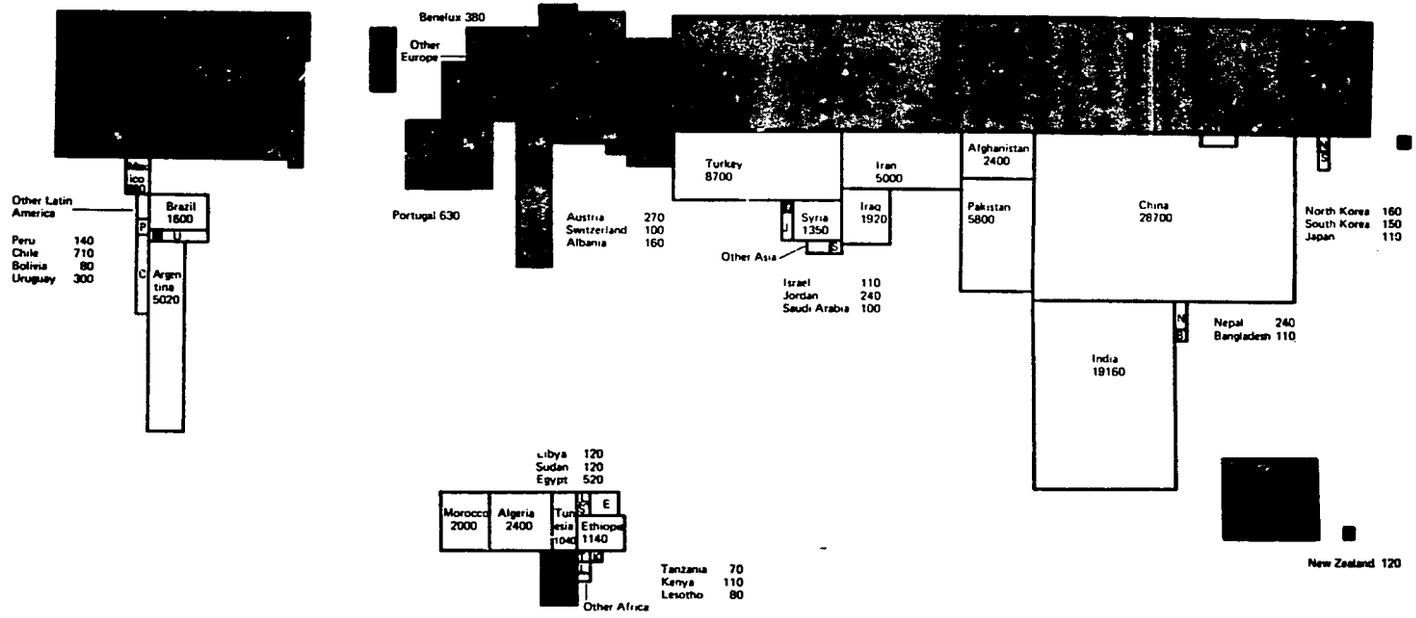
F_2 distribution program

In the 1973/74 winter, 3300 F_1 crosses were grown. Over half were discarded because of rust susceptibility and poor plant type. The crosses that were harvested were classified for potential septoria resistance based on whether or not the parents had septoria resistance. Five hundred rust-resistant populations that also potentially carry septoria resistance were sent to dryland locations. Eight hundred other populations were sent to irrigated areas where rusts are the main problems. In all, 75 locations received F_2 populations.

Distribution of F_2 seed allows national programs to select segregating lines under their local conditions. It is especially valuable for national programs that do not have large crossing programs.

Crossing block

The crossing block is a mini-bank of germ plasm. It consists of varieties and lines from throughout the world, each of which has at least one or two special characteristics. The 300 to 400 entries that make up the crossing block are sent around the world so that breeders can evaluate them under local conditions. In 1974 the crossing block was sent to 40 locations. The breeder may use some as parents in his breeding



Wheat area by countries: *The size of each country is proportional to its wheat producing area circa 1972 (data in thousands of hectares). Unshaded nations are developing countries (FAO class II) or countries that have a per capita gross national product under US$600.*

program or some may even perform well enough for direct release to farmers. In other words, distribution of the crossing block gives breeders access to a rich diversity of germ plasm. In addition, the worldwide data on disease resistance, maturity, and height of the entries which comes back to CIMMYT helps CIMMYT breeders.

Multilines

A multiline variety is a mixture of lines that are essentially identical genetically except that each line has a different source of resistance to the rusts. Thus, when a new race of rust develops in a field planted to a multiline variety the chances are that not more than one of the component lines will become susceptible. That means that if the multiline consists of 15 lines, only 6 percent of the plants in the field will become susceptible. Since most plants in the field are resistant, the new race cannot rapidly build to epidemic levels so even some susceptible plants may escape infection. Multiline varieties should assure farmers of stable yields despite changes in races of rusts.

CIMMYT has been working on a multiline variety based on the 8156 cross since 1970. Under names such as Siete Cerros, Mexipak, and Kalyansona, the 8156 cross has proved to be a high yielding, well adapted variety. It is grown on 13 million hectares in the developing

Glenn Anderson, associate director of the wheat program, discusses disease resistance with Guy Camus, a member of CIMMYT's board of trustees.

world. By crossing 8156 with a great diversity of varieties that have resistance to rusts and septoria and then carefully selecting the progeny, CIMMYT breeders are producing hundreds of lines that might be used in a multiline variety. Each of the lines has the same height, maturity, grain characteristics, and yield potential as Siete Cerros, but the genes for resistance are different.

Exactly which lines should be mixed together to form a multiline variety must be determined in the locality where the multiline will be grown. In 1974 the Third International Multiline Variety Trial, consisting of a set of 250 lines, was sent to 30 locations around the world.

Emasculation is the first step in the thousands of crosses made at CIMMYT each year.

As well as testing the lines individually, the lines must be tested in mixtures in various combinations. At the end of 1974, yield tests with eight experimental multiline mixtures began at Ciudad Obregon. This is the first time that CIMMYT has tested 8156 experimental mutliline mixtures.

In 1974 crossing began which may lead to a multiline variety based on the variety Anza. This variety is the Mexican cross Lerma Rojo-Norin 10 x Andes E. It has been released under various names in Australia, New Zealand, Iran, Sudan and the USA. Its wide adaptability and high yields suggest that it would make a good multiline variety.

Wheat for the humid tropics

Bread is popular in many countries of the humid tropics. These countries use scarce foreign exchange to import wheat for local bakeries. To reduce imports many of these countries are investigating the possibility of growing wheat in their "winter" season —a period of little or no rain and somewhat lower-than-average temperatures.

To serve areas like Bangladesh, Vietnam, Surinam, and Thailand, CIMMYT began, in 1974, growing the crossing block and the International Bread Wheat Screening Nursery in the winter season at the Poza Rica station which is located on the hot, humid Gulf coast of Mexico.

Varieties or lines that survive and have a satisfactory level of resistance to *Helminthosporium*, a fungus disease, will be distributed as segregating populations to humid tropical countries for evaluation and crossing.

DURUM

Aside from industrialized countries, durum wheat is an important crop in North Africa, the Middle East, part of India, Chile and Argentina. Worldwide 20 million tons are produced on 30 million hectares. It is used for spaghetti and other pasta products and for *couscous*. CIMMYT's breeding program aims at developing germ plasm for three types of areas in which durum is grown: Humid coastal areas where disease is the main problem, such as the Mediterranean basin; dry areas where diseases are not a major barrier, but varieties need special maturing behavior,

Yield improvement in durum wheats: Yields from trials at Ciudad Obregon, Mexico. (Stork has not been commercially released yet).

Name	Height	Year released	Yield, t/ha
Tehuacan 60	tall	1960	4.2
Oviachic 65	dwarf	1965	7.0
Chapala 67	dwarf	1967	7.0
Jori 69	dwarf	1969	7.7
Cocorit 71	dwarf	1971	8.3
Stork "S"	dwarf	—	8.6

such as Southeast Turkey and India; and cold areas and high plateaus such as those in Turkey, Iran, and Chile.

CIMMYT's expanded durum breeding program began in 1968. Two crops a year are grown at different locations in Mexico. Durum breeders are moving toward durum varieties with high yield potential, resistance to a broad spectrum of diseases, stable yields, ability to yield well at many locations, drought tolerance, short maturity (where needed), and good cooking quality.

The program produces a wide range of germ plasm which scientists in durum-growing areas can evaluate and choose from. CIMMYT staff members stationed in Algeria, Tunisia, Lebanon, and Turkey play a vital role in the durum program.

Fewer leaves

CIMMYT durum breeders are placing increasing emphasis on plants with fewer leaves. They also want more upright leaves.

Fewer leaves should mean less evapotranspiration. And this should save precious moisture for durum plants growing in dry areas. In addition, plants with fewer leaves have fewer places for dew to collect. That should hamper the progress of fungus diseases that spread when leaves rub together. Such fungi require water on the leaves to spread rapidly. On the other hand fewer leaves will mean that the photosynthetic area of each plant is reduced. International screening nurseries and yield tests will help to answer whether the advantages of fewer leaves outweigh the drawbacks.

Upright leaves should allow more light to reach the lower leaves and that might allow more tillers (extra stems) to survive.

Shorter plants

Durum plants that remain upright until harvest tend to yield more than plants that lodge (fall over). By genetically shortening the plant the breeder can reduce lodging.

Three genes are available for shortening durum plants and the effects of the genes are additive. That is, plants with two of the genes are shorter than plants with one gene and those with three genes are shorter than those with two genes, provided growing conditions are the same. Unfortunately, the genes for shortness are linked with genes for sterility and the sterility effects are also additive. In other words, the more genes for shortness a plant has, the greater the degree of sterility and, hence, the lower the yield. But Cocorit 71, a durum variety recently developed by CIMMYT, showed that the linkage between shortness and sterility could be broken. Cocorit has one gene for shortness. Its yield potential is substantially higher than that of Jori 69, a one-gene dwarf in which sterility limits yield somewhat. In new two-gene and three-gene dwarfs still in the CIMMYT experimental fields, the linkage with sterility has been completely broken. As a result they yield 15 to 20 percent more than Cocorit.

Yield potential

Durum grains are 25 to 50 percent heavier than grain of bread wheat. But even though durum has the same number of grains per head (spike) as bread wheat its yield per hectare is less. One reason may be that bread wheat produces more tillers that bear heads, so bread wheat produces more heads per square meter than durum. CIMMYT scientists are breeding for higher tillering capacity in durum, which should lift the yield potential of durum above that of bread wheat. Under dryland conditions, however, limited tiller number does not influence yield as greatly as under irrigated conditions.

In 50 bread wheat yield tests at Ciudad Obregon in 1973/74, the durum check variety, Cocorit, was the first or second highest yielding entry in 75 percent of the tests.

Industrial quality

Higher yielding durums must have good pasta-making quality if durum-producing areas such as North Africa are to regain their export markets. CIMMYT is testing the pasta-making quality of durum lines. Carotene pigment is determined routinely and macaroni-making equipment has been used experimentally.

Cold tolerance

Breeders are attempting to bring cold tolerance into short durums by crossing spring with winter durums. This cross creates plants that have "semi-winter" growth habit. That means less cold is required for the durums to induce flowering. Sensitivity to daylength, however, prevents undesirable flowering during the short days of winter.

Winter-types are being improved by the introduction of genes for insensitivity to daylength so that they will flower earlier. In true winter durums, flowering must be induced first by low temperature and later by long days.

Seeds from over 3000 crosses between spring and winter durums were sent to national wheat programs in Algeria, Ethiopia, Lebanon, Mexico, Tunisia and Turkey where local scientists can test and exploit them.

Durum multiline

As in bread wheat, the concept of a multiline variety holds promise as a weapon against dreaded rust diseases. Durum lines are being screened to identify sources of resistance to the various rusts. Assembling a multiline, however, will have to be done region by region because the mix of diseases varies from location to location.

Short maturity and rapid grain filling

CIMMYT is particularly interested in developing durums that have a short maturity or that fill the grain rapidly. Short maturity is essential in areas like central India where durums are grown on residual soil moisture after the monsoon rains have ended. Durums in such areas must have both a short vegetative phase and a rapid grain filling period to mature before drought and excessive heat occur.

S. Rajaram, bread wheat breeder, scores rust resistance in plots at Ciudad Obregon.

In areas like the Mediterranean basin, rain falls during the growing season of durums so varieties with a longer vegetative period can be sustained. Moreover a longer vegetative period is needed so that flowering occurs after the danger of late spring frosts has passed. While late maturing varieties escape frosts,they are exposed to drought, heat stress, and desert winds at the end of the season. Thus CIMMYT breeders are striving for durums that combine a vegetative period long enough to escape early frosts with a rapid grain-filling period to reduce the risk of late-season hazards.

Sources of variability

In developing new germ plasm CIMMYT breeders can draw on a collection of 10,000 durum lines (half of which is the U.S. Department of Agriculture collection). Several hundred lines (traditional varieties and advanced breeding lines) are added to CIMMYT's collection each year.

Distributing germ plasm

CIMMYT's experimental stations in different parts of Mexico allow durum to be grown throughout the year and therefore many more crosses can be made each year than is possible in most other countries. For the first time in 1974, CIMMYT sent F_1 crosses to breeders in key durum areas around the world. This allows scientists outside Mexico to work

with much more germ plasm than ever before. In fact, for some national durum programs this procedure may double or triple the number of crosses they can work with.

CIMMYT sent out 3300 F_1 crosses to North Africa, Turkey, India, Ethiopia, and the Mexican National Program. Before being sent, the crosses were screened against such problems as drought and local disease, so each location received only crosses likely to be appropriate for its conditions. Reserve seed of all the F_1 crosses is held at CIMMYT so that when information on the performance of the crosses in various locations flows back, the best crosses can be used in further breeding work.

Sending F_1 crosses is less expensive, in terms of research time, than sending more advanced generations.

TRITICALE

New triticales

Placing the pollen of a rye plant on the stamen of a wheat plant is the first and easiest step in creating a new triticale strain. Later, instead of planting the seed, the seed embryo is surgically separated from the endosperm and placed in an artificial nutrient medium to grow into a plantlet. The nutrient medium takes the place of the endosperm which in intergeneric crosses, like wheat x rye required to produce triticales, is rarely able to support the growth of the embryo. When the plantlet has sufficiently developed leaves and roots it is planted in soil. If this plant grows to maturity it would produce no seeds —it would be sterile like a mule. So to make the plant fertile, breeders bathe the plant in the chemical colchicine. Colchicine causes the plant's chromosomes to double and this process makes the plant fertile.

Techniques for culturing the embryo and doubling the chromosomes have been perfected at CIMMYT during the last 2 years. Thus CIMMYT scientists were able to create 84 new triticales in 1974, triple the number produced in 1972. Twenty-eight new triticales were received from breeders outside CIMMYT. CIMMYT is now working with about 185 such primary triticales.

Each new triticale strain (called a primary triticale) is an additional source of genes for the plant breeder. While a new strain might, after extensive testing and screening, become a candidate for commercial release, more likely it will be crossed with other triticale strains to concentrate desirable genes in a secondary triticale.

Winter triticales

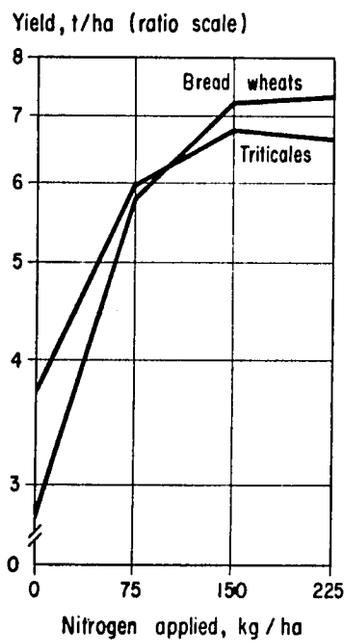
The discovery that the climate of the CIMMYT high altitude (2600 m) station near Toluca is cold enough to vernalize (induce flowering) winter cereals like winter wheat, winter rye, and winter triticale has permitted large-scale crossing between these types and spring triticales. At Toluca the winter cereals are planted in October and the spring

triticales are planted in January. Flowering occurs in both types in May-June so that numerous crosses can be made. The goal of this program is to use the genetic variability available in winter ryes for improving spring triticales. In addition, the crossing program leads to winter triticales. Winter triticales are screened under typical conditions for winter cereals at Oregon State University (USA) and the University of Guelph (Canada).

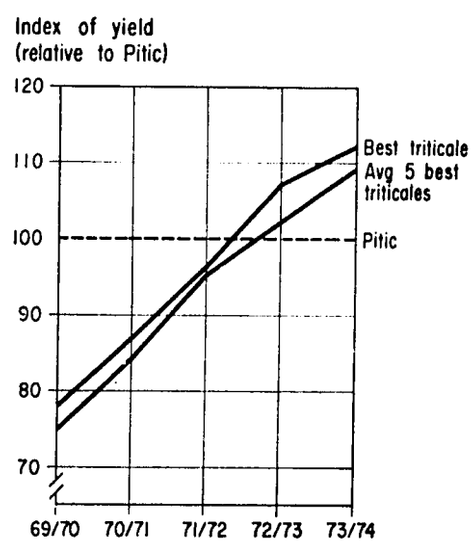
In 1974 CIMMYT screened 1000 winter ryes at Toluca and found 250 with good seed development. These will be used as sources of tolerance to low temperatures although most are susceptible to fusarium and stripe rust.

Identifying chromosomes

A post-doctoral scientist at CIMMYT modified the Giemsa staining technique so that chromosomes contributed to triticale by the rye parent can be distinguished from chromosomes contributed by the wheat parent. Use of the modified staining technique showed that extra wheat chromosomes sometimes substitute for rye chromosomes. That is, some strains of triticale are producing plants with as many as seven pairs of rye



Without fertilizer triticale yields well (Tests with six triticales and two bread wheats at Ciudad Obregón, Mexico, 1974).



In international trials in several dozen countries each year, triticale yields have improved rapidly relative to the yield of the bread wheat check variety, Pitic 62.

chromosomes (a full set) to as few as one pair of rye chromosomes.

Knowledge of how many and which rye chromosomes have been replaced by wheat chromosomes in a particular triticale line is valuable for the breeders. Crosses between triticales that have different rye-chromosome substitutions are sterile or segregate abnormally.

An experimental line known has Beagle is the first high yielding triticale in which all of the rye chromosomes and all of the durum chromosomes are present. Some scientists had previously thought this achievement was not possible.

Yield improvement

Crossing the dwarfing gene from bread wheat into triticale greatly raised the yield potential of triticale by reducing lodging. Cinnamon was the first dwarf triticale to enter yield trials —in 1971. Since then the number of high yielding lines has increased dramatically. In 1973, out of 150 lines tested, about 35 yielded 7 t/ha, while in 1974, out of 600 lines tested, 150 reached that level.

Test weight

Shrivelled or wrinkled grains were common in early triticale strains. Since this unattractive appearance might affect the willingness of farmers to try the new crop, CIMMYT scientists began selecting on a large scale for plump smooth grains in 1972. The plumpness of grains is related to their test weight —the weight of the grain per unit volume. CIMMYT triticale breeders are striving for a test weight of 76 kilograms per hectoliter. In 1974 over 70 percent of the 600 lines in advance yield trials had a test weight of 70 kg/hl or more. Sixty-two of the lines had a test weight of 74 kg/hl or more, while in 1973 only 11 lines reached that level. Four years ago, the best six lines in the triticale program had a test weight of only 68 kg/hl.

International nurseries

As one way to enable scientists around the world to learn how triticale strains perform in their locality, CIMMYT sends cooperators uniform sets of about two dozen new strains each year for planting in yield trials. In 1974 cooperators sent CIMMYT their data from the Fourth International Triticale Yield Nursery. This nursery was grown at 50 locations from seed sent out in 1973. The average yield of the best five strains was 3.5 t/ha compared with 3.2 t/ha in the 3rd ITYN (1972) and 3.1 t/ha in the 2nd ITYN (1971).

Cereal quality

As yields have increased over the years, the protein percentage has declined somewhat. The decline is not unexpected because yield increases have resulted in part from plumper grains. Thus if the actual protein content of the kernel remains the same while the carbohydrate content of the kernel increases, the protein percentage must decrease. Nevertheless, current high yielding lines have a high level of good quality protein. CIMMYT protein chemists analyzed 5500 lines in 1974. The lines

averaged 13.5% protein with 3.7% lysine in the protein.

Tests on bread-making quality and flour yield were conducted on 150 triticale lines in 1974.

To determine the true dietary value of triticale protein, cooperative studies have started with two organizations. In Mexico, the Instituto Nacional de Investigaciones Pecuarias will do bio-assays (feeding trials) with rats, and, in Guatemala, the Instituto de Nutricion de Centro America y Panama will do bio-assays with rats and young chickens.

Forage

Preliminary experiments at Ciudad Obregon suggest that triticale could be grazed or cut for forage in its early growth stages and then later the grain could be harvested. The grazing or clipping would cause less than a 20 percent sacrifice in grain yield while providing 2 to 3 t/ha of high protein dry matter.

This technique might make triticale very attractive to, for example,

Homegrown triticale provides a Mexican farm family with their daily bread.

farmers in the high valleys of Mexico who now handle oats and barley in this way.

Agronomy

To facilitate experimental work, weeds are controlled with herbicides. Agronomists showed in 1974 that triticale is more sensitive than wheat to two common herbicides, Tribunil and Dosanex.

In trials to test production practices for triticale, agronomists found that triticale should not be seeded more than 6 cm deep. Wheat, in contrast,can be seeded as much as 9 cm deep without decreasing yields.

In nitrogen trials, while lodging supressed yields somewhat at high levels of nitrogen application, yields of triticale with no nitrogen or low levels of nitrogen were often higher than those of the wheat checks. This characteristics may be valuable in areas where farmers apply little fertilizer.

Pathology

While triticales are not susceptible to the same diseases as wheat, diseases that are not common on wheat have been identified on some triticale lines. Examples: Take-all caused by *Gaeumannomyces graminis,* dwarf-bunt caused by *Tilletia controversa*, and leaf spot caused by *Cochliobolus sativus.*

Insect resistance

CIMMYT provided 169 triticale lines to Purdue University (USA) for tests of resistance to Hessian fly. This insect is an important enemy of cereals in many countries. The tests revealed that 126 lines were resistant to three races of Hessian fly.

Areas of possible adoption of triticale

Three types of areas seem to be the best candidates for commercial introduction of triticale: areas where wheat or barley or oats are grown but yields are poor, areas with certain soil problems such as aluminum toxicity (the rye genome in triticale may confer a degree of tolerance to aluminum toxicity), areas where disease severely limits yield of wheat.

Ethiopia. Segregating materials and uniform nurseries have been tested in Ethiopia for 5 years. In 1974, one or two promising strains were being multiplied for possible release. Over 2000 hectares of triticale were grown.

Kenya. The high elevations and devastating wheat disease problems make Kenya a good possibility for introduction of triticale. New wheat varieties usually last only 1 or 2 years in Kenya before a new destructive race of stem rust develops. In trials in 1974, triticale outyielded wheat at three locations. At one location which suffered severe drought, triticale had double the yield of wheat.

India. Research on triticale is being conducted at four locations in India. The most promising area for triticale may be the unirrigated hill area of Northern India. Triticales tested there have yielded markedly better than wheats.

Morocco and Tunisia. The septoria resistance of triticale lines makes them attractive along the humid coastline of Morocco and Tunisia. But severe spot blotching has occurred in some locations.

Argentina. Triticale might fit in well in the humid part of northeast Argentina where disease limits the production of wheat. Argentine scientists have produced excellent forage triticales from CIMMYT strains.

Brazil. Aluminum toxicity depresses wheat yields in vast areas of southern Brazil. Certain triticales yield much better than wheats in areas with aluminum toxicity.

Mexico. The Instituto Nacional de Investigaciones Agricolas conducted one-quarter-hectare screening trials with triticale in eight states in 1974. Triticales in Mexico do well, compared with wheat, at high altitudes where temperatures are cool and wheat diseases are severe.

Colombia, Peru, Ecuador. Wheat grown in the high valleys of the Andes is severely attacked by stripe rust. Triticale has a good potential for such areas.

BARLEY

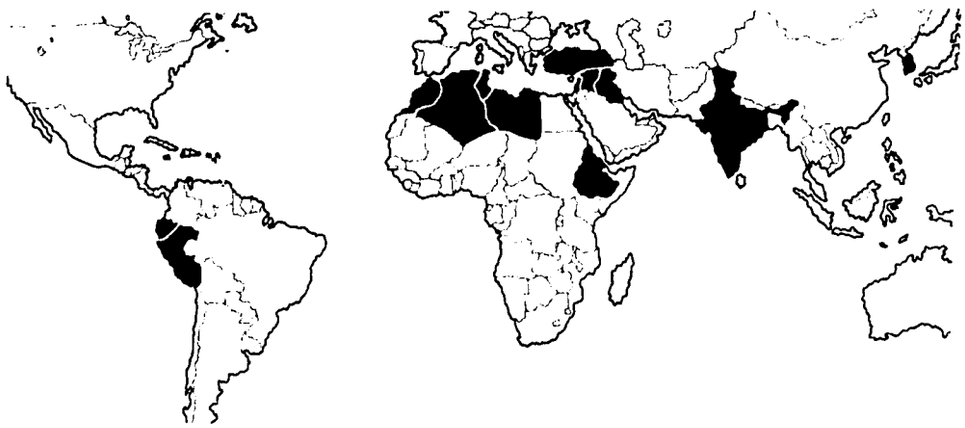
Barley is grown for food in many areas, especially where the growing season is too short or the rainfall is not adequate for other cereal crops. Substantial populations in the Mediterranean region, the Near East, India, Ecuador, Peru, and Eastern and Northern Europe eat barley. Most barleys have a poor quantity and quality of protein, and have hulls which are indigestible for humans. Moreover, barley varieties are not widely adapted —a variety that may be satisfactory in one area does poorly when grown in another area.

Some breeding work to improve yields and disease resistance has been done on malting barleys used in brewing and on barleys meant for cattle feeding, especially in the developed countries. But protein improvement and hull-less grains have not been important breeding objectives. Brewers need hulls for malting and higher protein content would be undesirable. Ruminant animals can digest the cellulose of hulls, so hull-less barleys are unimportant for feed varieties.

CIMMYT's barley program is the first to focus on the needs of barley-eating peoples. The program aims to produce varieties that are adapted, disease resistant, and high yielding, and that have satisfactory quantity and quality of protein. These characteristics combined with a hull-less grain would benefit 200 million of the world's most impoverished people.

Adaptability

Since the barley program began in 1972, crosses have been grown in two crops each year. One crop is grown at Ciudad Obregon which is near sea level at 27°N. The selections from the Ciudad Obregon harvest are then planted at El Batan which is at 2200 m elevation at 19°N. The harvest at El Batan is then moved back to Ciudad Obregon. By



Developing countries (FAO class II) in which barley is an important food crop.

1974 this process had removed all daylength-sensitive types from advanced lines. The growing period of sensitive types is lengthened or shortened by the daylength during the growing season. Insensitive types have a rather fixed growing period whether they are grown near the equator of far from it, hence they are adaptable.

Disease resistance

Staggering numbers of diseases attack barley. Scald (*Rynchosporium secalis*) is a worldwide enemy of barley. Powdery mildew (*Erysiphe graminis*) is serious in cool areas that have fog. Stripe rust is especially important in high plateaus which have low temperatures during the growing season.

Sources of resistance to many barley diseases have been found under Mexican conditions, but screening at numerous sites is necessary to determine if several genes exist for resistance to a disease. In 1973 a set of parental materials was sent to locations around the world for disease screening. In 1974 the first set of CIMMYT-bred lines was sent for testing in 35 countries.

Lodging

One reason traditional barleys are low yielding is that they lodge (fall over) before they are harvested. Lodging occurs because barley is tall, its stems are weak, and the roots do not support the aboveground portion of the plant well. The tendency to lodge is accentuated in areas that have high rainfall and in areas where barley is grown with irrigation or fertilizer.

CIMMYT breeders are using barleys from several countries to cure the lodging problem. Barleys from Japan and the USA contribute stiff stems. Certain Mexican varieties have sturdy root crowns. Indian varieties produced by mutation are short and have strong root crown and fairly stiff stems. The Indian mutants were used in the crossing program for the first time in 1974.

The barley program's first yield trials, which were planted in 1974 and will be harvested in 1975, include many advanced lines that have stiff stems and relatively well-anchored root crowns.

Naked grains

The grains for most barleys are covered with hulls. For human consumption the hulls must be removed from the grain by pounding or soaking. CIMMYT barley lines are being crossed with Godiva, a naked type from USA. Unlike most naked barleys, Godiva has large plump kernels with a high test weight.

Better protein

Barley generally has a moderate protein content, 8 to 9 percent, and, as in most cereals, an inadequate level of lysine, an essential amino acid, keeps some of the protein from being metabolized by the human body.

CIMMYT first attempts to raise the nutritional value of barley were made through crosses with a variety containing the hiproly gene. The hiproly variety has over 12 percent protein and a high lysine content. But crosses with the hiproly variety were low yielding because they produced fewer grains than normal because of partial sterility and lighter-than-normal grains because of shrivelling. Both defects were inherited from the hiproly variety.

In 1973 CIMMYT breeders began using an irradiated mutant called Riso mutant 1508 which was produced in Denmark. This variety has about 12 percent protein and its lysine level is 15 percent higher than that of the hiproly variety. It also has plumper grains and no sterility problem. Some lines from crosses with Riso mutant 1508 are now in their third selection cycle.

Earliness

Barley often is grown in areas where the rainy season is brief or where summers are short. For such areas barley must reach maturity quickly. Some of the improved barley lines CIMMYT is developing have extreme earliness.

Crosses with varieties like Early Russian, Svalof Mari, and Svalof Mona are now in their fifth selection season. Some of the crosses can be harvested 65 days after they are planted, like Early Russian, but they have higher yields. Naked grains and high protein content have also been brought into some of the early lines.

International testing

For the first time in 1974, the international barley observation nursery contained CIMMYT-bred lines. Over 150 entries went to 40 locations in 35 countries. This nursery will permit scientists in national programs to evaluate CIMMYT lines under local conditions and it will provide CIMMYT breeders with information about the resistance of the lines to the spectrum of diseases that attack barley around the world.

In addition, CIMMYT sent out crossing blocks (sets of varieties that

Barley lines that are vigorous, high yielding, and disease-free please CIMMYT's barley breeder, Enrique Rodríguez.

are potentially desirable parents) and F_2 bulks (segregating populations from which local scientists can make their own selections).

The Mexican National Institute of Agricultural Research began testing CIMMYT lines, but an unusually early frost destroyed the experiments.

The first international yield trials of CIMMYT barley lines will be sent out in 1975, only 2½ years after the barley program began.

PHYSIOLOGY

Physiological studies are aimed at learning what influences yield potential and how environment and management affect a farmer's ability to realize a variety's yield potential. Results from these studies provide criteria for breeders to use in selecting higher yielding strains.

Selecting plants in early generations

When a cross is made, the first two or three generations of progeny are made up of only a few hundred plants. Early generations of a cross are sown at abnormally wide spacings (low plant densities) to facilitate visual selection and maximize the seed production. Plants that show poor plant architecture, inadequate disease resistance, and so forth, can be discarded. Yield potential, however, cannot be estimated reliably until enough homogeneous plants have been produced to permit replicated

yield trials planted at normal densities. Usually yield trials begin in the F_4 or F_5 generation. A criterion for eliminating low yielding plants in early generations would reduce the amount of material that plant breeders must handle and would speed the development of new varieties.

Physiologists compared two methods of estimating the yield of individual plants in early generations: grain yield per plant and harvest index. Harvest index is the ratio of the weight of the grain to the dry weight of the above-ground portion of the plant (including the grain). They found that in widely spaced plantings, measuring grain yield per plant favors droopy leaved plants over erect-leaved plants. Measuring the harvest index of individual plants in wide spacing provided a more reliable estimate of how a selection will perform when it is planted at a normal density and narrow spacing.

Yield potential in three crops

The yield potential of a crop may be limited by the ability of plants to manufacture and transport carbohydrates to the grain or by inability of the plant to produce enough grains to use the available carbohydrates or by both. Outstanding varieties of bread wheat, durum wheat, and triticale were compared under optimum conditions (irrigated, well-fertilized, no disease problems). The experiments showed that the yield potential of bread wheat and durum wheat is about 8 t/ha and that of triticale perhaps 10 percent lower. Durum wheats tend to produce fewer grains per square meter than bread wheat and triticale, but they produce substantially heavier grains than either of the other crops.

Shade and yield potential

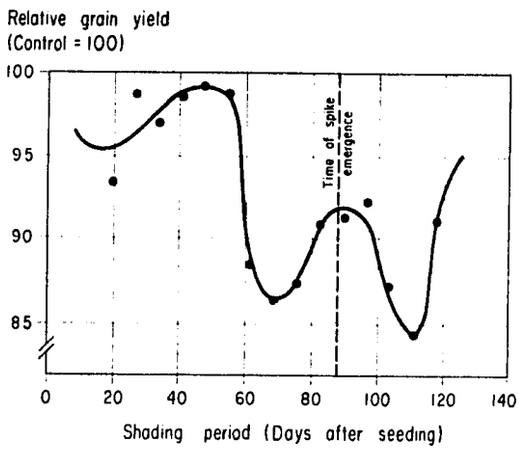
When is crop photosynthesis most important for grain yield? To find out physiologists shaded different plots for a 2-week period at different times during the growing season. They found that wheat yields are highly sensitive to low sunlight (reduced radiation) and hence reduced photosynthesis 30 to 5 days before flowering and 5 to 30 days after flowering. Yields were depressed by as much as 15 percent by 67 percent shading during these two periods. Shading during the sensitive period before flowering reduced the number of grains produced per square meter. Shading in the sensitive period after flowering reduced size of grains.

Temperature at critical stages

To test the effect of accelerating or slowing development by raising or lowering the crop temperature slightly, plots of Yecora wheat were heated or cooled at one of four stages of growth. Heating consisted of raising the air temperature a few degrees whenever it was below 32°C. Cooling consisted of lowering the air temperature a few degrees whenever it was above 10°C.

Except at the early vegetative stage, the heat treatment reduced yield. Yields were reduced by heat even during the mid-vegetative stage and

Low sunlight just before or just after the spike emerges sharply lowers wheat yields (The points plotted indicate the mid-point of of each 14-day shading period).

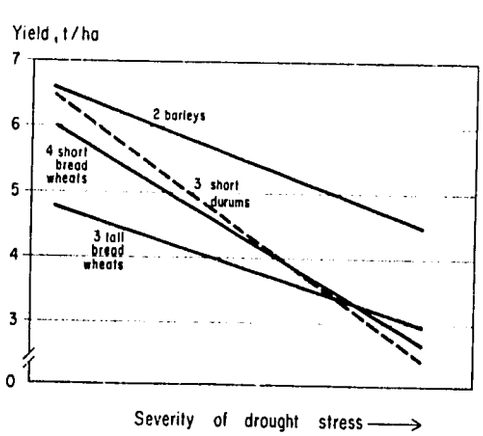


the late vegetative-anthesis stage which occur at the coolest time of year in Ciudad Obregon where the trials were conducted. During these two periods heating reduced the number of grains per square meter. Heating during the grain filling stage reduced the grain size.

Cooling had the opposite effect to heating. Especially during the mid-vegetative stage, cooling raised yield substantially.

Lodging in short wheats

Breeding short varieties dramatically increased the yield potential of wheat. The principal reason is that short wheats are more resistant to lodging (falling over) than tall wheats. Thus high rates of fertilizer, which tend to increase lodging, could be used with less danger. Nevertheless, even short wheat can lodge in strong winds or driving rains. Physiologists examined the yield reduction caused by lodging in high yielding semi-dwarf wheat and durum varieties by causing partial lodging (80°



Under drought stress, barley yielded about twice as much as wheats.

and 45° from vertical) in various periods starting at flowering.

Some varieties were able to right themselves. For example, the bread wheat variety Yecora when lodged 45° at flowering was almost completely vertical by maturity. Nevetheless its yield was reduced 1 t/ha. Varieties that did not right themselves suffered even worse yield reductions.

Shortening the vegetative period

Over half of the wheat plant's life is devoted to producing leaves and other vegetative parts. If varieties could be produced that have shorter vegetative periods without sacrificing yields, the crop would need less water and would be less exposed to drought periods and disease build-up. Physiologists attempted to shorten the vegetative period of Yecora, a highly productive variety, by exposing it at an early stage to photoperiod extension (24 hours of light daily for 18 days). This treatment reduced Yecora's vegetative period to 59 days from the normal 82 days. Although "early" Yecora had larger grains than normal because grain development occurred during a more favorable period, it had few grains per square meter and yield was nearly 1.5 t/ha lower than that of normal Yecora. Possibly the vegetative period was shortened too much. A less severe reduction might not lower yields.

Drought resistance

Several varieties of bread wheat, durum, and triticale were exposed to various degrees of drought after flowering. The aim was to identify strains that have drought resistance. Cocorit, a durum variety, and the triticales in the trial were more susceptible to severe drought stress than the bread wheats. Two varieties which presumably should have some drought resistance, Gabo from Australia and D67-3 from North Africa, had no better yields under severe stress than CIANO and Yecora, which are modern semi-dwarf Mexican wheats.

In another study, two barley varieties yielded almost twice as much as a number of bread wheats, durums, or triticales under drought stress. Again, at moderate drought levels, modern semi-dwarf wheats were equal to traditional tall wheats or better.

Erect leaves

In theory, wheat plants with erect leaves should be photosynthetically more efficient than plants with droopy or floopy leaves because they allow sunlight to penetrate deeper into the crop canopy and they shade each other less. Physiologists have been breeding lines with erect leaves that match the height, maturity, disease resistance, etc. of droopy leaved lines. Thus by testing an erect-leaved line against its corresponding droopy leaved line, the true value of erect leaves can be determined without being confounded by differences in plant type, maturity, or disease resistance.

In 1974, 1000 F_2 lines, 400 F_3 lines, and 300 advanced lines had been created. In the next year, yield trials with these materials will begin.

Growth patterns of wheat in the humid tropics

Many countries in the hot humid tropics like Bangladesh and Thailand import large amounts of wheat. To save foreign exchange, some are interested in growing wheat during their "winter" season. Aside from severe disease and insect problems in the humid tropics, yields of most wheat varieties are limited by physiological problems, largely related to high temperatures.

In 1974 CIMMYT physiologists continued trials in which the development patterns of wheat varieties are compared at three stations all of which are at about 20°N, but at different elevations: Poza Rica (60 m), Tlaltizapan (940 m), and El Batan (2200 m).

The studies showed that wheat varieties develop faster at higher temperatures. Although Poza Rica and Tlaltizapan had the same average daily temperature, the wheats developed faster at Poza Rica because the daily temperature range there was narrower than at Tlaltizapan. The warmer the climate, the fewer spikes and grains produced per square meter and hence the lower the yields.

Certain varieties exhibited a "cold response." That is, in the hot climate (Poza Rica), their flowering was delayed and they produced relatively more leaves and spikelets than other varieties, but their yields were no better. In the cool site (El Batan) they had about the same development pattern as other varieties. Apparently the development of these varieties is speeded relative to others by cool weather (below 10°C).

Siete Cerros and Anza were vigorous and high yielding at all three sites. Siete Cerros yielded 1.0 to 1.2 t/ha at Poza Rica, 4.7 t/ha at Tlaltizapan, and 5.2 to 7.0 t/ha at El Batan. Anza yielded 0.9 to 1.2 t/ha at Poza Rica, 4.0 t/ha at Tlaltizapan, and 5.3 to 7.9 t/ha at El Batan. Both have intermediate maturity, are insensitive to daylength and apparently have no cold response. Neither early nor late varieties had as consistent yields. In the hot climate, a few early dwarf lines and erect-leaved lines were not able to cover the soil surface by flowering time. Thus they were unable to capture all available solar energy. Such lines might yield better in the hot climate if they were sown more thickly.

DEVELOPMENT OF NEW GERM PLASM

Two types of unconventional germ plasm are being developed at CIMMYT. First, special desirable characteristics are being refined and transferred from unproductive varieties into adapted, high yielding, disease-resistant lines. Second, crops such as oats, barley, rye, and wheat are being crossed in hopes of producing a new crop, like triticale, or of transfering useful genetic material from one crop to another.

New sources of dwarfing

Most semi-dwarf varieties get their dwarfing genes from Norin 10. But two varieties, S948A1 and Tom Thumb, have different dwarfing genes

than Norin 10. Some lines with these sources of dwarfing were integrated in the bread wheat breeding program in 1974. Dwarf lines from S948A1 need more work to improve grain plumpness.

Branched spikes

In most wheats, spikelets are arranged along a central axis called the rachis. In some wheats, however, the rachis is branched so there is room for more spikelets. This in turn means that a branched spike might produce more grains than normal.

Branched wheats have been improved by increasing fertility, grain plumpness, and degree of branching, as well as by incorporating branching in genetic backgrounds that have vigorous tillering, strong stems, and disease resistance. In a trial with 26 branched wheats, yields ranged from 4.8 to 6.5 t/ha. Four lines yielded over 6 t/ha. The check varieties Cocorit 71 and Cajeme 71 yielded 6.7 and 6.6 t/ha.

Triticales with branched spikes are being developed, too.

Other special characters

Certain wheats have one special useful trait combined with numerous undesirable traits. Through crossing and selection the special traits are being combined with good agronomic characters before they are transferred to the conventional bread wheat breeding program. Some of the special traits: unusual insect and rust resistance, protein quality and quantity, unusual leaf type, long peduncles, thick stems, many spikelets per spike, many grains per spikelet.

Some triticales now have 40 to 50 spikelets per spike compared with 30 spikelets in normal triticales. Other triticales have 8 to 10 florets per spikelet. All of these materials are now being used in the conventional triticale breeding programs.

Wheat-triticale crossing

Wheats are being crossed with triticales to exchange germ plasm between these two cereals. In addition, triticale acts as a genetic bridge for transfering chromosomes and possibly even certain genes from rye to wheat.

Wide crosses

Techniques developed for creating triticale a wide cross (wheat x rye), have been used for four seasons in attempts to intercross other genera like oats, wheat, barley, and rye. The chemical E-amino caproic acid is being used to supress immunochemical barriers to alien pollen. No other successful wide crosses have been proven so far.

MILLING AND BAKING LABORATORY

CIMMYT's milling and baking laboratory tests bread wheat, durum wheat, and triticale in various ways to help breeders select lines that have good grain quality for making bread, tortillas, chapatis, macaroni, and so on. In 1974 the laboratory tested 27,000 samples from early generation

bread wheat lines for gluten strength. A large number of advanced-generation spring and winter wheats were also tested for bread-making quality. The information on winter wheat is an aid in planning crosses between winter and spring wheats.

The laboratory evaluated the pigment of grain from 6000 durum plants. Pigment content relates to the yellow color of macaroni and thus is an important industrial characteristic. During the first 3 years of selection, the average pigment content has improved greatly —rising from 3.8 ppm to 5.5 ppm.

Five trainees, from Algeria, Libya, Kenya, Tunisia and Turkey, worked in the milling and baking laboratory during 1974.

WHEAT TRAINING

Thirty-four young wheat scientists from 14 countries were trained in Mexico during 1974. Since 1960, 306 wheat scientists received in-service training.

The training program, which lasts 9 months, is designed to develop capability in field and laboratory techniques, give experience in working on an interdisciplinary research team, and increase understanding of agricultural development in relation to wheat production.

To improve contacts with former trainees, a newsletter, *Wheat Team Field Notes,* was started. Two issues were distributed during 1974. The newsletter reports research progress in national programs and at CIMMYT and it summarizes current wheat crop conditions.

An audio-visual learning center was set up for the trainees. Film strips with cassette narratives allow trainees to refresh their knowledge of basic areas in genetics, botany, physiology, soils, statistics, etc.

A former CIMMYT outreach staff member who has served in Algeria and Morocco was added to the training staff during 1974.

CIMMYT relies mainly on restricted and special grants to support its in-service training in wheat. In 1974 the following provided training support:

Ford Foundation	133.2 months
FAO	42.2
US Agency for International Development	36.2
Rockefeller Foundation	16.2
International Development Research Centre (Canada)	13.0
March Foundation	8.5
Fifamanor	7.4
*Hungary	7.2
Instituto de Ciencia y Tecnologia Agricolas (Guatemala)	7.0
CIMMYT core budget	5.7
*Libya	4.1
Total	280.7

*Governments that paid for training their own nationals.

Wheat in-service trainees 1960-74

Region and country	1974	1960-74	Region and country	1974	1960-74
North Africa and Near East	*20*	*166*	*South and East Asia*	*7*	*52*
Afghanistan	0	17	Bangladesh	2	8
Algeria	9	27	India	0	4
Cyprus	0	2	Korea	0	5
Egypt	0	8	Nepal	0	2
Iran	4	11	Pakistan	2	32
Iraq	0	7	Philippines	0	1
Jordan	0	5	*Latin America*	*3*	*57*
Lebanon	0	4	Argentina	0	17
Lybia	1	7	Bolivia	0	2
Morocco	0	17	Brazil	0	14
Saudi Arabia	0	1	Chile	0	3
Syria	0	5	Colombia	0	2
Tunisia	4	21	Ecuador	0	6
Turkey	2	31	Guatemala	1	4
Yemen	0	3	Paraguay	0	2
Tropical Africa	*4*	*22*	Peru	2	5
Ethiopia	0	7	Uruguay	0	2
Kenya	0	3	*Other*	*2*	*9*
Madagascar	1	1	Hungary	1	1
Nigeria	2	3	Poland	0	2
Somalia	1	1	Portugal	0	1
Sudan	0	4	Rumania	0	2
Tanzania	0	3	Spain	1	1
			USSR	0	3

INTERNATIONAL NURSERY TRIALS

Scientists in 83 countries planted CIMMYT's International Nursery Trials in 1974. There were over 1200 such trials around the world. The purpose of the trials is to test new lines of wheat from CIMMYT's breeding program and from other programs under the widest possible range of daylength, temperature, moisture, diseases, insects, and soils. Three fourths of the trials are grown without irrigation. The results of the trials influence breeders decisions. In addition, the trials are a means for exchanging advanced germ plasm between programs.

For these nurseries alone, CIMMYT airfreighted 4.5 tons of seed to scientists throughout the world.

OUTREACH ACTIVITIES FOR WHEAT

CIMMYT has continued its traditional emphasis on helping national wheat programs to strengthen their research and production activities.

During 1974, the CIMMYT wheat staff spent over 1200 man-days consulting with governments of wheat producing countries of Asia, Africa, and Latin America. This consultation includes participation in research

planning seminars, time spent in farmers' fields to observe what is holding back yields, and time spent with national policy makers discussing fertilizer supplies, grain prices, grain storage, and other policy questions.

CIMMYT sent experimental wheat nurseries for 1200 trials in 83 countries. These trials provide germ plasm for almost every country

International wheat nursery trials.

Country	1972	1973	1974	Country	1972	1973	1974
Africa				Hungary	2	5	10
Algeria	24	40	45	Ireland	0	0	1
Angola	0	0	4	Italy	1	4	9
Cameroon	1	2	2	Netherlands	0	2	5
Egypt	10	71	23	Norway	0	0	0
Ethiopia	17	27	35	Poland	4	6	17
Kenya	8	14	13	Portugal	6	9	10
Lesotho	1	2	2	Rumania	4	8	8
Malagasy Republic	0	0	1	Russia	8	34	20
Morocco	6	27	16	Spain	5	12	22
Nigeria	0	3	9	Sweden	5	3	3
Rhodesia	0	0	8	Switzerland	2	2	3
Senegal	1	4	4	East Germany	0	0	0
Somalia	0	0	4	West Germany	1	1	2
South Africa	8	30	17	Yugoslavia	3	10	12
Sudan	1	8	11	*Middle East*			
Tanzania	3	9	4	Cyprus	1	12	10
Chad	0	2	3	Iran	10	23	20
Tunisia	24	27	25	Iraq	10	0	7
Uganda	0	2	1	Israel	10	11	11
Zaire	0	0	2	Jordan	7	0	11
Zambia	0	2	2	Lebanon	18	32	27
Asia and				Libya	5	0	8
Pacific				North Yemen	0	0	4
Afghanistan	6	13	10	Saudi Arabia	0	0	4
Bangladesh	1	5	6	South Yemen	0	0	5
China	1	0	0	Syria	0	0	13
India	30	98	90	Turkey	35	38	34
Indonesia	0	2	1	*North and Central America*			
Japan	1	4	4	Canada	13	25	39
Nepal	6	7	14	Guatemala	7	12	10
Pakistan	21	45	47	Mexico	63	87	82
South Korea	5	12	10	U.S.A.	82	81	90
South Vietnam	0	0	1	Honduras	0	1	1
Thailand	1	5	5	*South America*			
Australia	2	9	13	Argentina	46	68	69
New Zealand	3	3	5	Bolivia	2	3	9
Europe				Brazil	35	51	41
Albania	0	0	5	Chile	20	26	23
Austria	0	4	3	Colombia	10	11	9
Bulgaria	1	5	4	Ecuador	8	13	16
Czechoslovakia	0	0	1	Guyana	0	1	1
Denmark	2	5	8	Paraguay	6	6	7
England	3	12	14	Peru	14	20	24
Finland	0	1	3	Uruguay	4	2	3
France	2	15	18	Venezuela	0	1	2
Greece	1	5	9	TOTAL	637	1140	1204

in the world that grows more than 100,000 hectares of wheat and for many smaller producers. In addition, CIMMYT supplied seed for individual requests to a large number of scientists worldwide.

Thirty-four trainees from 14 countries and 21 visiting scientists from 16 countries were involved in CIMMYT's training program in 1974. CIMMYT continued to maintain contacts with its large number of former trainees in Asia, Africa, and Latin America.

Eleven CIMMYT wheat staff members were stationed in five countries —Algeria, Tunisia, Lebanon, Turkey, and Pakistan— in 1974. The staff member in Lebanon serves as regional wheat pathologist for countries of North and East Africa and Asia.

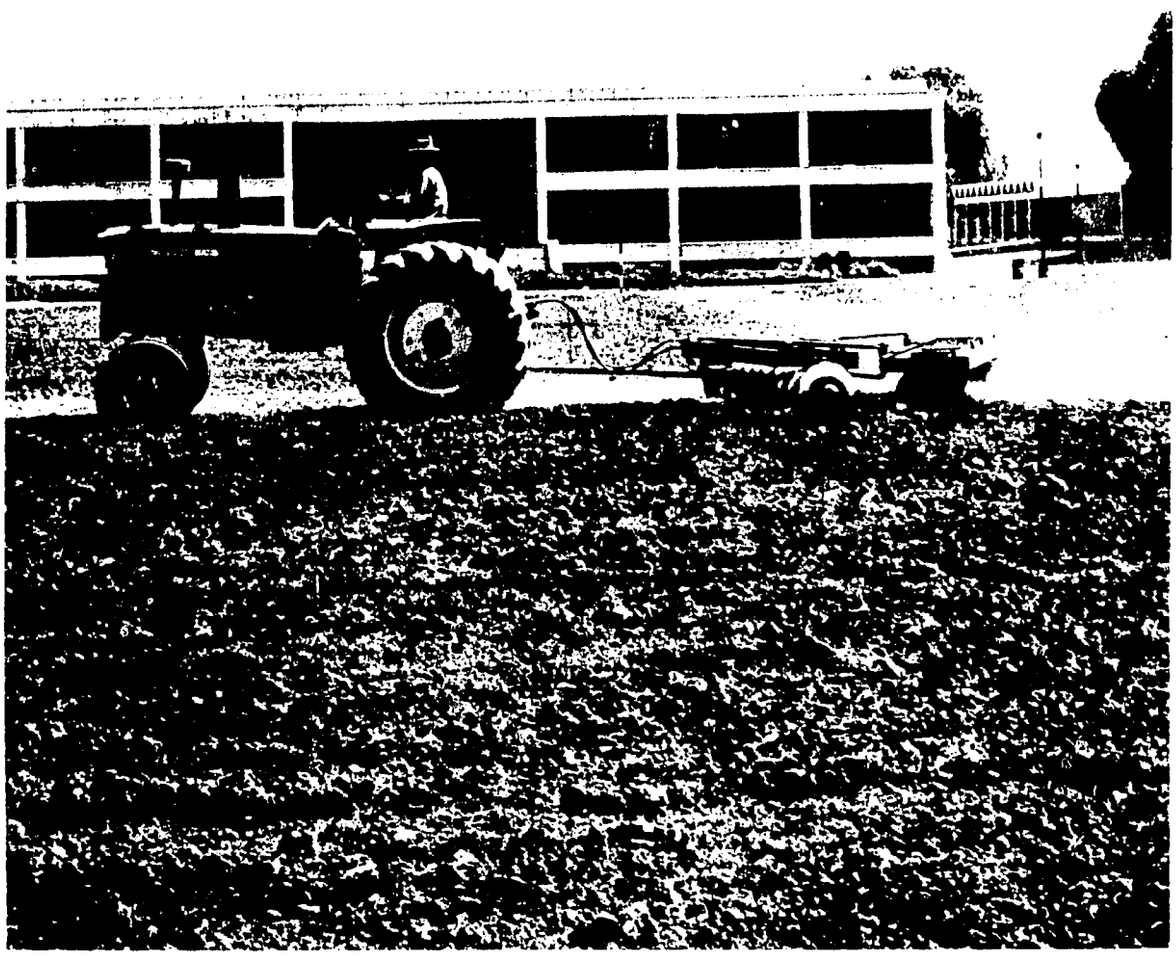
CIMMYT's staff in Turkey began consulting with countries of Eastern Europe, which welcomed an exchange of wheat germ plasm.

In Eastern Asia, traditional rice growing countries are asking for assistance to start a dry-season wheat crop. Requests have been received from Bangladesh, Burma, Thailand, Malaysia, Vietnam, and Indonesia. CIMMYT staff members have visited several countries and shipped seed.

While no CIMMYT wheat staff members are stationed in South America, the Mexico-based staff continued regular consulting calls in most major wheat-producing countries.

In Poza Rica's hot, humid climate, some bread wheats grow fairly normally while others suffer from problems like low tillering and high sterility.

supporting services



ECONOMIC STUDIES

The economics section supports CIMMYT's efforts to help national programs develop and diffuse new maize and wheat technology by identifying, for agricultural scientists and policy makers, ways to make new technology and agricultural policy more consistent with the circumstances of farmers.

Adoption studies

Eight adoption studies are under way. These studies are aimed at:

- —ascertaining how farmers classified by agro-climatic regions and farm size used the technology
- —establishing how the adoption of new technology was influenced by characteristics of the farmer such as education and off-farm work, by characteristics of the farm such as nearness to markets and importance of cereals, and by agricultural policy such as price policy and support of the extension program
- —augmenting various countries' capacity to do social science research at the farm and market level
- —enhancing CIMMYT's capacity to counsel national programs on the diffusion of new technology

In each study CIMMYT economists collaborate closely with national agricultural scientists and economists.

Drafts of studies for wheat in India and for maize in Kenya west of the Rift valley were completed in 1974. The studies on maize technology in Colombia, El Salvador, and Plan Puebla (Mexico) and on wheat technology in Tunisia, Iran, and Turkey are scheduled to be completed in 1975. At this time some preliminary comments on the pattern of adoption are possible.

Influence of agro-climatic factors

One of the clearest findings is the overriding importance of regional agro-climatic characteristics on the use of improved varieties and fertilizers. Climate's influence on variety use is most evident in Kenya, Turkey (see tables), and Iran where almost all farmers in some regions have adopted improved seeds while other regions have quite low rates of use. In Kenya, Turkey, and Iran, the difference between regions with high adoption rates and those with low rates exceeds 50 percentage points. For example in Kenya 83 percent of farmers in the two high elevation regions use improved varieties compared with 14 percent in the low elevation region. While not as marked, the influence of agro-climatic factors is evident in El Salvador (see table) where over 20 percentage points separate the adoption rate of hillside farmers from that of valley farmers. A slightly larger spread separates the two regions in Plan Puebla. In the region where farmers must wait for spring rains before planting, about a fourth use the recommended planting density for at least one maize field. In the region where residual soil moisture allows farmers to plant before the rains start, none of the farmers use the recommended spacing. In Colombia (see table) a far greater proportion

KENYA: Proportion of sampled maize farmers in maize growing areas west of the Rift Valley, divided by farm size, who planted hybrid maize mixed with other crops. 1973.

Region	Elevation [a]	Annual rainfall [b]	Farm size [c] ha			Users of hybrid maize, %			Users of fertilizer, %		
			small	large	special	small farms	large farms	special	small farms	large farms	special
A	high	high	under 3.2	3.2 +	--	80	86	--	47	72	--
B	high	medium	under 4.5	4.5-20	20 +	77	79	94	67	93	98
C	low	low	under 2.4	2.4 +	--	6	23	--	0	6	--

Source: Survey of 350 farmers sponsored by CIMMYT and carried out by John Gerhart with the support of agricultural scientists at Kitale Station. *a/* High elevation is above 1500 m; low elevation is below 1500 m. *b/* High rainfall is over 150 cm/year; medium rainfall is 100 to 150 cm; low rainfall is less than 100 cm. *c/* For Regions A and C, observations were arrayed by size and divided into two groups based on size. The same procedure was followed for Region B excluding farms over 20 hectares. Farms over 20 hectares in Region B made up the "special" group; nearly all once were part of European-owned farms.

of farmers in low altitude valleys use improved varieties than do other farmers.

The India study also supports the importance of agro-climatic factors. In summarizing the many existing studies on the adoption of new wheat technology in India, V.S. Vyas reports that the principal influence on the adoption of new wheat varieties is an assured water supply. While farm size has played a role, this is at times confounded by access to water. That is, in certain regions, a greater proportion of large farms have irrigation than do small farms and more large farms follow, albeit

TURKEY: Proportion of sampled wheat farmers, divided by farm size, who planted wheat of Mexican or Russian origin, and average fertilizer use. 1972.

Region [a]	Farm size, [b] ha		Users of new wheats, %		Avg. use of fertilizer, [c] kg/ha	
	small	large	small farms	large farms	small farms	large farms
Mediterranean						
valleys	under 8.1	8.1-150	87	94	113	122
hillsides	under 6.1	6.1-125	91	90	125	143
Aegean						
valleys	under 4.6	4.6-22	61	78	33	57
hillsides	under 3.9	3.9-37	2	20	26	59
S. Marmara						
valleys	under 3.4	3.4-14.5	3	10	57	53
hillsides	under 4.4	4.5-108	6	21	44	60
N. Marmara	under 8	8-128	61	83	91	106

Source: Study of 800 farmers sponsored by the Turkish Ministry of Agriculture and CIMMYT directed by Rechat Aktan and with subsequent analysis in collaboration with Nazmi Demir. *a/* Mediterranean region is centered on Adana, Aegean region is centered on Izmir, S. Marmara region is north of Izmir and along the Marmara Sea, N. Marmara is north of the Bosphorus in European Turkey. "Valleys" includes flat land. *b/* For each subregion, e.g. Aegean valleys, the observations were arrayed by farm size and then divided evenly into two groups based on size. *c/* Nitrogen plus phosphorus.

EL SALVADOR: Proportion of sampled maize farmers, divided by farm size, [a] who planted hybrid maize, and nitrogen use on maize. 1972.

Region	Users of hybrid maize, %			Nitrogen use, kg/ha		
	small farms	medium farms	large farms	small farms	medium farms	large farms
hillsides	16	28	30	21	38	51
valleys	37	37	67	41	53	67

Source: Study of 350 farmers sponsored by CIMMYT and undertaken by Jesus Cutie in 1973. *a/* Small farms: under 1.4 ha; medium farms: 1.4-3.1 ha; large farms: 3.2-31.5 ha.

not strictly, the new technologies. In areas where virtually all farms are adquately irrigated, for example in the Punjab, virtually all farmers, irrespective of size, have adopted new varieties. Even so, Vyas points out, the larger farmers tend to adopt first with the smaller farmers catching up within a few (2 to 4) years.

From the Indian data it might be concluded that agro-climatic factors have played a dominant role in the adoption of new wheats and, to a lesser extent, in the use of fertilizer. Farm size appears to be markedly influential in some regions, less in others, and only marginal in still others.

Fertilizer use also reflects the impact of agro-climatic factors in the other countries studied: aplication rates in the regions with greatest fertilizer use exceed those in the lowest regions by over 50 percent.

All this indicates that agro-climatic factors, with their implications for the attainment of such farmer goals as profits or risk aversion, significantly shape the pattern of adoption of new technology. This

COLOMBIA: Proportion of sampled maize farmers, divided by farm size, who planted improved maize on over half their maize area, and average fertilizer use in maize mixed with other crops. 1972/73.

Region	Farm size [d] ha.		Users of improved maize, %		Avg. use of fertilizer, [e] kg/ha	
	small	large	small farms	large farms	small farms	large farms
low altitude [a]						
valleys	under 1.9	1.9 +	19	65	6	34
hillsides	under 2.6	2.6 +	0	15	+	7
intermediate [b]						
valleys	under 2.6	2.6 +	19	30	1	15
hillsides	under 2.1	2.1 +	10	15	3	5
high altitude [c]						
valleys	under 1.0	1.0 +	5	12	9	13
hillsides	under 1.5	1.5 +	4	4	10	5

Source: Study of 750 farmers sponsored by Colombia's Instituto de Ciencias Agricolas and CIMMYT, undertaken by Humberto Colmenares in 1973. *a/* Sea level to 900 meters. *b/* 900 to 1800 meters. *c/* Over 1800 meters. *d/* For each sub-region, e.g. high altitude valleys, the observations were arrayed by farm size and then divided evenly into two groups based on size. *e/* Nitrogen plus phosphorus.

finding has an important bearing on economics research in developing countries. For most problems, if the research is to be useful, agro-climatic regions must be examined separately. The Kenya data suggest, for example, that Kenya's policy makers emphasize development of new varieties for the low elevation, low rainfall region. If the regions were combined, giving an adoption rate of about 60 percent for improved varieties, the implication would almost surely be that credit and extension services should be accented. By basing the analysis on agro-climatic regions, completely different policy implications may emerge.

This in turn points up the advantages from incorporating the knowledge and perspectives of agricultural scientists in work on economics. Their special knowledge of the relationship between plants and environments and of alternative farmer practices can be critical to effective research.

Farm size

Looking now at the influence of farm size on adoption of varieties a pattern again emerges. Larger farms have higher adoption rates than smaller farms in each of the agro-climatic regions. Usually the differences are small, under 15 percentage points, e.g. hillside farmers in El Salvador and Mediterranean farmers in Turkey. Such differences are probably not large enough to warrant special agricultural policy.

But in some areas differences between smaller and larger farmers in the adoption of improved varieties are more notable, as for example among valley farmers in El Salvador or farmers in Colombia's low altitude valleys. Such differences are also reported for some of the regions studied in India.

In general, farm size has the most impact where adoption rates of improved varieties are intermediate. Larger farmers are usually among the first to adopt new technologies and seldom have lower adoption rates than smaller farmers. The data suggest that when virtually all of the larger farmers of an agro-climatic region adopt new varieties, then virtually all of the smaller farmers also adopt, e.g. Turkey's mediterranean region. When a region's larger farmers have low rates of adoption, under 30 to 35 percent, the smaller farmers also have low rates, e.g. valley farmers in Turkey's South Marmara region. When, however, large farmers have an intermediate adoption rate, 35 to 85 percent, the differences among the size groups may be large, as they are among El Salvador's valley farmers. There is one exception to this, in Turkey's Aegean region the difference in adoption by small and large valley farmers is 17 percentage points. This region is now being studied more intensively.

Thus it appears that where improved varieties are very attractive to the bulk of the large farmers, small farmers will also adopt. Similarly, when the varieties are not attractive to the large farmers, they are not attractive to small farmers. But when a large but not overwhelming

Why the small farmer does or does not adopt new technology is being investigated by CIMMYT economists in collaboration with national economists in eight countries.

group does accept, the smaller farmers tend to lag well behind.

One explanation is that while all farmers are attracted by the higher average incomes promised by improved varieties, some are inhibited by their perception of higher risk. The risks perceived tend to influence small farmers more than large farmers. In regions like Kenya's high elevation, high rainfall area, farmers perceive little risk and virtually all adopt new varieties. In regions like the low elevation area in Kenya small profits are promised and virtually no one, regardless of farm size, adopts new varieties. In regions like El Salvador's valleys or Colombia's low altitude valleys, perceived risks keep many large farmers from adopting, but an even greater proportion of small farmers fail to adopt.

Other explanations come to mind, for example, access to credit or to the services of extension agents. While such access almost certainly favors large farmers, the contrasts among farm size groups between regions within countries suggest that these factors alone do not explain limitations on the diffusion of technology.

Until detailed analysis of each study —including such factors as education, tenure, distance to markets, and access to extension services— is in hand, we think profit and risk best explain the emerging patterns of adoption. Some comments from agricultural scientists on the suitability of new varieties for different regions support this view. For example,

hybrids for western Kenya include a heavy admixture of high altitude germ plasm from South America. They lose their relative advantage over local maizes as altitude declines. Agricultural scientists also report that the first versions of new wheats showed marked sensitivity to septoria disease. So,in regions like Turkey's Aegean where septoria occurs, it seems likely that farmers view the new wheats as more risky than local varieties. In Iran's southern region the irrigated area surveyed is suffering from increasing salinity and local varieties are thought to be less influenced by soil salts.

For fertilizer use, farm size seems to have more influence on adoption. With few exceptions large farms use more fertilizer per hectare than smaller farms. The exceptions occur in Turkey and in Colombia's high altitude hillside areas. They are also reported by Vyas for regions included in his survey of India. Even in Turkey, however, the pattern is consistent although the differences in fertilizer use are not marked.

This pattern of fertilizer use reflects differences between large and small farmers in risk-averting behavior, access to credit, and access to information. More complete analysis on the role of a wide range of variables on each of several practices will be available with the completion of the detailed studies.

Agro-climatic studies

With the results of the adoption studies highlighting the importance of agro-climatic regions in farmer response to new technology, the economics section continued collaborating with maize and wheat physiologists aimed at enlarging CIMMYT's knowledge of the agro-climatic conditions characterizing the world's maize and wheat producing areas. An improved data base will help both programs set research priorities.

Workshops on micro-level data

An important function of the economist is to collaborate with agricultural scientists to identify farmers' circumstances and to interpret their implications for technology and for policy. This point of view emphasizes the importance of reliable information at the micro-level. However, the capacity to get such data is not readily available in many countries. For these reasons, CIMMYT and the Agricultural Development Council (USA) sponsored a series of international workshops in 1974 involving participants skilled in data collection in rural areas of developing countries. Workshops were held in Singapore (for South Asia), Beirut (for the Near East) and Mexico (for Latin America). Seventy-five investigators participated, most of them natives of developing countries. The workshops were organized around five general themes designed to elicit the "rules of thumb" used by experienced researchers in conducting surveys. Information from the workshops will be published.

Other activities

CIMMYT's economics section is collaborating in field work with national programs that are closely associated with CIMMYT's maize and wheat programs. This collaboration emphasizes farm and market research aimed at assessing elements that influence farmers' production activities in maize or wheat.

With such information at hand, new technologies can be made more consistent with farmer circumstances and agricultural policy more consistent with rapid diffusion of new technology. CIMMYT is helping to (1) identify national economists who will conduct micro-level research jointly with agricultural scientists, (2) formulate useful research topics, and (3) implement such research. These activities are now under way with the national maize program in Zaire. Planning is nearly completed for similar work in Ethiopia, Pakistan, Turkey, and Tunisia.

In conjunction with CIMMYT's maize program, additional work was initiated on the value of maize with high quality protein. Research is being supported by Instituto de Nutricion de Centroamerica y Panama in Guatemala and a field study will be undertaken there in 1975. In addition, an agency of the Peruvian government and CIMMYT will investigate the intake of various important nutrients by maize eaters in Peru's highlands. Our aim will be to determine the impact that investment in a quality protein maize program might have on the diets of the maize eaters.

Staff

In 1974, the staff consisted of one full-time professional and one visiting scientist who is working in the economics section for 1 year. Three Ph.D. candidates (one from Argentina, one from Mexico, and one from USA) were working on thesis topics of special interest to CIMMYT. Two economists will be added to the professional staff next year. Outside Mexico, six economists are collaborating on the adoption studies.

LABORATORY SERVICES

CIMMYT operates common service laboratories —a protein quality laboratory and a soils and plant nutrition laboratory— to help the wheat and maize programs.

Protein quality laboratory

The protein quality laboratory assists the breeders by analyzing total protein content and some essential amino acids which limit the quality of the protein in experimental lines of cereals. During 1974 analyses were made on 6500 barley samples, 6300 maize samples, 4100 triticale samples, 1600 wheat samples, and 33 sorghum samples.

Barley, wheat, and triticale materials were evaluated by the dye-binding technique which allows selection of materials with high protein or high lysine content, or both, in the preliminary screening. After this preliminary screening, protein is determined in selected samples, and finally lysine is determined in the most promising lines.

The new ninhydrin test which permits the rapid detection of free amino acids in maize endosperm is used in the laboratory on certain samples, where the breeder requires non-destructive analysis in order to plant the same kernel that has been evaluated in the laboratory. Opaque-2 maize contains more free amino acids than normal maize, therefore this qualitative test is used as preliminary screening. For quantitative evaluation, the protein and tryptophan are determined on endosperm samples of genetic families. In most selected samples, lysine is determined, and to more thoroughly evaluate the protein quality in certain cases, a complete amino acid analysis is done by ion-exchange chromatography.

The laboratory also trains young scientists from different countries who are working in the national programs that require a service laboratory to evaluate the quality of their genetic materials. In 1974, the laboratory had two trainees from Mexico and one each from Egypt, Philippines, Yugoslavia, Peru, Colombia, and India.

The head of the laboratory traveled to Brazil, Argentina, Guatemala, India, Nepal, and Thailand to consult with laboratories of national maize and wheat programs.

Soils and plant nutrition laboratory

The soils and plant nutrition laboratory does chemical analysis of samples of soil, water, plant tissue, and grain. During 1974 the laboratory tested 800 samples of soil for pH, nitrogen, and assimilable ions; 16 samples of water for pH and soluble ions; and 4600 samples of plant tissue and grain for nitrogen content. Total sugars were also determined on 800 tissue samples for the maize and wheat physiology sections.

Bioassay of cereals

In 1973 CIMMYT discontinued bioassays of cereal protein in which the meadow vole was the test animal. To replace the CIMMYT tests, agreements were made in 1974 with the Instituto de Investigaciones Pecuarias (INIP) in Mexico and with the Instituto de Nutricion de Centroamerica y Panama (INCAP) in Guatemala for animal assays of CIMMYT cereals.

INIP is using laboratory rats to evaluate the protein of one wheat, seven triticales, and five quality protein (opaque-2) maizes supplied by CIMMYT. When lines of barley and sorghum become available that have improved nutritional value they will be tested too. Trials with chickens and pigs are also planned.

INCAP is evaluating one wheat, four triticales, and five quality protein maizes with rats. Assays involving poultry and humans are planned.

In cooperation with the Instituto de Ciencia y Tecnologia Agricolas (ICTA) in Guatemala which is multiplying certain CIMMYT quality protein maizes, INCAP is planning to introduce quality protein maize in a village in the Guatemalan highlands. ICTA will provide 5000 tons of quality protein maize which will be used by 500 volunteers in the village. The villagers will purchase the grain at the market price so that the economic comparison between groups of villages will not be upset. INCAP will make detailed health and growth studies on children and adults comparing those who eat normal maize with those who eat quality protein maize.

Samples of CIMMYT triticales and maizes were also sent to Washington State University (USA) for trials with chickens and turkeys. Samples of quality protein maize continue to be sent to Purdue University (USA) for trials with rats.

EXPERIMENT STATION MANAGEMENT

CIMMYT conducts research at eight sites in Mexico. Four are owned by Mexico's National Agricultural Research Institute and the other four by CIMMYT.

	Elevation	*Latitude*	*Hectares used by CIMMYT*
CIANO-INIA	Sea level	27°N	100
Los Mochis-INIA	Sea level	25°N	2
Navojoa - INIA	Sea level	27°N	14
Rio Bravo - INIA	Sea level	26°N	1
Poza Rica - CIMMYT	Sea level	20°N	38 (twice a year)
El Batan - CIMMYT	2240 m	19°N	42
Toluca - CIMMYT	2640 m	19°N	67
Tlaltizapan - CIMMYT	940 m	18°N	31 (twice a year)

In 1974 CIMMYT completed its building program for the experimental stations. At El Batan the main items were a house for the station superintendant and a small storage building for the wheat program. A greenhouse was built at Toluca for the triticale program.

A killing frost on the nights of 7 and 8 September 1974 caused severe damage to crops planted above 2000 meters elevation, which includes the El Batan and Toluca stations. On 21 September as a result of rains from hurricane Fifi, the San Marcos River flooded the Poza Rica station; 17 hectares were damaged, 5 severely. The maize crop was completely destroyed. Repairs were carried out in time to enable the maize program to plant the 1974/75 winter cycle.

The extra 12 hectares needed for experimental work on the high plateau (El Batan-Toluca) still did not become available, so 12 hectares of land were rented near El Batan.

In 1974 CIMMYT's research station manager spent 7 weeks as a

consultant to help experimental stations in Nepal, Tanzania, Nigeria, and Algeria.

Visitors from 10 countries spent various lengths of time studying CIMMYT's experimental stations. Courses on experiment station management were given to the trainees in residence.

STATISTICAL SERVICE UNIT

The CIMMYT staff has used computer services for more than 10 years. Several types of activities are handled by computer:

- –general accounting
- –international nursery trials, including the printing of field books, analysis of data, and printing analyzed results
- –analysis of individual research trials
- –maize germ plasm bank inventory and performance data
- –analysis of economic data

Until 1974 CIMMYT hired computer time on university and commercial computers. These arrangements have not proved wholly satisfactory. As a result, during 1974 CIMMYT installed a modern electronic accounting machine to handle all accounting and inventory functions. In addition a statistical service unit is being established to handle computing needs of all programs. The unit will have its own mini-computer and staff including a biometrician in charge who will be on loan from the British Ministry of Overseas Development.

CIMMYT has benefitted from the advice of two consulting groups. A survey of CIMMYT's computing needs was made in 1974 by P.S. Ross and Partners, management consultants, who were hired by the International Development Research Center of Canada as part of a general assessment of management accounting and computer facilities of all international centers. Also CIMMYT has been assisted by David Rogers of FAO and his staff group headed by Gilbert Hersh of the University of Colorado. Their collaboration includes development and testing of efficient programs for handling of germ plasm bank records, breeding systems and data, and international nursery data on the mini-computer, and staffing assistance and advice.

INFORMATION SERVICES

New publications

Twenty-one new titles were published in 1974 (see table). The information services also distributed the Proceedings of the International Triticale Symposium published by the International Development Research Center, Canada. This seminar was co-sponsored by CIMMYT.

In addition to new titles, two publications were reprinted due to high demand: *Field technique for fertilizer experiments* (6th printing) and *Chemical screening methods for maize protein quality at CIMMYT* (2nd printing).

Cooperation with other organizations

Information services personnel collaborated with the Escuela "Antonio Narro" in organizing rural sociology and information meetings at Saltillo, Mexico. They also participated in the courses being taught at the

Publications issued in 1974

Title	*Pages*	*Printed*
Research bulletins		
Epidemiology of wheat rusts in the western hemisphere.	27	1500 English 1500 Spanish
Information bulletins		
This is CIMMYT	24	2000 English 2000 Spanish 2000 French
Maize diseases	77	4000 English 4000 Spanish 1000 French
Results of the second and third international maize adaptation nursery 1971-72, 1972-73	119	1500*
Results of the third international opaque-2 maize trials 1972-73	41	1500*
Results of the eight international spring wheat yield nursery 1971-72	137	1500*
Results of the second and third international durum yield nurseries 1970-71, 1971-72	120	1500*
Translations and reprints		
Evaluación de avances y problemas en la obtención de especies forestales resistentes a la roya.	50	500 Spanish
Evolucionar o perecer	30	500 Spanish
Población humana, demanda alimentaria y necesidades de la fauna y la flora	11	500 Spanish
La productividad agrícola y el problema alimentario de la población humana	43	500 Spanish
Avances hacia la obtención de nuevos genes de cereales	8	500 Spanish
Identificación de cromosomas del genomio-D de trigo hexaploide en un triticale de 42 cromosomas	12	500 Spanish
La producción de alimentos a nivel mundial para el futuro	12	500 Spanish
Other publications		
Proceedings -- World wide maize improvement in the 70's and the role for CIMMYT	426	1000 English 1000 Spanish
CIMMYT Review 1974	95	4000 English 4000 Spanish
Visitor's guide	8	2000 English 1000 Spanish 1000 French
CIMMYT report on wheat improvement 1973	113	2500 English 2500 Spanish
CIMMYT report on maize improvement 1973	113	2500 English 2500 Spanish
Proceedings – Wheat, triticale, and barley seminar	378	1500 English
Situación mundial de los fertilizantes	7	200 English 200 Spanish 100 French
The Puebla Project: 7 years of experience, 1967-73	132	3000 English 3000 Spanish

*Text in English, Spanish, and French.

Puebla Training Center, sponsored by the Puebla Project. In cooperation with the communcations department, Graduate School, Chapingo (Mexico) three students did their M.S. theses under supervision of information services staff. The audiovisual section fully cooperated with the Secretaria de Agricultura y Ganaderia in developing materials illustrating the Plan Agricola Nacional which were presented to the President of Mexico by SAG authorities.

Mailing list surveys

Two types of surveys were made on the CIMMYT publications mailing list during 1974. All addressees were sent a card asking if they wished to continue receiving CIMMYT publications. Three months later, those who did not reply were sent a second card. Persons who did not reply to the second card were dropped from the mailing list. As a result the mailing list was reduced from 6500 addresses to 4500.

In addition, a short questionnaire was sent to a small random sample of the addresses on the mailing list. The survey showed that, of the addressees on the mailing list, 55% are active scientists, 15% are administrators such college department chairman or officials of international aid agencies, 10% are libraries, 7% are extension technicians, and the rest are farmers, economists, agricultural supply salesmen, etc.

One-fifth of the respondents were mainly interested in wheat. About twice as many were mainly interested in maize. The remainder said they were equally interested in both programs. Scientists had about the same division of crop interests as all respondents.

The respondents were asked which language –English, French or Spanish– they prefer for publications. About half said English and half said Spanish. Less than 5 percent prefered French. Among the Spanish speakers, about half indicated good facility in English. An even larger proportion of the Spanish-speaking scientists, especially wheat scientists, indicated good facility in English.

Audiovisuals

A major exhibit was prepared, designed, and mounted for the conference "World Wide Maize Improvement in the 70's and the Role for CIMMYT" held in 1974. The exhibit involves flow charts, live models, and photographs on every aspect of the maize program. The exhibit was displayed in the administration building, and now serves as part of the permanent exhibit depicting CIMMYT's role in improving world food production.

The audiovisual section continued its supporting role to the crop program in art and photography production. The audiovisual section does layouts, pictures, graphs, and design for publications and conferences.

Slide sets

Several slide sets were completed during the year:

–This is CIMMYT (new version) (50 slides)
–Maize diseases: bacteria,virus,and nematodes (23 slides)
–Maize diseases: fungi (48 slides)

—Maize diseases: inoculum collection and reproduction, and artificial inoculations (75 slides)
—Laboratory techniques for determining industrial quality (50 slides)
—CIMMYT's maize advanced unit (50 slides)

All these slides sets are in color and have English, French, and Spanish texts.

Visitors services

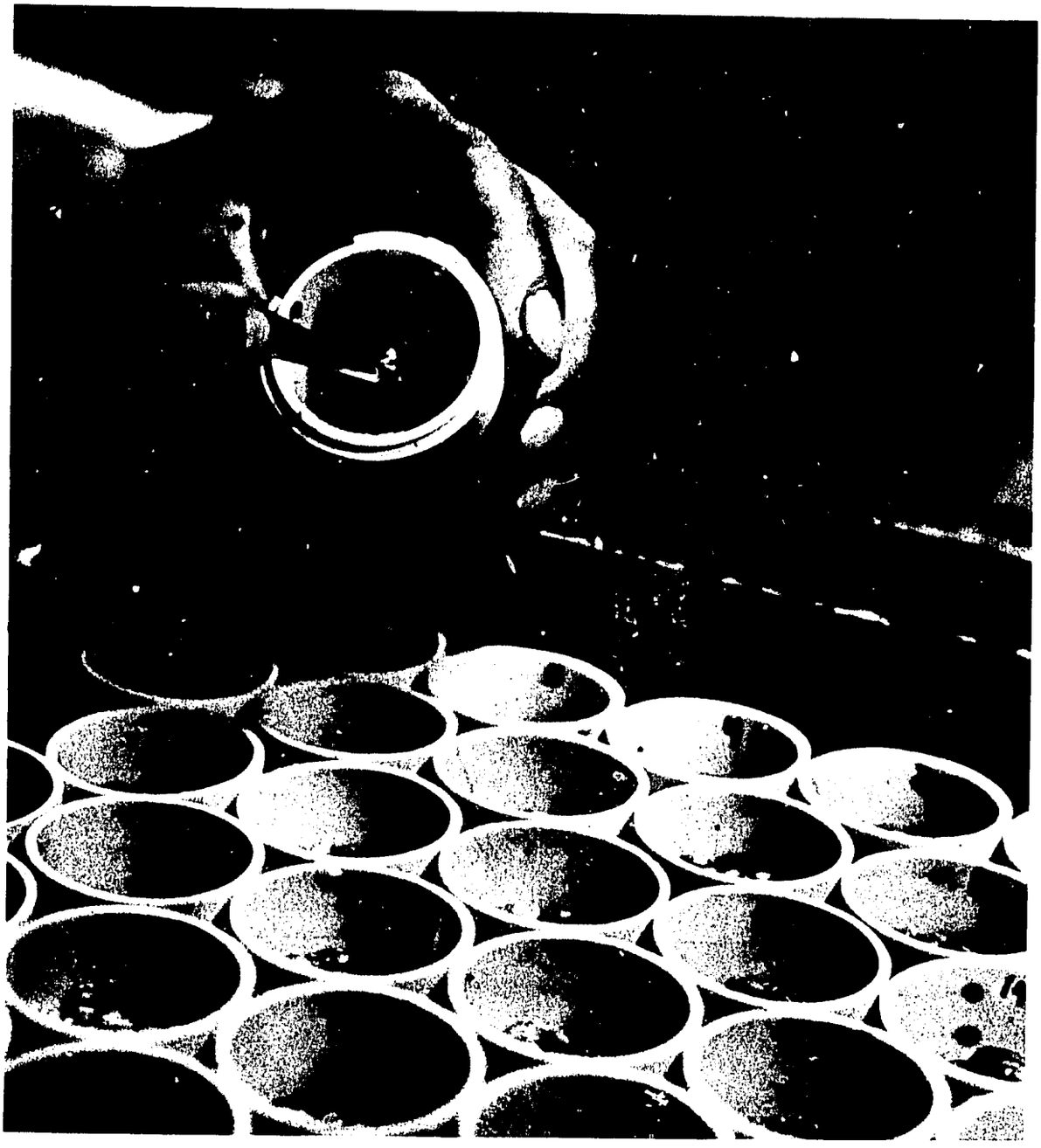
In 1974, about 3000 visitors were registered at CIMMYT, both individually and in groups. Many others visited the experiment stations, where they come to observe CIMMYT research work. A pamphlet was prepared giving detailed information for visitors to CIMMYT. This pamphlet is in English, Spanish, and French.

Part of the day's work for Gil Olmos, CIMMYT's visual aids specialist.

Library and bibliographic services

During the year, the list of journals to which CIMMYT subscribes was checked by a staff committee to assess the real value of many journals and periodicals to the scientists. Unneeded journals were eliminated. CIMMYT has arranged for the Commonwealth Agricultural Bureaux (United Kingdom) to publish a journal of abstracts dealing with quality protein maize. CAB routinely produces abstracts of articles published by 9000 agricultural journals in 46 languages. CAB will reproduce all abstracts dealing with quality protein maize, and CIMMYT will serve as distribution agent. Publication will start in 1975 with a retrospective issue covering 1960 to 1974, and thereafter issues will appear quarterly. About 1500 copies will be distributed to scientists and institutions. This service will be financed as part of the UNDP-CIMMYT project on quality protein maize. A similar publication of abstracts on triticale is planned.

special reports



Special report: **RESEARCH ON PLANT NUTRITION: THE NEEDS, CIMMYT'S ROLE**

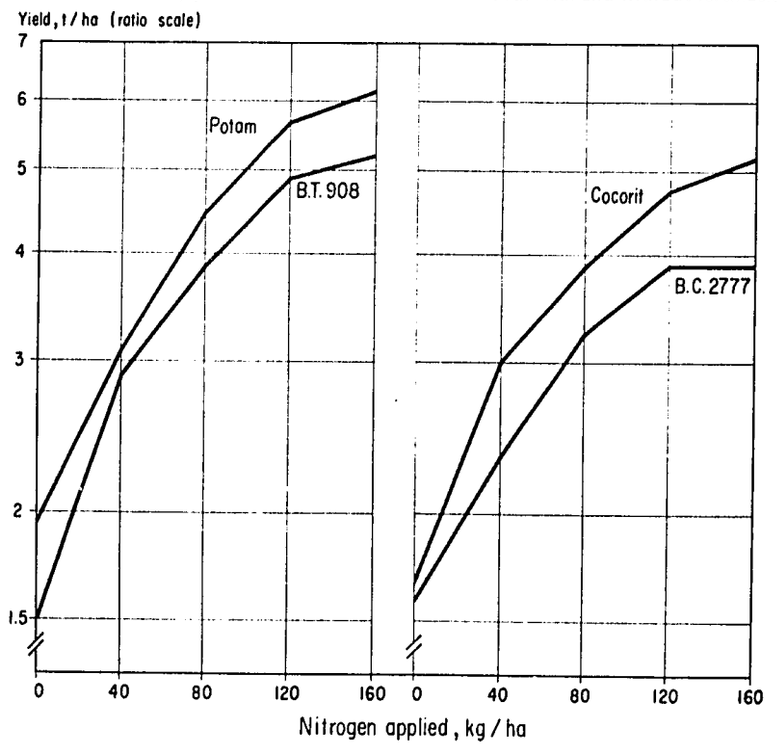
Doubling the world's cereal supply within the next 25 years must be achieved mainly by more intensive use of existing crop land. Land can be made more productive in various ways —irrigation, drainage, growing more than one crop a year— but the most important, worldwide, is the addition of plant nutrients and their efficient use.

Much of CIMMYT's research leads to more efficient use of plant nutrients regardless of whether the nutrients come from inorganic chemical fertilizer, organic sources of nutrients, or biological sources.

CIMMYT contributes to more efficient use of chemical fertilizer through research in Mexico mainly by development of more efficient cereal plants, that is, by breeding plants which place a higher percentage of their dry matter in grain. This type of plant makes efficient use of fertilizer. In addition CIMMYT's training programs for production agronomists from national programs include the design of fertilizer trials on farmers' fields, and the preparation of fertilizer recommendations to farmers. These activities are location-specific.

CIMMYT conducts no research on organic nutrients in Mexico, but CIMMYT staff members serving as short-term consultants to national programs, or posted to national programs, are assisting with several forms of research on organic nutrients.

In unirrigated trials in Morocco, Potam, a semi-dwarf bread wheat, and Cocorit, a semi-dwarf durum, yielded better than tall varieties both with and without fertilizer.



CIMMYT and its network of collaborating scientists are interested in three forms of biological nitrogen. One is the wheat-medicago rotation which is being tested in North Africa. The other two are in the area of "radical" research: nitrogen fixation by tropical grasses, which may prove relevant to tropical maize, and wide crosses between genera or plant families, which may extend the capability for nitrogen fixation to additional plants.

Breeding efficient cereal varieties. Agronomic testing has demonstrated that the new dwarf varieties are more efficient because they have a higher harvest index (greater proportion of grain to total plant dry weight) and they do not lodge (fall over) when increased quantities of nitrogen fertilizer and water are added during the growing season.

Some new dwarf varieties of wheat yield better than traditional tall varieties at all levels of fertility —even when no extra nitrogen is added, and even when grown under natural rainfall conditions, rather than under irrigation. The accompanying chart provides a typical example from trials in Morocco where a new dwarf wheat variety, Potam, is compared with a traditional tall wheat variety, B.T. 908, and a dwarf durum variety Cocorit, is compared with B.C. 2777, a tall traditional type.

All CIMMYT breeding programs are now intercrossing a large number of different varieties to provide a wide spectrum of genetic variability for selection in the subsequent segregating generations. Early segregating generations are grown with adequate moisture and high fertility to enable the breeders to select lines or families with a high potential for yield under favorable conditions. These selected lines are then distributed to collaborating breeding programs worldwide where they are further tested and selected for yield under different moisture and fertility conditions.

Influence of nitrogen on yield of two triticale varieties grown in the same experiment in northern Mexico, 1974.

Nitrogen applied, kg/ha	Yield, t/ha	
	UM x Tcl bulk	DR-44 x IRA
0	3.5	4.5
75	5.3	6.4
150	6.8	6.5
225	8.5	5.8

The CIMMYT testing system does not now, however, differentiate plants that are more efficient in taking up nutrients from the soil. By selecting for grain yield the breeders are almost certainly selecting for efficient use of the nutrients *after* absorption by the plant. In some trials where varieties have been grown on low fertility soils, one variety will produce an exceptional yield relative to the others under test, indicating an ability to take up more nutrients from the same soil. The table gives a recent example from the triticale program. A deeper root system probably explains why the variety DR-44 x IRA was able to reach a wider soil profile, and thus draw upon nutrients below the root zone of the other variety and show a higher yield with no nitrogen fertilizer.

These results underscore the need for a better understanding of the root system of cereals and the need to develop a technique to select varieties with more extensive or more rapidly growing root systems.

CIMMYT has recently been cooperating with scientists at Washington State University to test a mist growth chamber for measuring differences in root structure. Several other techniques are employed by plant scientists, including root washing, glass-sided root boxes, etc.

CIMMYT should in future give more emphasis to studies of root structure and its

effect on yield. One benefit will be to areas of the world where rapid leaching and denitrification are a problem.

Using nutrients below the root zone of existing varieties is likely to be of short-term benefit because these nutrients are not inexhaustible. But there are collateral benefits in tapping moisture deeper in the profile.

The present CIMMYT testing system also does not take sufficient account of problem soils, such as those that have excess salt content or the highly acid soils with their mineral toxicity problems. In such soils the efficiency of fertilizer uptake by most cereal varieties is poor.

One example is the acid soils of southern Brazil which cause severe aluminum toxicity in most CIMMYT wheats undergoing test. However, some genetic tolerance is evident —traditional local wheats of southern Brazil are more tolerant to aluminum than wheats selected in Mexico.

CIMMYT has been collaborating with a scientist at Oregon State University who has developed a simple screening technique for determining the degree of tolerance of cereal seedlings to aluminum. CIMMYT has now installed equipment to screen all CIMMYT parental varieties of bread wheat, durum wheat, and triticale for tolerance to aluminum toxicity.

A special program is being organized for

Norman Borlaug, left, director of CIMMYT's wheat program discusses new triticales with George Dion of the Canadian International Development Agency and Don Winkelmann, CIMMYT economist.

intercrossing aluminum-tolerant parents identified by the Oregon method and the best Mexican wheat varieties to provide segregating progeny for selection in Brazil by local scientists. This should enhance fertilizer efficiency in aluminum-toxic areas. Some triticales have been found to possess a 10-fold advantage over the average wheats for tolerance to aluminum.

We need better estimates of the location and extent of problem soils and their economic importance. Approaches to appropriate organizations are being made for assistance in this survey.

Factors that limit the expression of yield. Many factors, either individually or in combination, can reduce the yield of a cereal crop below its genetic potential, thus wasting fertilizer applied to the crop. Some examples are agronomic management (timing and amounts of fertilizer applied), pests and diseases, inadequate moisture.

Managing fertilizer application. Fertilizer is used efficiently if the timing and amounts applied match the nutrient requirements of the crop at each stage of the growing cycle. This requires knowledge of plant needs, plus estimates of the nutrients and moisture available in the soil, and, finally, a calculation of the additional fertilizer required to balance the nutrient uptake of the crop.

CIMMYT staff members assigned to national programs are helping to train production agronomists in these forecasting methods, and are participating in national fertilizer trials which will provide local knowledge needed to prepare fertilizer recommendations for farmers. In North Africa more than 100 fertilizer trials were made from 1968 through 1974 by local agronomists and CIMMYT staff. These trials have shown

—Some dwarf varieties are consistently superior in yield to the local varieties even without application of nitrogen.

—The previous cropping history of the experimental field (rotation and type of fallow) influences the amount of nitrogen required.

—In most situations there was no difference in yield between a single or split application of nitrogen. Occasionally however, it was beneficial to apply half the fertilizer at seeding time and half at the maximum tillering stage of growth. One benefit would be that the second application could be withheld in dry years. (Lack of benefit from splitting the nitrogen application suggests that the newer slow-release forms of nitrogen would offer little advantage in the winter season in North Africa. The reverse appears true in the high-rainfall areas of Africa where leaching can be a major problem. National programs are testing sulfur-coated urea on maize in tropical West Africa).

—In comparisons of chemical compounds containing nitrogen such as urea, ammonium nitritate, ammonium sulfate, and combinations in North Africa, there were no differences in yield of rainfed wheat grown in the winter.

Similar fertilizer management trials are needed in every major production region of the world, in fact in most national programs. The results are location specific —information obtained from fertilizer trials in Mexico is not reliable in other climatic regions. Moreover, the training of local agronomists to advise farmers can best be conducted within national programs, not outside the host country.

In CIMMYT's experience, training agronomists to advise on fertilizer efficiency should always include emphasis on soil preparation and weed control. Uneven land preparation tends to lower yields and thus waste fertilizer because of flooding in some areas and excessive drying in others. Poor seedbed preparation results in uneven stands. And weeds consume fertilizer intended for the crop.

Pests and diseases in relation to fertilizer efficiency. When pests and diseases infest a crop, they reduce the yield and thus waste fertilizer. A large part of CIMMYT's extensive breeding programs are devoted to the development of varieties and populations that carry genetic resistance to pests and diseases.

Another approach to pest control, and thus to greater fertilizer efficiency, is the disease and insect surveillance network for wheat. Since 1972 a network organized by a CIMMYT staff member in Beirut has operated from Morocco to India. Another surveillance system for wind-borne diseases began in the Andean Region of South America in 1973. When these networks provide early warning of new disease pathogens, they should make fertilizer use less risky for farmers throughout these regions.

Forecasting moisture by the season. A cereal crop requires a balance of nutrients and moisture to produce optimum amounts of grain. The farmer with access to irrigation can normally control the amounts of nutrients and moisture, and thus achieve efficient uptake of fertilizer. By contrast, the farmer who relies wholly upon rainfall must adjust his fertilizer application, up or down, according to the rainfall he expects during the season.

At present, the forecasting of rainfall for the total growing season is beyond man's knowledge. Dr. R.A. Fischer, CIMMYT wheat physiologist points out that "Reliable seasonal forecasts of rainfall would probably save more nitrogen than all the fertilizer research conceivable."

CIMMYT scientists and the staffs of the World Meteorological Organization and the U.S. National Aeronautical and Space Adminstration have recently discussed ways to improve longer-range rainfall and crop production predictions.

Organic sources of nutrients. Organic sources of nutrients are plant residues left in the soil by previous crops, thus providing nutrients to the next crop, and animal manures and human wastes incorporated in the soil.

Organic nutrients have some advantages and some limitations. A kilo of plant nutrients derived from organic sources provides the same benefits to a crop as a kilo of inorganic chemicals (N-P-K). Organic nutrients have some superiority over inorganic chemicals because manures and crop residues improve the tilth of the soil and increase the water-holding capacity, thus improving crop growth.

The disadvantages of most organic materials lie in their low content of plant nutrients and their great bulk for handling. For example, 1 ton of chemical fertilizer of a formula 10-10-10 contains 10% nitrogen, 10% phosphoric oxide, and 10% potassium oxide. Thus the farmer gets 300 kilos of plant nutrients while handling 1000 kilos of fertilizer. By contrast the amount of animal manure which provides the same nutrients might weigh 10 to 20 tons and be 100 times more bulky than chemical fertilizer. Because of weight and bulk, animal manures are generally used only on the farm or in the village area where the manure is produced.

In only a few countries in Eastern Asia are human wastes used widely in agriculture.

Some advanced countries in North America and Europe produce treated fertilizer from city sewage, but the problem of low percentage of nutrients, and great bulk, remains.

Crop residues can be incorporated into the soil (for example, by plowing under the straw of maize or wheat) as a routine part of the cropping cycle, but incorporation generally requires more power for cultivation than can be achieved with hand labor or draft animals.

Undoubtedly the world is wasting great quantities of plant nutrients by its present inability to use the available crop residues and animal or human wastes fully. CIMMYT does not conduct research on any form of organic nutrients in Mexico, but CIMMYT scientists assigned outside Mexico are collaborating with national programs that are studying ways to use organic nutrients better. In Nepal, scientists are examining the possibility of composting natural vegetation and applying the residues to crops in the Himalayan foothills where chemical fertilizer is not available. In Zaire, scientists are developing crop rotations of legumes and maize as possible substitutes for chemical fertilizer in interior provinces. In Algeria and Tunisia, a 2-year rotation of wheat and medicago promises to increase soil fertility from non-weedy crop residues.

CIMMYT believes that national programs should continue to investigate opportunities to apply organic nutrients that are economic under local labor and cropping practices. But organic nutrients are unlikely to provide a significant alternative to chemical fertilizers worldwide.

Biological sources of nitrogen. "Biological sources" of nitrogen refers to bacteria and fungi, living in the root zone of plants, that fix nitrogen from the air and deposit the nitrogen in the form of nitrates in the soil or within the root structure where the nutrients can be taken up by the plant for its own growth.

Rhyzobium bacteria in legume root nodules are a major source of nitrogen fixation. There are also free-living, nitrogen-fixing bacteria in the soil, sometimes in association with the roots of other plants such as rice, sugarcane, and some tropical grasses. One British scientist has estimated that nitrogen "fixed" by bacteria and fungi in the production of economic crops equals five times the total nitrogen manufactured in the form of nitrogen fertilizer.

CIMMYT is interested in three sources of biological nitrogen: Use of legumes in rotation with wheat in North Africa, nitrogen fixation associated with tropical grasses, and wide crosses between plant genera which might introduce nitrogen fixation benefits to more crops.

Wheat-medicago rotation. CIMMYT scientists in Tunisia and Algeria are helping the national wheat programs introduce legumes into their wheat rotation. Varieties of medicago (an annual pasture legume species) are being tested in a 2-year rotation with wheat. Medicago would replace the present 1-year weed fallow in the rotation. Weeds now provide poor grazing for sheep, deplete soil moisture and fertility, and leave a residue of weed seeds to infest the following wheat crop.

The work in North Africa has been stimulated by the success of a similar program in southern Australia during the last 40 years. Twenty million hectares in Australia have been improved by seeding "medics" and subterranean clover in rotation with wheat.

Several thousand hectares of medics are now under trial in North Africa. Some CIMMYT scientists believe the system is likely to cause a greater agricultural revolution in the region than the introduction of new dwarf wheat varieties.

In 1974, CIMMYT assigned an Australian consultant, Mr. E.D. Carter, to study the potential of the wheat-medicago rotation in Algeria. He found that in the cereal zone of Algeria up to 5 million hectares could be improved by replacing the existing weed fallow with self-regenerating annual medicago species. If properly managed, medicago pastures in a wheat-medicago rotation would annually provide 60 kg/ha of nitrogen, improve the soil's capacity to hold water, increase levels of soil organic matter, reduce levels of weed seeds in the soil, and provide

enough additional forage to support an extra 10 million sheep (or the equivalent in other livestock). The added nitrogen, improved soil structure and water-holding capacity, and lowered weed competition could double wheat yields. An additional benefit is that increasing the livestock potential of the cereal zone could reduce the grazing pressure in the steppe zone. Young livestock could be sent to the cereal zone for fattening.

Changing to wheat-medicago rotation on a large scale will require several major investments. First, implements that permit rapid shallow tillage, rapid sowing, and leveling of the seedbed must be produced. Second, greater amounts of soluble phosphate fertilizer must be made available. Third, 30,000 tons of medicago seed must be grown or imported. Fourth, personnel from farm machinery operators to research and extension personnel must be widely trained.

Much of the Mediterranean area might benefit from this system of farming once its effectiveness is demonstrated in the Maghreb.

Nitrogen fixation associated with tropical grasses. Recent work in Brazil by Dr. Johanna Dobereiner, and in Nigeria, France, England, and the USA by other workers, has suggested that nitrogen is produced by mutual assistance between bacteria and tropical grass roots. Dr. Dobereiner believes that bacteria live inside the cortex of the root (the outer covering) in some tropical grasses and approximate a primitive legume-type of symbiotic (mutually beneficial) association. Some of these pasture grasses "produce" significant quantities of organic nitrogen.

In addition, greenhouse experiments in France and the USA have shown high nitrogen-fixing activity in association between bacteria and maize roots. Maize, like all cereals, is a member of the grass family.

It may be time to survey maize varieties in hope of finding some with high nitrogen-fixing capacity, and to look at the agronomic practices which produce environmental conditions more favorable to growth and nitrogen fixation of the organisms concerned. This research could have revolutionary potential over the next few decades, leading to the possible reduction in use of nitrogen fertilizers on tropical cereals.

Wide crosses between plant genera. CIMMYT scientists in collaboration with Dr. Lynn Bates at Kansas State University have embarked on a wide-cross program to combine different genera of cereals. Dr. Bates is using immunosuppressant drugs to break down the incompatibility between plant genera. Initial tests at CIMMYT have been promising.

The crossing of plant genera has begun with the crossing of near relatives, such as wheat x rye (which already produced triticale) or wheat x barley (now in the greenhouse stage at CIMMYT). It probably will move to more distant relatives, such as maize x sorghum, and ultimately crosses between families such as wheat x soybean, will be attempted.

Today, transferring the nitrogenase enzyme system for legumes to cereals must be regarded as a remote possibility, approachable only by a long series of steps, each step providing a better knowledge of the barriers between plant families. The possibility of having legume-type roots on the base of wheat plant was once considered a dream. Now plant scientists are less skeptical following three revolutionary developments in the last 5 years:

—Transfer of genetic information from bacteria to plant cells.

—Establishing of symbiosis between *rhizobium* and plant cells *in vitro.*

—Transfer of nitrogenase from nitrogen-fixing Klebsiella to non-fixing mutants, and to another bacterium, *E. coli.*

CIMMYT staff members feel the idea is worth exploring with a small part of CIMMYT's research resources. The work would require at least 20 to 25 years.

Conclusion. Studies of root structures, as an approach to moisture stress and fertilizer efficiency, and studies of nitrogen fixation in tropical grasses and their application to maize are two areas of possible expansion. As a substitute for staff work on either of these topics, CIMMYT may seek collaborative research projects in a research center possibly in Europe or North America.

" Radical" research such as wide crosses between plant genera may require 25 years to achieve a crop ready for commercial use. The present large-scale research on triticale (wheat x rye cross) is now in its 21st year at the University of Manitoba (Canada) and its 11th year at CIMMYT, and triticale is beginning to achieve commercial adoption.

Development of a commercial maize crop carrying the nitrogen fixing characteristic could be considered a development comparable to a wide cross, requiring 25 years from greenhouse to commercial use.

To sum up, the highest priority in plant nutrition research at CIMMYT is the conventional breeding of more efficient cereal plants, and development of related agronomic practices. We can justify no more than 5 percent of our resources for radical research such as wide crosses. This time and money permits CIMMYT a leadership role for promoting similar work by other institutions. And it is the work of other institutions that is likely to achieve a scientific breakthrough. Once the breakthrough has been achieved, CIMMYT is ready to invest substantial resources (as with triticale) to bring new technology into commercial use.

In Nepal, Mr. S.M. Gurung, a farmer, right, and Mr. Hem Thapa, maize scientist, left, show local farmers the results of feeding pigs opaque-2 maize.

Special report: NEW FACILITIES TO SUPPORT THE WIDE CROSS PROGRAM

In 1974 CIMMYT created a new cytogenetic laboratory for wide cross work in both maize and wheat. The staff will consist of a head of the laboratory (a visiting scientist in cytogenetics, initially provided by Plant Breeding Institute, Cambridge University); two postdoctoral fellows, one each for wide crosses of wheat and maize; and technicians specializing in embryo culture of maize and wheat.

The new unit will have office space and laboratory benches in the El Batan laboratory building, one new greenhouse, and space for microscopes for cytology analysis.

The bread wheat, triticale, and maize programs will each continue to provide one staff scientist for wide cross work.

In authorizing the cytology laboratory, the CIMMYT board of trustees established the following guidelines:

—Wide cross work should be undertaken on an exploratory basis for 2 years, 1974 and 1975, followed by a critical review of progress.

—Both maize and wheat programs should maintain their separate wide cross work, being serviced by a common cytogenetics laboratory.

—Necessary staff, as far as possible, should be provided by visiting scientists and postdoctoral fellows, to minimize long term commitments.

—Total application of resources should not exceed 5% of CIMMYT's core budget or staff time.

--CIMMYT's work should serve as catalyst to encourage other institutions to begin wide crosses with maize and wheat.

Special report: WIDE ADAPTATION

As plants have evolved and spread into new environments over long periods of time, they have developed mechanisms that enable them to adapt to their new surroundings.

Adaptation means the ability of plants to survive and multiply. As plant species migrate closer to the desert, only the drought-resistant plants survive; as they move into higher latitudes, only the early maturing and winterhardy plants survive. This process of "survival of the fittest" tends to favor plants that are specifically adapted to the particular environment in which they grow.

Various mechanisms enable plants to survive in harsh environments. For example, annual plants germinate, grow, and mature during the time of the year when the conditions favor reproduction —moist soil, warm temperatures, and adequate sunlight. When the conditions are unfavorable— drought excessive heat or cold— the plants survive as seed ready to germinate when conditions are again favorable.

Plant processes are coordinated with growth conditions through the evolution of biochemical and physiological control mechanisms. For example, seeds of many plants that are adapted to desert conditions require prolonged leaching of germination-inhibiting chemicals before they can germinate and grow. This mechanism prevents premature growth after a short rain in the middle of the dry season.

In plants that must survive long cold winters and grow and set seed in short summers, two control mechanisms are common: First, some plants require long days —as much as 20 hours of daylight— before they will flower and reproduce. These are known as daylength-sensitive plants. If such plants

are grown in the tropics many cannot flower and set seed, because the days are too short (daylight lasts only about 12 hours throughout the year at the Equator). Second, some plants require exposure to sub-freezing temperatures before they can initiate the reproductive phases and set seed. This cold conditioning is called "vernalization."

Different species and varieties of plants differ in the degree of expression of these and other control factors. The intensity ranges from nil to very strong, depending largely on the environment in which they evolved or were bred.

Nikolai Vavilov, the Russian plant scientist said that "Plant breeding is evolution directed by the will of man." This is particularly true when breeding for crop adaptation. Man is able to modify several parts of the cereal plant-environment system, he changes nature's prime objective from plant survival to maximum production of seed and he changes the plant's environment by supplying soil moisture through irrigation, by adding plant nutrients to the soil, and by controlling weeds, diseases, and pests.

Man is also able to modify and blend a wide array of plant characteristics by hybridization. He is not governed by the same rules as nature. For example, man, rather than the plant, can decide when seeds should germinate. In the higher latitudes, man can plant seed of daylength-neutral plants that have little or no cold requirement and obtain high yields of grain of he chooses the correct planting time.

Cereal breeders providing improved varieties for their own country, or specific region within their country, have concentrated on selecting lines specifically adapted to the environment of the region. Sometimes they have selected varieties that have sufficiently wide adaptability to allow the plants to successfully compensate for wide seasonal variability from year to year.

The creation of international agricultural research institutes like CIMMYT has added a new dimension for plant breeders —the breeding of crop plants adapted to a wide range of environments in many different countries.

CIMMYT cereal breeders believe that it is not possible for them to breed varieties specifically adapted to every micro-environment where maize or wheat is grown. Instead they make large numbers of crosses from varieties originating in many parts of the world. Then segregating populations or large numbers of selected lines are distributed to breeders in over 80 countries so they can choose the material best suited to their local needs. In addition the methods used for breeding these populations are designed to produce varieties that have wide adaptability. The presently used techniques were originated in the late 1940's by Dr. Norman E. Borlaug. He pioneered on an extensive basis the growing of two generations of all wheat breeding material each year. This was accomplished by growing the segregating populations during the winter —the commercial wheat crop season— in Sonora, Mexico, at sea level at 27°N. A second generation was obtained by planting during mid-May at 2600 m. at 19°N near Toluca, Mexico. The Toluca site is characterized by heavy rainfall throughout the season and cool temperatures. Consequently, severe epidemics of both stem and stripe rust develop every year.

This procedure not only halved the time necessary to breed new varieties, but Dr. Borlaug found that the resulting wheat lines were daylength insensitive and could be grown successfully in many different environments in the world from Alaska to the tropics under irrigation or natural rainfall. Thus they were widely adapted and have greater utility.

This practice of selecting successive gener-

ations under different environmental conditions has been extended to include a wider range of environments that exist in Mexico (by collaboration with breeders in other countries) and also to include all the cereal crops handled by CIMMYT (bread wheat, durum wheat, barley, triticale, maize, and cold-tolerant sorghum). The technique has proved successful for all these crops.

During recent years, many lines and families have also been tested simultaneously in a wide range of environments by means of the international screening nurseries. These nurseries permit the adaptability of the lines under test to be evaluated. The data is particularly valuable for testing disease susceptibility --the most important current limitation on the range of adaptability of some otherwise superior germ plasm.

CIMMYT scientists believe that breeding of widely adapted crop lines at an international center has many advantages:

–Superior crop lines can be used immediately over broad areas to increase food output.

–Since developing countries still lack adequately trained breeders to produce varieties for all regions of their countries, farmers can begin to grow improved varieties by selecting one or two superior lines from the international nurseries distributed from CIMMYT.

–Widely adapted varieties reduce the effect of seasonal climatic fluctuations, soil differences, etc.

--New sources of desirable characteristics such as disease and insect resistance and improved nutritional quality can be included in a few widely adapted lines and have a quick, wide-spread effect.

–When a desirable characteristics is genetically complex, it can be bred into a few widely adapted lines, but it would be almost impossible to breed it into a large number of specifically adapted varieties (an example is hard endosperm forms of opaque-2 maize for which numerous modifier genes are necessary).

Although techniques for producing widely adapted cereals have been successful, they are crude –only after testing does the breeder know if the selected lines are widely adapted. Moreover, while the scientific basis of aspects of wide adaptation such as day-length sensitivity and cold requirement are well understood, these account for only some of the reason for adaptability.

Many physiologists, biochemists, and geneticists are studying plant adaptability, but usually only with single plants or with relatively uniform genetic lines. CIMMYT is collaborating with a number of these scientists to apply their findings to large segregating populations.

During 1974 Dr. D.E. Byth of the University of Queensland (Australia) spent some time at CIMMYT as a visiting scientist using CIMMYT nursery data to test a biometrical technique for measuring adaptability. The technique involves numerical classification or pattern analysis methods which have been used in botanical research for a number of years, but which, until recently, have not been applied to problems of varietal adaptation.

The principal advantage of the technique is that it uses field data to provide a biologically meaningful method of identifying groups of varieties that respond similarly to a range of different environments. This technique shows promise as a tool for selection of varieties or lines with different patterns of adaptation, and for the identification of the physiological factors concerned.

CIMMYT scientists will continue to breed for wide adaptability and encourage research scientists worldwide to continue their fundamental research into this basic aspect of crop behavior.

At CIMMYT's in-house review the entire scientific staff visits both wheat and maize experimental plots.

Special report: BASIC RESEARCH CONDUCTED IN COOPERATION WITH CIMMYT

The need for basic research to support rapid progress grows as CIMMYT's production-oriented research programs expand and become more complex. CIMMYT believes that more basic research can best be conducted with scientific collaborators in universities and centers specifically equipped for this work. No more than 5 percent of CIMMYT's time and money is devoted to "radical research" such as wide crosses. This investment only permits CIMMYT to encourage and guide similar work in other institutions. A scientific breakthrough is more likely to occur as a result of work at other institutions.

The research of some of the cooperating groups is financed by agencies that also support CIMMYT. Many projects, however, are supported by local sources. The links with CIMMYT vary from formal contact arrangements to informal, scientist-to-scientist cooperation. All forms are effective.

The following examples, while not all-inclusive, indicate the scope of the collaboration and the benefit being derived by CIMMYT. They also illustrate how CIMMYT acts a vehicle for adapting basic research to the needs of farmers.

Wheat. Scientists in the USA cooperate with CIMMYT in many research projects on wheat. At the University of Nebraska, scientists are surveying the world collection of wheat for varieties with a higher protein or better quality protein. Several superior varieties identified at Nebraska are currently being incorporated into the CIMMYT wheat breeding gene-pool. The Nebraska group has also identified winter wheat lines that

have proved to have outstanding characteristics when tested in the International Winter Wheat Nursery. The U.S. Agency for International Development is funding the work at Nebraska.

For the past 4 years, scientists from CIMMYT, the University of California at Davis, Oregon State University, and Turkey, with funds from the Rockefeller Foundation, have collaborated in a project to produce new germ plasm by crossing winter wheats with spring wheats. Some lines already exhibit superior resistance to disease, drought, and cold.

Since CIMMYT was founded it has drawn heavily on research and germ plasm from the U.S. Department of Agriculture's world wheat collection. This is CIMMYT's main source of genetic variability. The USDA Rust Laboratory supplies data to CIMMYT from its local research and the International Rust Nursery. CIMMYT has obtained sources of disease resistance from this nursery and has used the nursery as a valuable aid for testing breeding lines for disease resistance.

At Washington State University, a new technique for studying wheat root systems has been developed. CIMMYT scientists have provided seed for testing in hope of finding a simple technique for selecting wheats with more efficient root systems.

The Rockefeller Foundation is financing work on rooting behavior and nematode control in wheat at the University of California, Riverside. A graduate student from that institution is working in Mexico with CIMMYT scientists on drought-simulation field experiments.

Cornell University scientists are studying the photosynthetic efficiency of leaves in relation to yield in wheat in collaboration with CIMMYT and with funds from the Rockefeller Foundation.

A U.S. Department of Agriculture expert has investigated, for CIMMYT, the damage the hessian fly does to wheat in North Africa. He has also provided differential varieties to identify the biotypes of the fly present in North Africa.

Several techniques used in CIMMYT's wheat quality laboratory originated at universities in Washington, Kansas, and Nebraska.

CIMMYT scientists have been collaborating with Oregon State University which developed a simple method for measuring the tolerance of wheat seedlings to aluminum. Mexican wheat varieties are susceptible to aluminum toxicity in the highly acid soils of southern Brazil. CIMMYT has now installed equipment to screen all parental wheat varieties with the ultimate aim of breeding aluminum-tolerant wheats for use in Brazil.

In Britain, the Ministry of Overseas Development (ODM) has made a grant to CIMMYT to expand cooperation with British wheat scientists in 1975.

At the University of Reading, effects of temperature and daylength on the development of the apical meristem (growing point) of wheat have been studied in growth chambers. A student from Reading is doing M.Sc. thesis research on wheat growth at CIMMYT under an ODM grant.

Groups at Wye College and the Plant Breeding Institute, Cambridge, are studying the hormonal basis of dwarfing in wheat, in cooperation with CIMMYT breeders. Different types of dwarfing genes have been identified together with their mode of action.

Other scientists at the Plant Breeding Institute, Cambridge, have intercrossed CIMMYT spring wheats with Northern European spring and winter wheats to widen the range of germ plasm available to both research groups. This cooperation is providing CIMMYT breeders and their worldwide collaborators with access to the high yielding and disease-resistant germ plasm of Europe.

In Australia, all cooperation with CIMMYT is financed by local sources. Scientists at the University of Latrobe, Australian National University, and the Commonwealth Scientific and Industrial Research Organization (CSIRO), Canberra, are developing a wheat crop model using the latest scientific theories. CIMMYT supplies field data for develop ng and testing the model. CIMMYT will benefit from new ideas that emanate from this type of research.

Three CIMMYT visiting scientists, from University of Sydney, University of New England, and University of Queensland, have attempted to analyze the results of the International Spring Wheat Yield Nurseries in different ways to measure variety adaptation. One method may give CIMMYT wheat breeders a powerful tool for selecting for adaptability.

A research group at CSIRO, Canberra, concerned with the physiology of adaptation, is anxious for closer association with CIMMYT. They have one of the world's most advanced phytotrons and CIMMYT welcomes the opportunity to cooperate.

The Wheat Research Institute, Wagga, and the Queensland Wheat Research Institute have carried out research and breeding with CIMMYT's dwarf wheats. They have incorporated varying degrees of insensitivity to daylength and cold. These materials have been of value to CIMMYT breeders.

A scientist at the University of Sydney has provided new sources of rust resistance to CIMMYT which have been used to improve the adaptation and rust resistance of CIMMYT wheats.

In Germany, wheat scientists from Weihenstephan will be exchanging breeding material with CIMMYT as the result of a recent agreement.

A researcher in West Berlin has incorporated CIMMYT male-sterile restorer genes into European winter wheats and is providing performance data to show that they are the best of several sources of restorer genes.

In the Netherlands, a scientist at Wageningen is studying the performance of Mexican dwarf wheats alongside European wheats in the field and in a phytotron. The results are helping to explain environmental influences on grain yield and their interaction with genotypes.

The Commission for Agricultural Meteorology of the World Meteorology Organization and the Crop Ecology and Genetic Resources Unit of FAO began an international experiment in 1972 to gather crop and weather data in relation to development patterns of wheat varieties. CIMMYT has supplied the seed for the project's annual trials. Data from this experiment is being made fully available to CIMMYT. Because reliable weather data is collected, the results should improve understanding of the wheat plant's development in different environments.

The insect and disease surveillance network, which operates from Morocco to India, is an outstanding example of multinational collaboration. The network warns of imminent outbreaks. A CIMMYT wheat patholgist coordinates this program. As part of this service, samples of diseased plant tissues are submitted to experts in Netherlands, Israel, West Germany, Yugoslavia, Egypt, and Pakistan for race identification.

The Directorate International Technical Aid (DITH), Netherlands, has given a Dutch scientist a grant to expand his international service to identify stripe rust races in collaboration with CIMMYT. Part of this grant will also help Tel Aviv University do research and identification studies on *Septoria tritici*, a fungus of wheat.

Barley. Although the barley breeding program at CIMMYY is only 3 years old, already there are several collaborative research programs with scientists in other countries.

Under a grant from the U.S. Agency for

International Development, Montana State University is doing basic research and breeding for countries with dry agricultural areas. This research also will help CIMMYT by providing parental barley material with desirable agronomic, physiologic, disease-resistance, and quality characteristics.

A Danish scientist has been advising CIMMYT on methods for measuring protein quality in barley, and he has also provided genetic material to CIMMYT.

A CIMMYT visiting scientist from the Waite Agricultural Research Institute, Australia, tested starch-gel and acrylamide-gel electrophoretic techniques for selecting barleys that have high quality protein.

A German scientist whose speciality is hull-less barleys and who has recently started working with varieties that have high quality protein has agreed to exchange breeding material with CIMMYT.

Another German scientist is using mutation techniques to reduce the susceptibility of hull-less barleys to threshing damage. He is selecting embryos that are deeper-set in the endosperm. This material could be of great value for improving the barley food crop.

Triticale. Like any wide cross between different genera, triticale has suffered from sterility, chromosome aberrations, grain shrivelling, uncommon disease problems, etc. Scientists from several countries and CIMMYT are collaborating to find solutions.

In Canada, the Canadian International Development Agency and the International Development Research Center (IDRC) support CIMMYT's triticale program. In addition these organizations finance more basic research in Canadian institutions to assist the triticale network. IDRC also has groups of scientific experts which advise CIMMYT on the possible commercial and industrial uses of triticale and methods of determining nutritional quality in triticale.

Cytogenetic studies at the University of Manitoba are elucidating the origin and consequences of chromosome malfunctions in some triticales. This work is coupled with the creation of some new primary triticales. Biochemical studies at the University of Manitoba have shown that one cause of shrivelling is amylase activity in the developing endosperm which leads to degradation of starch granules even while they are forming. Degradation of starch granules is normally associated with germination of the grain.

Recently the University of Guelph started a winter rye breeding program to provide the triticale network with a wide range of genetic variability for creating primary triticales.

At the Canadian Department of Agriculture, studies of the physiology and histology of triticale seeds have differentiated two distinct sites of shrivelling, the seed coat and the endosperm. This work has been valuable to CIMMYT triticale breeders.

In the USA, a scientist attached to Oregon State University has been studying different species of wheats crossed with rye. Testing is being conducted in collaboration with CIMMYT.

At the University of California, Davis, a researcher is breeding and testing triticale. He also supervises a high elevation nursery in California where triticales from CIMMYT, University of Manitoba, and the University of California are being tested under conditions which permit both spring and winter types to be identified. Another researcher is studying the cytology and cytogenetics of triticales from several sources including CIMMYT. A graduate student is studying the causes of seed shrivelling in triticale as thesis research.

The industrial uses of triticale are being investigated at Texas Technical University. Little other effort has been given to this area of research so this collaboration is par-

ticularly valuable to CIMMYT.

In Britain, one scientist has been producing primary triticales using elite European winter wheats that should substantially expand the basic germ plasm pool of triticale. The selections are made both in Britain and Mexico.

Scientists at the Plant Breeding Institute (PBI) Cambridge, are studying hybrid necrosis, a genetic problem in triticale. When certain parents are cross pollinated, the progeny exhibit necrotic lesions on the leaves and eventually die. Unfortunately, some of the best wheat parent varieties appear to carry the undesirable feature.

A study at PBI of developing endosperm cells of triticale has shown that the rye chromosomes divide more slowly than the wheat chromosomes and occasionally the slow division interferes with formation of the cell wall. As a result, large aggregations of chromosomes occur which ultimately break down and leave a large hole in the endosperm, providing another cause of grain shrivelling.

Scientists at the Commonwealth Mycology Institute, London, and Department of Agriculture and Fisheries for Scotland have helped CIMMYT identify diseases found on triticale in Mexico and other countries. Since triticale is a new crop species and since it has germ plasm from both wheat and rye in its cells, some triticale disease symptoms are unfamiliar to CIMMYT scientists.

In Sweden a scientist at the Institute of Genetics has concentrated his research on octoploid triticale. His materials, advice, and scientific skills have been made available freely to CIMMYT since the inception of its triticale program.

Another Swedish scientist refined a new chromosome staining technique and while a visiting postdoctoral fellow at CIMMYT for a year he was able to stain and identify rye chromosomes in various triticale stains. A series of type strains based on chromosome composition was set up. The type strains range from triticale having a complete set of rye chromosomes (seven pairs) to strains having only one pair. This information is vital to CIMMYT to ensure rapid progress.

A scientist at Lund has used high energy radiation and chemical mutagens to treat some CIMMYT triticale. CIMMYT has grown the treated seed to look for mutant lines with plump seed. No such lines have been obtained from this project.

The main type of collaboration with other countries has been the interchange of different types of genetic variability. For example, a scientist at Freie University, West Germany, is providing triticale from crosses of a wide range of wheat and rye species. He is the only scientist producing tetraploid triticale.

At another German institution, the University of Hohenheim, scientists are selecting fertile, short-strawed, high yielding inbred lines of rye for the production of hybrid rye. A number of these lines and the original parental materials will be crossed with wheat at CIMMYT to produce primary triticales. Because the wheat and rye chromosome components of a triticale behave as inbreds, the inclusion of fertile inbreds of rye in triticale may produce a cytologically more stable plant.

The Vegetable Crops Research Institute, Hungary, has produced winter triticale with the "Tom thumb" dwarf gene, a different source of dwarfing than that used in CIMMYT material which contains the "Norin" dwarf genes. Studies at the institute have shown that the CIMMYT triticale strain PM-13 has better resistance to frost in Hungary than some winter wheats, even though it is a daylength insensitive spring type.

The National Institute of Agricultural Research, Spain, has been working on triti-

cale for many years and has produced both hexaploid and octaploid types.

Haile Selassie University in Ethiopia is experimenting with the use of triticale as a substitute for tef (*Eragrostis tef*), a local food grain. Mixtures of tef and triticale, with some modification of the cooking procedure, are producing acceptable injera, an Ethiopian "bread". This research is financed by IDRC in collaboration with CIMMYT.

In Mexico a researcher at the National University has been studying phytotoxins produced by fungi that infect stored triticale grain, and has identified genetic differences in the susceptibility of strains of triticale to fungi of stored grain.

Maize. The CIMMYT maize staff has collaborated with maize scientists in the USA for many years. Some examples:

Purdue University, with financial support from USAID, is studying the genetics and physiological adaptation of maize with high quality protein. One scientist is investigating the modifier genes that influence the hardness of the grain associated with quality protein gene, opaque-2. These studies may lead to more efficient methods of breeding quality protein maize with hard endosperm. Another scientist exchanges maize lines and data with CIMMYT for studies of growth patterns in relation to weather.

Cornell University is testing and helping to select CIMMYT maize populations resistant to European corn borer. A researcher there has shown that in U.S. germ plasm the content of the chemical substance responsible for resistance (DIMBOA) in first generation borer-resistant lines is about 10 times greater than that found in susceptible lines. In contrast he has shown that resistant families from one CIMMYT population have low DIMBOA content. This has suggested that in the CIMMYT material other mechanisms are involved in providing resistance to borers.

The University of Kentucky has analyzed data from CIMMYT's maize growth analysis studies using a crop growth simulation model. This work helps explain what happens during the various growth phases of tropical maize.

CIMMYT is collaborating with the University of Colorado, FAO, and maize germ plasm banks in Mexico, Peru, Colombia, Brazil, Argentina, and the USA in developing a storage and retrieval system for information on maize germ plasm. Funds are being provided in part through the International Board for Plant Genetic Resources. The IBM Research Laboratory in Mexico City is providing the services of a research scientist and computer time free of charge for 3 months to install and test the system.

Initial contacts have been made between CIMMYT and the Boyce Thompson Institute for Plant Research Inc., New York, for a joint project. CIMMYT physiologists have found that tropical maize accumulates dry weight at about the same rate as the highly efficient hybrids of the U.S. cornbelt, however, less of the dry weight accumulates in the form of grain, so tropical maizes are commercially less efficient. Scientists from the Boyce Thompson Institute are interested in the growth regulating control of grain storage potential in tropical maize. A better understanding of this process could open the way to breeding tropical maize with greatly improved yield potential.

In Britain, faculty members at Reading University and University of Nottingham are using data supplied from CIMMYT physiological trials and yield trials to develop a mathematical model of how a maize crop functions and yields.

An investigator from the Tropical Products Institute, London, is working at CIMMYT with financial support from ODM on the relation of field infection to storage infestation of maize, and on the relative

importance of endosperm hardness and protein quality in determining the degree of infestation of stored maize.

A researcher at the Plant Breeding Institute, Cambridge, coordinates the Northern Maize Committee of the Maize and Sorghum Section of Eucarpia (an organization of European plant breeders). He will visit CIMMYT in 1975 to develop a link between CIMMYT and the maize breeders of Europe.

Many nations are interested in earlier-maturing maize to fit into double or multiple cropping systems. A scientist at the University of Hohenheim, West Germany, is providing valuable information on high density selection methods and maize types with early maturity and superior cold tolerance. A scientist at the University of Giessen has been selecting early maturing maize originating in Poland and Yugoslavia. His research findings and material have been made available to CIMMYT.

CIMMYT has contracted with scientists at the University of the Philippines at Los Baños to breed maize varieties that are resistant to downy mildew for worldwide distribution. Although this disease is mainly a problem in Southeast Asia, it is becoming more important in Australia, USA, Mexico, and South America.

At the International Institute of Tropical Agriculture, Nigeria, a scientist is making fundamental studies of maize root systems under normal and high soil temperatures. High soil temperatures have been shown to adversely affect the emergence of the maize seedling from the soil.

Quality protein. To develop chemical tests and animal nutrition tests for measuring the protein quality of maize, sorghum, triticale, and barley lines, CIMMYT is involved in several collaborative programs.

Purdue University, with funds provided by USAID, and CIMMYT, funded by United Nations Development Program, have developed several biochemical techniques for measuring amino acids as an indicator of protein nutritional quality. These techniques are

Each year a small mountain of seed is sent around the world for nursery trials distributed by CIMMYT.

now widely used by cereal workers throughout the world.

To compare the accuracy of various animal feeding trials, researchers at University of Manitoba, Michigan State University, Washington State University, Pennsylvania State University, Arizona State University, Purdue University, Instituto de Nutrición de Centro América y Panamá (INCAP), Centro Internacional de Agricultura Tropical, and the Mexican National Institute of Animal Research (INIP) have conducted tests with such test animals as rats, voles, chicks, turkeys, pigs, and humans, using grain samples provided by CIMMYT.

Recently CIMMYT arranged with INCAP in Guatemala and INIP in Mexico to carry out collaborative research and testing using rat, pig, and human assays of advanced breeding material of maize, triticale, barley, and sorghum.

Radical research. A scientist at Kansas State University (USA) and CIMMYT have embarked on a program to combine different genera of cereals through the use of immunosuppressant drugs to break down the incompatibility barriers between plant genera. CIMMYT has made promising initial tests of crosses between wheat and barley and between rye and barley.

Under a grant from the British Overseas Development Ministry, cytological aberrations that occur in wide crosses will be studied at CIMMYT by a cytogeneticist from the Plant Breeding Institute, Cambridge. Two British post doctoral scientists will work with the program.

A British scientist from the Aberystwyth Plant Breeding Station is field testing the technique for wide crossing.

Crosses of maize with tripsacum are being studied in the USA at the University of Illinois in collaboration with CIMMYT and crosses of maize and teosinte are being studied at the University of Chicago.

These activities have expanded greatly in the past 2 years and seem likely to continue to expand in the foreseeable future.

Special report CIMMYT'S GERM PLASM SERVICES

CIMMYT offers various germ plasm services to scientists throughout the world.

Maize germ plasm. Over the last 30 years, CIMMYT and its predecessor agencies in cooperation with the government of Mexico have acquired 12,000 accessions of maize (*Zea mays* L.) and near relatives of maize from 46 countries. Since 1972 CIMMYT has maintained a tripsacum garden containing all known species of this wild perennial relative of maize. CIMMYT's maize collection is the largest in the world.

Seed in sample quantities is supplied to scientists without charge. CIMMYT asks a return of data from testing by collaborators.

Seed in the collection is kept viable by periodic replanting, and by storage at low temperature in fireproof facilities at CIMMYT headquarters.

Field tests of part of the CIMMYT collection are made in replicated field trials each year, and data are maintained on economic characteristics of the accessions. CIMMYT is preparing to publish an open-ended catalog of these data, in collaboration with Dr. David Rogers of FAO, and the University of Colorado (USA). Dr. Rogers is developing a standard system for cataloging all major collections of maize germ plasm.

Duplicate seed of CIMMYT accessions will be placed in long term storage at the U.S. National Seed Storage Laboratory, and CIMMYT will maintain its viability.

Germ plasm for wheat, barley, rye, and triticale. CIMMYT looks to the U.S. Department of Agriculture (USDA) world seed collections of wheat, barley, and rye for the storage, classification, and servicing of small grains. CIMMYT maintains only working collections for its own breeding use: about 4000 accessions of wheat (out of a world collection of about 26,000), 4000 accessions of barley (out of a world collection of about 15,000), and a small working collection of rye used in the triticale breeding program.

CIMMYT shares germ plasm and data from its working collections of small grain with collaborating scientists, but CIMMYT does not attempt to maintain a general seed service for these grains. Instead, requests are referred to USDA.

CIMMYT's collection of triticale accessions, together with that of the University of Manitoba (Canada), constitute the most comprehensive collection of germ plasm for this man-made grain (wheat × rye). CIMMYT is one of the principal suppliers of breeders' seed to triticale researchers worldwide.

"Gaps" in the maize and wheat collections. CIMMYT shares the concern that gaps in the world plant genetic resources for maize and wheat should be filled, but CIMMYT does not employ full-time staff for this work.

A CIMMYT staff member working on crosses between maize and tripsacum has participated for a few days each year in the collection of additional germ plasm for tripsacum which grows wild in Mexico and neighboring countries.

CIMMYT and the governments of India and Brazil have discussed means of collecting additional maize germ plasm in remote areas. Maize from the Northeast Frontier territory of India and from the upper Amazon basin in Brazil represent two gaps in the world collection of *Zea mays* L.

In 1973 two CIMMYT scientists working on triticale collected land races of rye in Turkey which have been introduced into the triticale breeding program in Mexico.

CIMMYT can help plan and finance the search for additional germ plasm in maize, wheat, and small grains, but CIMMYT's regular research staff members are not able to leave their other duties to participate as plant explorers.

Special report: WORLDWIDE USE OF CIMMYT BREAD WHEAT GERM PLASM

Varieties with germ plasm from the CIMMYT wheat breeding program can be found in virtually all wheat growing countries. In many countries, a substantial proportion of the high yielding varieties grown are the result of CIMMYT breeding work.

CIMMYT developed germ plasm reaches farmers' fields in three ways. First, after appropriate testing, a nation may decide that a CIMMYT selection is suitable for direct release to farmers. CIMMYT does not release varieties itself; release is wholly the responsibility of national governments and the governments decide what to name a variety. For example, when Pakistan decided to release the Mexican variety Siete Cerros to Pakistani farmers it was renamed Mexipak 65.

Second, a variety may be created after national scientists have made selections from a population received from CIMMYT. Mexipak 69 is the name given in Pakistan to a reselection from Siete Cerros.

Third, CIMMYT developed germ plasm may be used by national scientists as parental material in breeding new varieties. Tarnab

Table 1. **Contribution of Mexican wheats to wheat production in various countries.**

Variety	*Mexican identification*	*Year released* [a]	*Est. area sown* [b] *(000 ha)*
INDIA			
Kalyansona	Siete Cerros	67 R	6500
P.V. 18	Super X		
Sonalika	(53-388-An x Pi "S" -LR)(B4946-A4-18-2 x Y53) $Y60^3$	67 R	3000
Chhoti Lerma	LR64 "S" -Hua. R.	67 R	1000
Safed Lerma	$Y^{50}E$ - L52/LR	67 R	1000
UP 301	Inia 66 "S"	69 R	1000
Sharbati Sonora	Sonora 64 "S"	67 M	
Lerma Rojo 64A	Lerma Rojo 64A	65 D	1000
Sonora 64	Sonora 64	65 D	
Lal Bahadur	554723 x R 631-1	69 L	
Hira	Pi "S" - Son 64	71 L	
Moti	Pi "S" x NP 852	71 L	
Janak	Pi "S" x HD 854	73 L	
Malavika (durum)	(Pi "S" x TAC125)TA^4 x Z-B Wells x Lakota	73 R	
UP 215	Tobari "S"	73 R	
Shera	LR64A x Son 64	73 R	
HD 2009	LR x Nai 60	74 R	
HD 1981	Pi "S" x RN (HD845)	74 R	
PAKISTAN			
Mexipak 65	Siete Cerros	67 D	4500
Mexipak 69	Siete Cerros	68 R	
Indus 66	Super X	66 D	
Penjamo 62	Penjamo 62	65 D	
Khushal	Combinador x C271	69 L	
Tarnab 69	2813 (Y62 63)-C271	69 L	
Blue Silver	Sonalika (India)	69 D	
Chenab 70	C271 Wt_E x Son 64	70 L	
Barani 70	Pi "62" Gb55 x C271	70 L	
Green Valley	Chhoti Lerma (India)	70 D	
Kalam 71	Combinador x C271	71 L	
S A 42	$C271^2$ x LR Son 64	72 R	
BANGLADESH			
Norteño 67	Norteño 67	74 D	
Mexipak 67	Siete Cerros	68 D	
NEPAL			
Lerma Rojo 64	Lerma Rojo 64	67 D	70
Sonalika	Sonalika (India)	68 D	
Kalyansona	Site Cerros	67 D	
Lerma 52	Lerma 52	53 D	
AFGHANISTAN			
Mexipak	Siete Cerros	68 D	450
Lerma Rojo	Lerma Rojo	68 D	
Bakhtar		72 R	
Ephrat		73 D	
IRAN			
Inia	Inia 66	68 D	150 ?
Moghan	LR-NIOB x An^3E	73 R	1

Table 1. Continued

Variety	*Mexican identification*	*Year released* [a]	*Est. area sown* [b] *(000 ha)*
Karaj 1	(200H-Vilufen)Roshan	73 L	
Arvani 1	Roshan/Mentana-KenyaxMayo 48	73 L	
Khazar 1	P4160$_E$-Narino 59 x LR64 A	73 R	
IRAQ			
Mexipak	Siete Cerros	67 D	
Inia 66	Inia 66	69 D	600
Jori (durum)	Jori	72 D	
SYRIA			
Mexipak	Siete Cerros	71 D	
Pitic	Pitic 62	68 D	300
Syrimex	Pi "S" x LR^3	69 R	
SAUDI ARABIA			
Mexipak	Siete Cerros	69 D	
Mexipak Red	Super X	69 D	10
LEBANON			
Mexipak	Siete Cerros	67 D	20
ARZ	My54$_E$xLR/H49((LR64xTzpp-Y54)	73 R	
JORDAN			
Mexipak	Siete Cerros	69 D	
ISRAEL			
Mivhor 177	Siete Cerros	66 R	
Ceeon	Yt65 A^3/NIOB	68 R	
Miriam	Ch$^{53}_E$xY_q54/Merav	70 L	80
Hazera 18	Son 64A - Tzpp/Yar 60	70 R	
Lakehish	Florence AurorexY$_E$ NIOB21	71 L	
Hazera 335	Inia "S" x Son 64-Tzpp/Y54	74 R	
Penjamo 62	Penjamo 62	68 D	
TURKEY			
Mentana	Mentana	63 D	600
Dicle 74 (durum)	Cocorit 71	74 D	
Cigueña	(Son64^{2}xTzpp Y54/An64A)F$_1^2$,Y.Kt.	74 R	
EGYPT			
Super X	Super X	71 D	
Mexipak	Siete Cerros	72 D	270
Chenab 70	Chenab 70 (Pakistan)	73 D	
S.A. 42	S.A. 42 (Pakistan)	73 D	
LIBYA			
Sidi Misri 1	Siete Cerros	72 D	
SUDAN			
Mexicani	LR NIOB x An^3_E	71 R	5?
ETHIOPIA			
Laketch	B156 white	70 D	
Kenya Kanga	Kenya Kanga (Kenya)	72 D	
Supremo Kenya x Y_q48		70 D	
KENYA			
Africa Mayo	Africa x Mayo 48	60 R	28
Kenya Leopard	(Lageadinho x K 354P^3) x (c 1.12632 x K354P^3)	66 L	
Kenya Kanga	Mexicox [(Wis 245 x Sup 51)x(F$_1$ Fn/Y^2) A]	71 L	

Table 1. Continued

Variety	*Mexican identification*	*Year released* [a]	*Est. area sown* [b] *(000 ha)*
Trophy 68	T-K[2] x Y60	69 R	
Token	T K [illegible] x Y50[2]	69 R	
Kenya Kiboko	C 8154 Fr[2]x(Gb54-36896)Gb54	73 L	
Kenya Nyati	Ro nany [2] x AfM	73 L	
RHODESIA			
Zambesi	81[illegible]6 x Lee - ND74	66L	10
Tokwe	Mex [illegible]6xMezoe ND74	67 L	12
SOUTH AFRICA			
Inia	In a 66	D	
Tobari	Tobari	D	
Flameks	M Mt x Ky Sup	R	
T-4	LR NIOB x An[3]E	R	
Barta	Lee Frontana/Afr 48xMayo 54		
Sonderend	LR64 Son64[2]x Napo 63	74 R	
Aerie	Yecora 70	74 D	
Kasteel	Pr "S" x Flameks	70?	
Elize	Inia 66 - P4160[3]	74 L	
Helène	Bbx Cno "S" Son 64	74 R	
Gerda	Cajeme	74 D	
Bonnie	Tokwe x Jaral 66	74 L	
TUNISIA			
Inia	Inia 66	68 D	30
Tobari	Tobari 66	68 D	
Soltane	Son KT Rend	74 R	
Vaga	Cajeme 71	74 D	
Amal (durum)	Brant "S"	74 R	
Maghreb 72 (durum)	GII "S" (Bc180 LK)(GZ×61-130)	74 R	
Carthage	Np Tob "S" x 8156	74 R	
Douaga	KT Pet Rat x 8156	74 R	
ALGERIA			
Siete Cerros	Siete Cerros	72 D	330
Inia	Inia 66	72 D	120
Jori (durum)	Jori 69	72 D	120
Tobari 66	Tobari 66	72 D	
Soltane	Soltane (Tunisia)	74 D	
MOROCCO			
Siete Cerros	Siete Cerros	68 D	80
Tobari	Tobari 66	68 D	150
Pergamo	Pergamo 62	68 D	150
Potam 70	Potam 70	72 D	

69 is a Pakistani variety developed from 2813 (Y62 63) x C271. The parent 2813 (Y62 63) was bred by CIMMYT.

Table 1 is a compilation of varieties bearing CIMMYT germ plasm that contributed to wheat production throughout the world in 1973. Where possible, the area planted to each variety has been estimated. Many of the varieties shown in Table 1 were released in 1972 or 1973. These varieties

Table 1. Continued

Variety	*Mexican identification*	*Year released* [a]	*Est. area sown* [b] *(000 ha)*
CANADA			
Pitic 62	Pitic 62	73 D	50[c]
Norquay	LR 64/Son 64× Justin	74 L	
USA			
Red River	Tobari "S"	68 R	
Pitic 62	Pitic 62	D	
Anza	LR/NIOB An[3] E	72 R	
Cajeme 71	Cajeme 71	73 D	
Bonanza	Pi "S" Chris "S" × Son 64	72 R	
Siete Cerros	Siete Cerros		276
Bluebird 2	Bluebird 2 Yecora 70		
Inia 66	Inia 66		
Inia 66 R	Inia 66 R		
Protor	Tob Cno	73 R	
Prodax	Cal × Robin	73 R	
Produra (durum)	Pelicano	74 R	
Prospur	Np63×Tzpp Son 64A	74 R	
Colano	Pi "S" Cris "S" Son 64	74 R	
MEXICO			
Lerma Rojo 64		64 D	63
Delicias 70		70 D	
Siete Cerros 66		66 D	74
Yecora 70		70 D	
Cajeme 71		71 D	450
Tanori 71		71 D	
Jori 69 (durum)		69 D	22
Cocorit 71 (durum)		71 D	
Jupateco 73		73 D	
Torim 73		73 D	
GUATEMALA			
Nariño 59	Nariño 59	60 D	
Pato	Tzpp Son 64 × Nar 59	71 D	30
Maya 74	Cno Gallo	74 R	
COLOMBIA			
Bonza 63	Rio Negro × Bonza [2]	63 L	50[c]
Tiba	Fr/Y48 My54×Menkemen	63 L	
Zipa 68	F Y 48 × Afm[2]	68 R	
CHILE			
Toquifen	C14[4] P4160 Yt[54]E	69 L	10
Mexifen	Son 64 × Sk[6] E An[3]E	71	

were not yet being grown by farmers or were planted on an insignificant area.

Table 1 was assembled from many sources. When available, reports of national research and production programs have been used. For several countries, national scientists provided data in correspondence. In a few instances, CIMMYT scientists collected estimates in conversations with national scientists and agricultural officials.

Table 1. Continued

Variety	*Mexican identification*	*Year released* [a]	*Est. area sown* [b] *(000 ha)*
Quilafen (durum)	$Ld357_E$-Tc^2	61 D	
ARGENTINA			
Precos Parana Inta	Son 64 x Knott 2	71 R	50
Marco Juarez Inta	Son 64 x Kl. Rend	72 R	
Tala	(Son 64 x Kl. Rend) Mass. 6	73 L	
Lapacho	Cno 67 "S"	73 R	
PORTUGAL			
Mexicano 1481	NIOB x P14	71 R	
AUSTRALIA			
WW 15	LR NIOBxAn^3_E	67 R	87
Duramba	MexDwarf 5231D	71 L	
Condor	WW15 x WW80	74 L	
Kite	Mex Dwarf x Eagle	74 L	
Egret	WW 15 x Heron	74 L	
NEW ZEALAND			
Kamaru	LR Nor 10B x An ^3_E	72 R	

a/ D = Direct release, R = Reselection, L = Local breeding, M = Mutation. *b/* Circa 1973

Table 2. **Names that have been used for Cross 8156 in various countries.**

Red seeded selection	*Country*	*White-seeded selection*	*Country*
Super X	México	8156 Blanco	México
Siete Cerros Rojo	México	Siete Cerros 66	México
PV - 18	India, Pakistán	Siete Cerros	México
Pv - 18 A	India	7 Cerros 66	México
V - 18	India	V - 17	India
Indus 66	Pakistan	S 227	India
Mexipak Red	Saudi Arabia, Lebanon	Sona 227	India
MR 548	India	HD 1593	India
NP 323	India	HD 1592	India
CB 90	India	Kalyansona	India
PM 17	India	Kalyansona 227	India
		Kalyan 227	India
		Kalyan	India
		Mexipak - Mxp	Pakistán, Iraq, Syria
		Mexipak White	Lebanon
		Mexipak - 65	Egypt, Lebanon, Pakistan
		Mexipak - 69	Pakistan
		MexiPak	Iraq
		Sidi Misri 1	Lybia
		Laketch	Ethiopia
		Mivhor 1177	Israel
		Hazera 1177	Israel
		Bakhtar	Afghanistan

Table 3. **Estimated plantings of high yielding spring wheats and total wheat area in four regions (circa 1973).**

Region	Area, 000 ha. All wheats a/	High yielding varieties b/ Total	Cross 8156
Asian subcontinent	27,000	18,620	11,500
Middle East	17,000	1,760	900
Africa	9,000	1,150	700
Western Hemisphere	36,000	1,075	100
Total	89,000	22,505	13,400

a/ FAO. b/ From Table 1.

Table 1 shows that 18 million hectares of spring dwarf wheat from Mexico are grown in India, Pakistan, Afghanistan, and Nepal. About 65 percent of this area is planted to selections from cross 8156 such as Kalyansona and Mexipak (Table 2 shows the variety names used for selections from Cross 8156 in various countries). Sonalika may cover 20 percent of the area under high yielding varieties in these four countries.

In the Middle East, 1.5 to 2.0 million hectares are planted to high yielding varieties in the spring wheat areas. About half this area is planted to varieties from Cross 8156. Other important varieties are Penjamo 62, INIA 66, and Syrimex.

In Africa about half the 1.3 million hectares under high yielding varieties of wheat may be planted with Cross 8156 derivatives.

Small areas are sown to CIMMYT wheats in USSR, China, Spain, Portugal, Australia, and New Zealand. Little is known about planting of Mexican wheats in the People's Republic of China, however the PRC imported 5000 tons of Mexican wheat in 1973 and 15,750 tons in 1974 (Potam, 9700 t; Tanori, 3850 t; Saric, 1100 t; INIA, 550 t; Jori, 550 t). These imports are enough to plant at least 300,000 hectares. The extent of plantings from previous imports from Pakistan is unknown.

In the Western Hemisphere, the high yielding varieties are important in southwestern USA and on a small scale in some areas of Canada. For example, wheat of CIMMYT origin account for 85 percent of the spring wheat area of California.

In South America the new dwarf wheats are gaining popularity in Argentina, but the older, taller wheats of Mexican origin are still grown in the Andean region.

Although less than 10 percent of world wheat plantings involve Mexican wheats, possibly 35 percent of the wheat grown in developing non-communist nations of Asia has CIMMYT-developed germ plasm. Of the high yielding spring wheats of Mexican origin grown around the world, perhaps 60 percent are Cross 8156 varieties (Table 3).

Special report: CIMMYT'S REGIONAL SERVICES

The formation of regional services outside Mexico is likely to be the largest change in CIMMYT's organization during the 1970's. Until now, CIMMYT's outreach activities have been bilateral. Staff members travelling from Mexico have dealt individually with more than 80 governments, seed for international trials has been shipped from Mexico

directly to 80 nations, workshops held at El Batan in Mexico have drawn upon scientists from around the world.

There are two disadvantages to that system: First, in the past decade or so, hundreds of maize and wheat scientists in developing countries have received advanced training and are ready to play a larger role in their own regions. Second, CIMMYT staff resources in Mexico have been stretched to the limit. Staff travel out of Mexico cannot increase further without curtailing research. International nurseries are grown at so many locations that in 1974 air shipments of sample seed from Mexico reached 7.0 tons, and many shipments arrived too late for planting because of air express difficulties or late quarantine clearance.

Regional services are needed in which scientists from producing countries can participate, and in which CIMMYT staff members posted to the region can supplement the

Keith Finlay, deputy director of CIMMYT, admires the diversity of spike types that can be found in barley germ plasm.

services now provided from Mexico.

Central American prototype. In 1974 CIMMYT formed a regional service for maize improvement in Central America. This project serves as a prototype for others.

Two staff scientists, one a breeder and one an agronomist-trainer, are assigned full-time to maize improvement in the area. They consult with governments on maize research and production; they distribute international trials twice a year, using seed from the national programs as nucleus, but adding exotic materials; they arrange training outside the region for local researchers; they train production agronomists within the region, preferably within the agronomist's own national program; they organize an annual workshop for local scientists; they administer a travel fund to enable local scientists to visit other countries in the region to see outstanding examples of research and production.

The two CIMMYT scientists have no research plots of their own. They share in the work of about nine national programs.

This service has just begun, but Central America is already receiving more complete services from CIMMYT than ever before. The regional staff is taking competitive pride in the work of the region. It is too soon to observe the role of local scientists, but it is expected that local scientists will shortly make most of the decisions on their regional maize nurseries, and will manage their own regional workshop.

Regional programs being negotiated. Two more maize regional services are under negotiation. The Andean region of South America (Bolivia, Colombia, Ecuador, Peru, Venezuela) produces 3 million tons of maize a year. In addition the tropical portion of Brazil produces 5 million tons of maize and uses varieties similar to those in the lowland regions of the Andes.

Both CIMMYT and Centro Internacional de Agricultura Tropical (CIAT) have been assisting in maize improvement in the Andean region. In 1974 CIMMYT and CIAT agreed to form joint services for maize improvement in the Andean region to be located at CIAT headquarters, and staffed jointly by CIMMYT and CIAT.

Two staff members would provide essentially the same services as those described for Central America. In addition, one CIMMYT-CIAT breeder would be stationed in the highlands of the Andes to specialize in improving floury maize, a cereal which is peculiar to the highlands. Almost 1 million tons are grown and eaten by subsistence farmers there. This regional service should begin during 1975. Financing would be by the United Nations Development Programme (UNDP).

In Asia, 12 maize-producing countries from Indonesia to Pakistan, have been cooperating under the Asian Corn Program since 1966. A three-man Rockefeller Foundation staff at Bangkok has provided assistance. The present program is terminating in 1975, and CIMMYT has been asked by governments of the region to formulate a new set of services.

An agreement under discussion between CIMMYT and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) would permit CIMMYT to post a two-man maize staff to the Hyderabad headquarters of ICRISAT where the CIMMYT scientists would organize regional services for Asia like those for Central America.

This proposal will require an agreement with the government of India, and, subject to that agreement, could begin during 1975. Financing would be by UNDP.

A regional service for wheat is expected to begin in East Africa during 1975. Initially one CIMMYT breeder will be stationed at the Kenya Wheat Experiment Station,

Njoro, located at an elevation of 2200 m in a climate which could provide a suitable summer wheat nursery for all nations of the region. This means that national scientists will grow their usual research crop in the winter season within their own stations, then ship seed of their best materials to Njoro to be advanced another generation during the summer season.

The CIMMYT regional services would also include the circulation of regional trials, selection of fellows for advanced training, consulting with governments within the region, and organizing periodic regional workshops for wheat workers.

Producing regions for maize and wheat which can serve as the basis of regional services for crop improvement.

	Number of producing countries	1972 production (million tons)
Maize:		
Central America and Caribbean	9	2
Andean regional and tropical Brazil	7	8
South and southeast Asia	12	12
Tropical East Africa	15	9
Tropical West Africa	16	4
Southern cone of South America and temperate Brazil	6	8
Wheat:		
Mediterranean and Near East	19	45
Andean region	5	0.3*
Tropical East Africa	4	2
Southern cone of South America	5	12

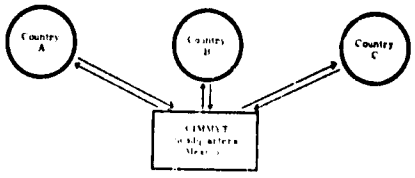
*Wheat production in the Andean region is small, but regional services can be important there because: (1) the Andean region imports more wheat than it grows, (2) Andean countries produce more barley than wheat, and the same regional team can provide services to both wheat and barley, (3) diseases of wheat and barley move out of the Andean region, and affect the wheat crop of the southern cone countries.

Other possible regional programs. CIMMYT proposes to negotiate other services for maize and wheat improvement in a number of regions during the next few years (see table). No two of these regions are alike in population, internal transportation, or quality of agricultural services. Nevertheless, CIMMYT estimates that, on average, two staff scientists assigned to each region could perform the services described for the Central American program above. The average cost of a two-man staff and their associated program would be US$200,000 per region per year. The total cost of all regional services now anticipated would be $1.5 to 2.0 million a year by 1980, at constant 1975 prices.

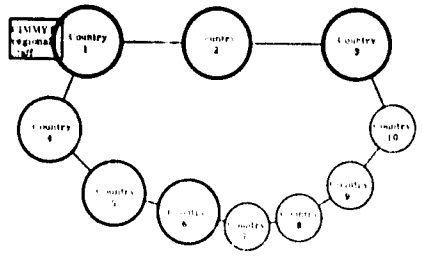
CIMMYT is discussing these services with some governments in each region. Wherever appropriate the regional services will be centered at the headquarters of another international center, as already proposed with CIAT and ICRISAT.

Role of economics. CIMMYT economists in Mexico are now assisting the new regional groupings by organizing economic studies in each region. In some regions, a fulltime economist may be assigned on a resident basis. The first economist posted outside Mexico is likely to be stationed in East Africa in 1975, under UNDP financing.

Local scientists. In the long run, the most important result of the new regional services will be the increasing ability of national programs to share technology and training among themselves, as suggested by "new system" shown in the accompanying diagram. The size of the circle for each country program suggests the strength of its research program. Maize is used here as an example. Thus, three national programs are stronger than the others: they are able to conduct independent breeding and to assist their neighbors. Another three countries possess intermediate skills: they are able to test superior progeny from outside their country



The "old" system of regional services: two-way flow of seed, CIMMYT staff members, visiting scientists, etc., to and from individual governments.



The "new" system. The three sizes of circles for country programs suggest the stronger, intermediate, and weaker services for crop improvement. Scientists from the stronger countries will be used as consultants to help the weaker countries within the regional programs.

and to share in the decisions on experimental varieties. The four countries represented by the smallest circles have the fewest trained scientists, and are able to test only elite varieties (those that have already been tested by their neighbors and found to be superior for the local environment).

CIMMYT anticipates that consulting work in each region will gradually be shared by the scientists from the strongest maize programs (those represented by the largest circles). This will give a broadening experience to the scientists who serve as consultants.

Under this evolution of responsibilities, several important functions would continue to be performed by an international center like CIMMYT. First, the international center would maintain a world collection of germ plasm, ship samples to breeders, and develop new experimental germ plasm which would be fed into regional trials. Second, CIMMYT would continue to observe the worldwide testing of germ plasm to identify wide adaptation (that is, superior performance of varieties across climatic zones, which indicates greater stability of yield). Third, CIMMYT would continue to provide in-service training for maize and wheat researchers in national programs. Fourth, CIMMYT would maintain a full range of research disciplines and provide the backup skills for the regional services, whose staff would remain skeletal.

Such a division of labor between an international center and the regional services should provide the greatest economy of cost and encourage the stronger national programs to contribute to crop improvement among their neighbors.

1974 CIMMYT Source and Application of Funds [a]

US$5,085,000		**Core unrestricted income** [b]
	US$1,350,000	U.S. Agency for International Development
	751,000	Inter-American Development Bank
	750,000	Ford Foundation
	750,000	The Rockefeller Foundation
	440,000	Government of West Germany
	366,000	International Bank for Reconstruction and Development
	150,000	Government of Denmark
	529,000	Administrative charges and miscellaneous income
1,330,000		**Core restricted income** [c]
	782,000	United Nations Development Programme Research and training in the development of quality protein maize
	452,000	Canadian International Development Agency Triticale research project
	39,000	The Rockefeller Foundation Puebla Project
	31,000	Inter-American Development Bank Project in Central America and Caribbean
	26,000	International Development Research Centre Research on low temperature tolerant sorghums
1,385,000		**Special projects income** [c]
	799,000	Ford Foundation Projects in Algeria, Argentina, Egypt, Lebanon, Pakistan, Tanzania, Tunisia, and miscellaneous training
	244,000	Government of Zaire Programme National Mais, Zaire
	131,000	The Rockefeller Foundation Projects in Central America, Mexico, Pakistan, and Turkey and miscellaneous training
	63,000	International Potato Center Regional program in Mexico
	42,000	Inter-American Development Bank Training in wheat and maize
	38,000	International Institute of Tropical Agriculture Project in Tanzania and miscellaneous training
	15,000	U.S. Agency for International Development Projects in Morocco and Nepal, and miscellaneous training
	13,000	Overseas Development Administration Visiting scientists and training
	10,000	Food and Agriculture Organization of the United Nations Training in wheat
	9,000	International Development Research Centre International triticale workshop in Mexico, wheat and maize workshops in Lebanon, computer equipment, and miscellaneous training
	20,000	Training grants from 12 donors
7,800,000		**TOTAL INCOME**
6,073,000		**Core operating costs**
	1,224,000	Wheat
	1,112,000	Maize
	140,000	Economics
	599,000	Experiment stations
	80,000	General service laboratories
	406,000	Information services and library
	620,000	Training
	38,000	Conferences
	555,000	General operations
	716,000	Administration
	225,000	Indirect costs
	358,000	Capital acquisitions
1,401,000		**Special projects expenses**
	1,205,000	Direct expenses
	196,000	Administrative charges
7,474,000		**TOTAL EXPENSES**
326,000		**Reimbursements to donors and unexpended balances**
7,800,000		**TOTAL EXPENSES, REIMBURSEMENTS, AND BALANCES**

a/ From the 1974 CIMMYT Audit Report of Price Waterhouse y Cia., S.C., Mexico. b/ Funds available for core operations without restriction for use within the budget approved by CIMMYT Trustees. c/ Funds available only for the activity specified by the donor.