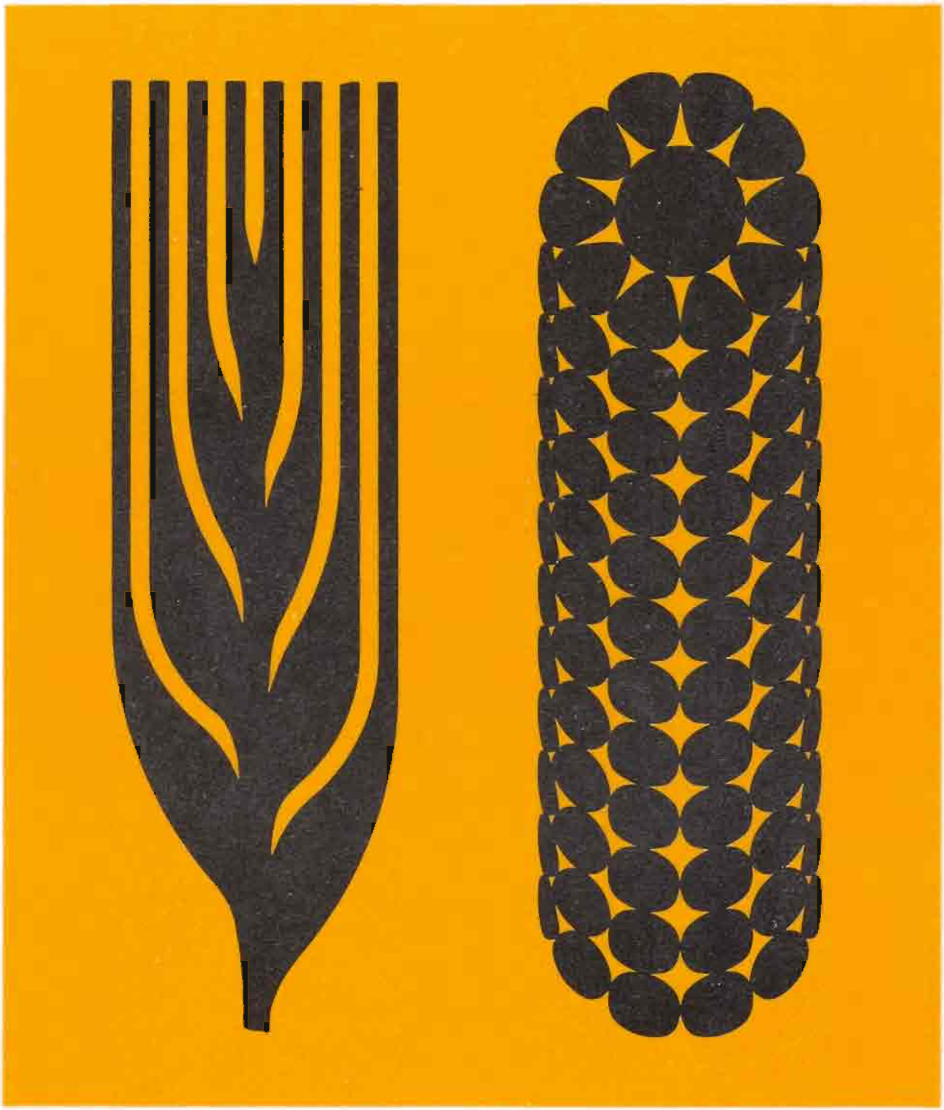
CIMMYT REVIEW 1977



CIMMYT REVIEW 1977

CENTRO INTERNACIONAL DE MEJORAMIENTO DE MAIZ Y TRIGO 1977
International Maize and Wheat Improvement Center, Apartado Postal 6-641, Mexico 6, D.F., Mexico

ISSN 0304-5463

Correct citation: Centro Internacional de Mejoramiento de Maíz y Trigo. 1977. CIMMYT Review 1977. El Batán, México.

Spanish edition: CIMMYT Review 1977 is published in English and Spanish. A copy of the Spanish edition is available on request.

CIMMYT. The International Maize and Wheat Improvement Center (CIMMYT) receives support from government agencies of Canada, Denmark, Iran, Japan, Netherlands, Saudi Arabia, Switzerland, United Kingdom, USA, West Germany, and Zaire; and from Ford Foundation, Inter-American Development Bank, International Development Research Center, Rockefeller Foundation, United Nations Development Programme, and the World Bank. Responsibility for this publication rests solely with CIMMYT.

contents

Trustees 5
Staff 6

INTRODUCTION 8

MAIZE IMPROVEMENT 10

Maize introduction 11
Procedures for new varieties 13
International maize trials 16
- Elite variety trials 16
- Experimental variety trials 16
- International progeny trials 17
- Requests for seed increase 20
- 1977 International trials 20

Flow of new germ plasm 20
- Introduction nurseries 21
- Flow from the bank 21
- Early tropical pools 21
- Temperate pools 21
- Improving wide adaptation 21

Germ plasm bank 22
- Collection and storage 22
- Regeneration 22
- Classification and cataloging 22
- Shipments to clients 22

Special research projects in Mexico 24
- Shorter maturity 24
- Reduced plant height 25
- Wider adaptation 25
- More efficient tropical plants 26
- Drought tolerance 26

Protein improvement 27
Disease and insect resistance 29
- Insect and disease nurseries 29
- Insect-rearing laboratory 30
- Collaborative research 30

Wide crosses 31
Maize training 32
- In-service training 33
- Training in national programs 33
- Academic training 33
- Visiting scientists 34

Maize cooperative projects 35
- Pakistan 36
- Egypt 38
- Zaire 38
- Tanzania 39
- Nepal 40
- Guatemala 41
- Central America and Caribbean 41
- South and Southeast Asia 42
- Andean countries 42

Cold tolerant sorghum 43
- East African origins 43
- Breeding 44
- Protein quality 44
- International testing 44
- Sorghum training 45
- Road ahead 45

WHEAT IMPROVEMENT 46

Wheat introduction 47
Bread wheat 50
- Variety releases 51
- Yield testing 53

Disease resistance 53
Multilines 53
Spring x winter wheat 54
Wheats for the humid tropics 56
Cooperative program with Brazil 56
International nurseries 56
Durum wheat 57
Higher yield 57
Disease resistance 57
Broader genetic base 58
Drought tolerance 58
Durum quality 59
Triticale 59
Higher yield 59
Grain quality 60
Earliness 61
Lodging resistance 61
Daylength response 62
Protein 62
Baking quality 62
Disease resistance 62
Winter triticales 63
Farm trials 63
Fertilizer response 63
Forage triticales 64
Broad adaptation 65
National programs 65
Barley 65
Wider adaptation 66
Disease resistance 66
Earliness 68
Hull-less grain 68
Straw strength 68
High yield 68
International testing 69
Winter x spring crosses 69
Development of new germ plasm 69
New sources of dwarfing 70
Protein improvement 70
Resistance to rusts 70
Larger spikes 71
Branched spikes 72
Triticale 72
Intergeneric crosses 72
Wide crosses 73
Crosses of barley and wheat 73
Crosses with grasses 73
Physiology 74
Drought resistance 74
Long spikes in short days 75
Fertilizer and yellow berry 76
Slow rusting 76
Chemical control of rust 76
International trials 77
Milling and baking laboratory 77
Wheat training 79
Farm trials 80
Variety trials 81
National training programs 81
Wheat cooperative projects 81
Pakistan 82
Tunisia 83
Turkey 84
Algeria 84
Nepal 86
Mediterranean and Mideast 86
East Africa 87
Andean region 88

SUPPORTING SERVICES 89
Economic studies 90
Laboratory services 92
Experiment station management 94
Statistical services 95
Information services 95

CIMMYT income and expenditures 98

trustees

staff

Direction
Haldore Hanson, USA, Director General
Keith W. Finlay, Australia, Deputy Director General
Robert D. Osler, USA, Deputy Director General and Treasurer
Norman E. Borlaug, USA, Director-Wheat Program
Ernest W. Sprague, USA, Director-Maize Program
R. Glenn Anderson, Canada, Associate Director-Wheat Program
R.L. Paliwal, India, Associate Director-Maize Program

Maize headquarters staff
Carlos De Leon, Mexico
N.L. Dhawan, India
Kenneth S. Fischer, Australia
Jacqueline James, UK
Elmer C. Johnson, USA
Federico Kocher, Switzerland
Alejandro Ortega C., Mexico
Shivaji Pandey, India
Surinder K. Vasal, India
Alejandro Violic, Chile
Shree P. Singh, India, Sorghum

Pre-and post-doctoral fellows
Magni Bjarnason, Iceland
Gregory O. Edmeades, New Zealand
Peter G. Goertz, W. Germany
Jean Hanson, UK
Clair H. Hershey, USA
John A. Mihm, USA
Vicente Rodriguez, El Salvador
Thomas C. Stilwell, USA
Suketoshi Taba, Japan

Wheat headquarters staff
Maximino Alcalá D., Mexico, International Nurseries
H. Jesse Dubin, USA, Pathology
Santiago Fuentes F., Mexico, Pathology
Man Mohan Kohli, India, Triticale
Paul N. Marko, USA, Training officer
Matthew McMahon, Ireland, Agronomy
H.G. Nasr, Lebanon, Associate training officer
Sanjaya Rajaram, India, Bread Wheat
Enrique Rodríguez C., Mexico, Barley
Ricardo Rodríguez R., Mexico, Germ plasm
Gregorio Vazquez G., Mexico, Durum wheat
Reyes Vega R., Mexico, Field supervisor
Hugo Vivar F., Ecuador, Assistant training Officer
Francis J. Zillinsky, Canada, Triticale

Wheat pre-and post-doctoral fellows
Dietrich Leihner, W. Germany, Durum wheat
Guillermo Ortiz F., Mexico, Durum wheat
John F. Pepe, USA, Triticale
Bent Skovmand, Denmark, Bread wheat
Julian B. Thomas, UK, Wide crosses
Enrique Torres, Colombia, Pathology
Patrick C. Wall, Ireland, Physiology/Agronomy

Wheat field research assistants
Roberto Avalos P., Mexico, Barley
Sergio Muñoz V., Mexico, Bread wheat
Ramón Ortiz B., Mexico, Germ plasm
J. Joaquín Paredes L., Mexico, Triticale
Alfredo Regalado O., Mexico, Bread wheat

Economics
Donald L. Winkelmann, USA, Principal Economist
Michael P. Collinson, UK, Economist, East African region (headquarters: Kenya)
Edgardo Moscardi C., Argentina, Economist
Dalip S. Sidhu, India, Visiting economist

Laboratories
Evangelina Villegas M., Mexico, Biochemist, in charge general laboratories

Wheat industrial quality laboratory
Arnoldo Amaya C., Mexico, Cereal chemist, in charge
Roberto Peña B., Mexico, Research assistant
Raúl Ruiz E., Mexico, Research assistant

Protein quality laboratory
Enrique I. Ortega M., Mexico, Supervisor
Juan Luis Juárez G., Mexico, Research assistant
Rigoberto Valenzuela Y., Mexico, Research assistant

Plant and soils laboratory
Reinald Bauer, W. Germany, Supervisor
Alejandro Alonso L., Mexico, Research assistant
Jaime López C., Mexico, Research assistant

Statistical services
Peter Walker, UK, Biometrician

Experiment stations
John A. Stewart, UK, Head
Roberto Varela S., Mexico, Supervisor
Florentino Amacende A., Mexico, Superintendent, Poza Rica
J. Antonio Miranda M., Mexico, Superintendent, Toluca
Ricardo Márquez L., Mexico, Assistant superintendent, El Batan
Angel Palma F., Mexico, Assistant superintendent, Tlaltizapan

Information services
Steven A. Breth, USA, Science writer
James H. Bemis, USA, Science editor
Cristina Mercader de Leal, Mexico, Librarian
Linda G. Ainsworth, USA, Head, visitors service
Leobardo Terpan, Mexico, Photographer
Juan Zamora Z., Mexico, Photographer

General administration
Emilio Madrid C., Chile, Executive officer
Gregorio Martínez V., Mexico, Public affairs officer
Betsey V. Marsh, USA, Grant management officer
José Ramírez S., Mexico, Supervisor, accounting services
Eleonora Lindelius M., Mexico, Principal accountant
Ma. del Pilar Meza, Mexico, Principal accountant
Antonio Tristan, Mexico, Principal accountant
José de Jesús Buenrostro L., Mexico, Internal auditor
Ma. Alicia Mina M., Mexico, Supervisor, Personnel services
Leonardo Abin M., Mexico, Senior personnel assistant
Ma. de los Angeles Ezeta, Mexico, Purchasing officer
Hugo Alvarez V., Mexico, Assistant purchasing officer
Alberto Bourlon Ch., Mexico, Supervising engineer, Building maintenance
Ana Laura Sobrino de Gómez, Mexico, Head, Travel services
Armando Cornú M., Mexico, Head, Food and housing services
Manuel Gutiérrez S., Mexico, Government permits
Everardo Ríos D., Mexico, Head, vehicle services

Maize cooperative projects
Central America and Caribbean Region
Willy Villena, Bolivia (Headquarters: CIMMYT, Mexico)
Roberto Soza, Chile, (Headquarters: CIMMYT, Mexico)

Andean Region
James B. Barnett, USA (Headquarters: CIAT, Colombia)
Gonzalo Granados, Mexico (Headquarters: CIAT, Colombia)

Asia Region
Takumi Izuno, USA (Headquarters: India)

Egypt
Wayne L. Haag, USA

Guatemala
Hugo S. Córdova, El Salvador
Federico Poey, USA

Nepal
Donald R. Schmidt, USA

Pakistan
A. Frederick E. Palmer, UK

Tanzania
David W. Sperling, USA
James Deutsch, USA

Zaire
Thomas G. Hart, USA
Richard N. Wedderburn, Barbados

Wheat cooperative projects
Andean Region
Arthur R. Klatt, USA (Headquarters: Ecuador)

East Africa Region
Gerbrand Kingma, Netherlands (Headquarters: Kenya)

Mideast Region
J. Michael Prescott, USA (Headquarters: Turkey)
Eugene E. Saari, USA (Headquarters: Egypt)

Algeria
Walter Nelson, USA
David A. Saunders, Australia
George Varughese, India, Team leader, North Africa

Nepal
Torrey Lyons, USA

Tunisia
John B. Doolette, Australia

introduction

CIMMYT occasionally looks over its shoulder at the population clock.

On January 1, 1977 this clock showed 4,056,000,000 people in the world. The clock was advancing 200,000 persons per day, 6 millions per month, and 73 millions per year.

During the decade just past —from the mid-sixties to mid-seventies— radical changes occurred. Population in developing countries rose 30 percent, from about 1400 millions to about 1800 millions. And grain production in developing countries kept pace but barely, rising 31 percent during the same years. Thus more than 100 developing countries —measured as a group— preserved their inadequate per capita grain production.

These developing countries have continued to import 10 to 12 percent of their total annual grain requirements. Imports have generally ranged from 30 to 35 million tons a year, and rose to an all-time high in 1974 when 48 million tons were imported at a cost of over $10,000 million. Better harvests in 1975 and 1976 reduced imports to the former trend line —still a 10 percent grain deficit.

The crops assigned for CIMMYT's attention —wheat, barley, and maize— continue to provide between 40 and 50 percent of the calories and protein consumed in developing countries.

Wheat production rose 50 percent during this past decade when population rose 30 percent. Maize production rose 38 percent in the same years. But about half of these gains were made possible by a larger area planted.

Over the next decade, population growth in developing countries will again be 30 percent or a little more, and the food requirements of developing countries will again rise by 30 percent or more, just to maintain the present inadequate diet.

In this next decade, most of the increased grain production must come from increased yields on present cropland. Very little new cropland can be opened up.

If 30 percent more grain is to be produced by higher yields, that can be achieved only by better technology at the farm level.

It is against such a target that CIMMYT reports its progress in 1976, and plans its activities for the years beyond.

Haldore Hanson
El Batan
May 1, 1977

Performance of cereals in developing countries and worldwide 1961-65 compared with 1971-75.

Cereal	Annual area 1961-65 (million ha)	Annual area 1971-75 (million ha)	Annual area Increase (percent)	Annual yield 1961-65 (kg/ha)	Annual yield 1971-75 (kg/ha)	Annual yield Increase (percent)	Annual production 1961-65 (million m.t.)	Annual production 1971-75 (million m.t.)	Annual production Increase (percent)
Developing countries									
Rice	85.8	93.0	8	1614	1884	17	138.5	175.4	27
Wheat	50.4	61.3	22	976	1211	24	49.2	74.3	50
Maize	44.8	53.4	19	1132	1313	16	50.7	70.1	38
Sorghum	33.1	35.1	6	628	803	28	20.8	28.1	35
Millet	34.1	36.2	6	521	540	4	17.8	19.6	11
Barley	16.6	15.4	(7**)	937	1083	16	15.5	16.7	8
All cereals*	270.7	299.9	11	1098	1296	18	297.3	388.9	31
World									
Wheat	210	221	5	1209	1621	34	255	362	42
Rice	124	135	9	2039	2353	15	253	319	26
Maize	100	112	12	2170	2749	27	216	308	42
Barley	68	86	26	1466	1851	26	100	159	59
Sorghum	39	42	8	918	1200	31	36	51	42
Millet	66	69	4	572	666	16	38	46	21
All cereals*	677	722	7	1460	1846	26	988	1333	35

Source: FAO Production Yearbooks. *Includes cereals not listed. **Decrease.

maize improvement

MAIZE INTRODUCTION

The world maize crop of 1976 established an all-time production record of 320 million metric tons. This is satisfying to us, because CIMMYT's activities must be judged by what happens in farmers' fields.

In developing countries, maize production rose 38 percent in a 10-year period, while population increased 30 percent in the same years. That means farmers raised their maize production fast enough to feed the new population, and added a little extra food.

Disappointments also can be found in the recent data.

About half the increased maize in developing countries comes from planting a larger area, and half comes from rising yields per hectare. If we ask how developing countries obtained millions of additional hectares for their maize crop, the answer must be that most are ploughing up pastures, invading forest areas, or switching some land areas from other crops to maize.

This process cannot continue much longer. Arable land is already used up in most developing countries. Future food gains must come largely from higher yields per hectare, and that requires the application of better technology at the farm level.

As the table shows, maize yields in developing countries rose only 16 percent in 10 years, while population rose 30 percent. That is a critical comparison for CIMMYT.

Changes in maize production and population: 1961-65 to 1971-75.

Developing countries	1961-65	1971-75	Percent Increase
Average annual maize area harvested (million ha)	45	53	19
Average annual maize yield (kg/ha)	1132	1313	16
Average annual maize production (million metric tons)	51	70	38
Population (millions)	1448*	1876**	30
World			
Average annual maize area (million ha)	100	112	12
Average annual maize yield (kg/ha)	2170	2749	27
Average annual maize production (million metric tons)	216	308	42
Population (millions)	3160*	3831**	21

Source: FAO Production Yearbooks. *1963 **1973.

Another discouragement is this: developing countries were able to produce 70 million tons of maize per year in recent times, but they were also importing 5 million tons a year, more or less. That indicates a food gap which the increase of maize production has not yet solved.

CIMMYT's role

How does CIMMYT help? In 1976, the maize nurseries were tested in 59 countries. In 1977 this number of collaborating countries has risen to 68. These countries grow over 90 percent of the maize in developing countries.

In 1976 we brought young scientists from 45 of these countries to Mexico to give each of them one season of experience in maize research and production.

Our staff traveled in 1976 to 42 of these countries, to observe experimental maize trials, to see the constraints in farmers' fields, to consult with governments on their support for maize improvement.

We are finding a greater commitment by governments to increase their food production. And we observe the quality of maize research improving each year. That reflects better training.

The gap between research and the farmer

We still find a missing link in many national programs. Not long ago, a group of CIMMYT staff visited a number of maize-growing countries in

Willem Stoop, right, a post-doctoral fellow, and trainees measuring the amount of light penetrating the crop canopy

Central America. In each country they asked what is the optimum yield of the best maize varieties in the research station. The answer was 5 to 6 tons per hectare. And what is the average yield of maize in the farmers' fields? The answer was 1.5 tons per hectare or less. Why the difference?

We believe that every country needs to test and demonstrate new maize varieties on farmers' fields, for two reasons: to prove whether the new technology is actually better than the old, under farmers' conditions; and to persuade the farmer that new technology works on his land. Farmers are not persuaded by the research station.

Many governments are introducing on-farm testing, for the first time. This will help close the gap between research station and farmer. But there are other obstacles too: poor price incentives, poor supply of fertilizers; very often, poor salaries of extension workers which cause a constant turnover. It takes a rare combination of new technology and good government policies to produce a green revolution.

About this report

In pages which follow, we have assembled an overview of our recent work.

Our international testing program in 1976 was the largest in CIMMYT's history. Thirty 'elite' experimental varieties were grown at more than 200 sites in 1976 —the first time our testing program reached this level of payoff. Seventeen governments immediately ordered more seed for the new varieties.

CIMMYT now has assigned its maize staff members to work in six national programs and three production regions of the world. Their activities are summarized in this report.

From this overview, we draw confidence that the world-wide network of maize scientists can develop new technology at a pace which will permit maize production to stay ahead of population growth —for some additional years.— *E.W. Sprague.*

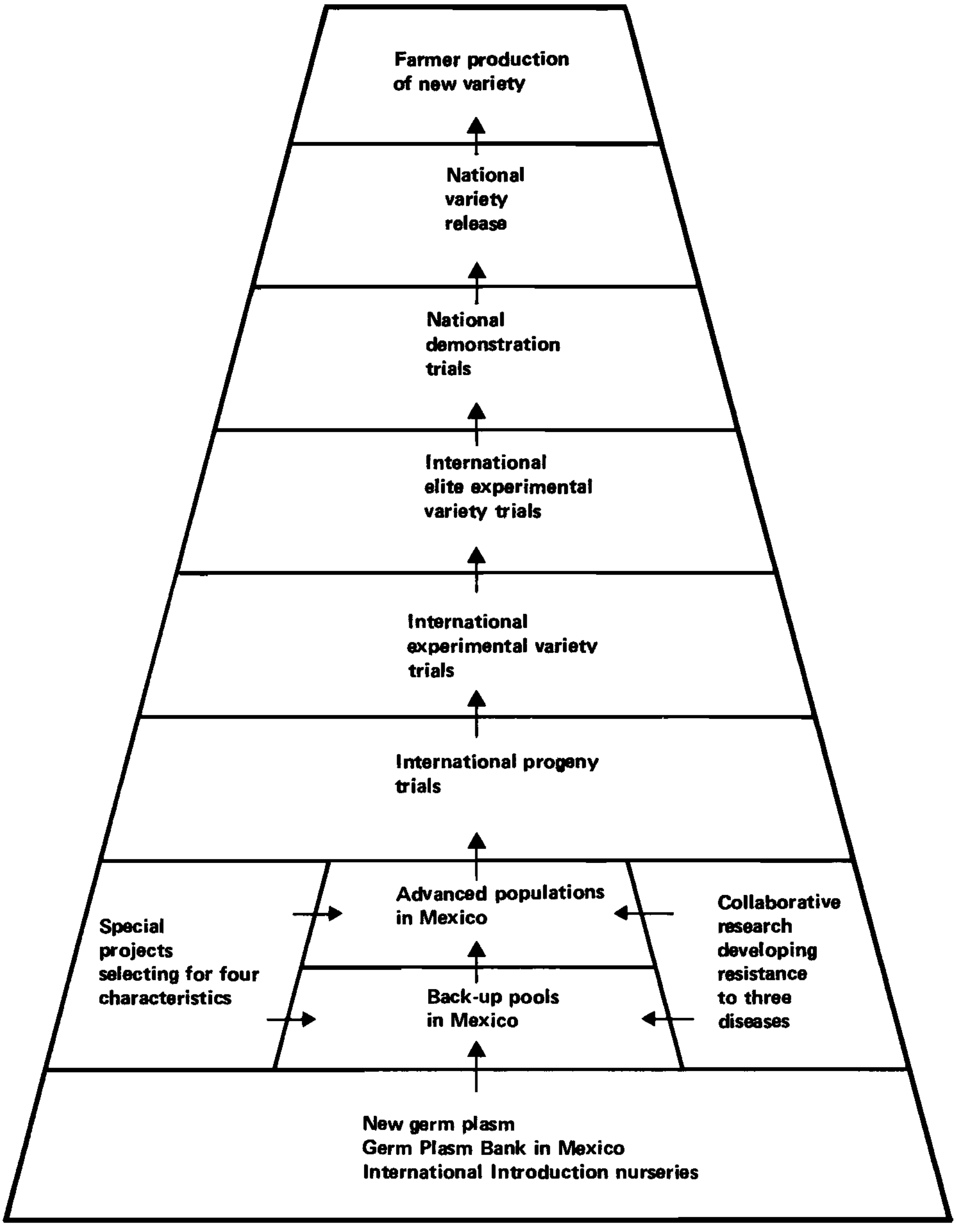
PROCEDURES FOR NEW VARIETIES

The process of varietal development will be described only briefly here. During the 1970's CIMMYT has evolved a number of germ plasm pools (first stage of improvement) and advanced populations (improved over many generations). Each year selections from these pools and populations are tested in Mexico, then the superior materials are tested by a network of more than 500 collaborators in over 60 countries. The judgment of the worldwide network thus guides the national programs, and helps CIMMYT develop more productive populations for shipment to them.

The release of new varieties to farmers in developing countries is a decision which CIMMYT leaves to each collaborating government.

This process of varietal development is summarized in the Maize Pyramid diagram.

THE MAIZE PYRAMID



Farmer production of new variety

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

National demonstration trials
National programs alone decide whether an elite experimental variety justifies wider demonstrations on farmers' fields. CIMMYT supplies basic seed for increase by governments. In larger countries, demonstration trials take place at hundreds of sites.

Elite experimental variety trials
Remnant seed for the elite variety is increased in Mexico to generate the quantity required for 200 test sites the following year. For the first time, some trials are held on private farmers' fields.

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

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

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

'Special projects' are developing shorter maturity, reduced plant height, wider adaptation and more efficient tropical plants (those putting a large amount of dry matter into grain).

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

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

New germ plasm
Each year new germ plasm is tested and some is selected for addition to the back-up pools. Selections may come from the germ plasm bank (12,000 accessions of varieties, lines, wild types) which are continuously being classified; or from introduction nurseries (new materials received from national programs).

INTERNATIONAL MAIZE TRIALS

In May 1976 CIMMYT shipped seeds for maize trials to 59 countries. This was the largest maize testing program in CIMMYT's 11-year history, the number of trials rising from about 300 in 1975 to about 500 in 1976. The increase was determined by national requests. The 1976 shipments included 205 elite variety trials, 219 experimental variety trials, and 85 progeny trials.

By December 15, 1976 (cutoff date for the preliminary report) results from about 100 trials had been received in Mexico. A preliminary report was printed directly from the computer without intermediate typing. This was the second year that a preliminary report on world-wide maize trials was completed within the same calendar year that the seeds were grown. Such rapid reporting permits the preliminary results of 1976 to guide the 1977 plans.

About May 1977 a final report will be issued incorporating all 1976 data received to that time. The delay of reporting over a half year period is caused by the spread of planting dates in different parts of the world.

Elite variety trials 1976

The year 1976 was the first in which maize testing by CIMMYT reached elite varieties. Three previous years of trials were required to assemble the 30 elite varieties distributed to collaborators in 1976.

Some remarkable results can be cited.

One trial (No. 18) contained 17 elite varieties suitable for the lowland tropics, each with 'normal' protein. These were tested in 50 countries against each other and against the best local varieties and hybrids.

In 28 of the first 31 countries reporting, the best elite at their location outyielded all checks, including hybrids. The margin of yield superiority was 10 to 31 percent. The best elites also equalled or outperformed the checks in earliness, shorter plant height, disease resistance, and lodging resistance.

Elite trial No. 20 contained six elite varieties considered suitable for the sub-tropics or temperate regions. These were tested in 28 countries. Among the first 14 countries reporting, one West African site found the best elite at that location outyielded all checks by 50 percent, and 10 of the 14 sites found the best elite outyielded all checks.

Experimental variety trials 1976

A total of 219 experimental variety trials were distributed in April 1976 to collaborators in 49 countries. Each collaborator was asked to grow the trial with superior local varieties or hybrids as checks, and to report the results. Data from 32 sites was submitted in time for the preliminary report. The results of experimental varieties were similar to those described for elite varieties above. Approximately 80 percent of the sites found that experimental varieties outyielded all checks by a margin of 10

Suketoshi Taba, a post-doctoral fellow, bagging tassels which will be later used in making pollinations

to 20 percent. It is interesting to note that experimental varieties developed from trials in one country often gave top performance in other countries, thousands of miles away. This again emphasizes the value of international collaboration.

From these 1976 experimental varieties, approximately 20 elite varieties will be selected for seed increase and testing by a larger number of collaborators in 1977.

International progeny trials 1976

For the third year, progeny trials (seeds from the best ears in the advanced populations) were distributed to collaborators in 1976, this time to 85 locations. Each collaborator received 250 progenies from an advanced population, which he tested against the best local varieties (checks), and was asked to choose the 10 best progeny. Selection criteria included yield, shorter plant height, fewer days to maturity, resistance to several diseases, and resistance to lodging.

The 10 best progeny from each site have now been intercrossed by CIMMYT in Mexico during the winter season 1976-77, to create an experimental variety which will be tested by a larger group of collaborators in 1977.

These 1977 experimental varieties should be outstanding if judged by the performance of the 10 progeny from which each is created. For

International maize trials 1975 and 1976.

Region and nation	1975 Progeny trials	1975 Exp. var. trials	1976 Progeny trials	1976 Exp. var. trials	1976 Elite trials
Central American and Caribbean	*66*	*66*	*45*	*84*	*67*
Bahamas	0	0	0	0	2
Belize	0	1	0	5	2
Costa Rica	4	4	0	6	5
Dominican Republic	0	4	3	6	2
El Salvador	4	7	3	6	3
Grenada	0	0	0	0	2
Guatemala	7	6	3	8	6
Haiti	0	4	0	3	4
Honduras	5	4	4	5	6
Jamaica	0	4	0	3	6
Mexico	39	24	28	29	19
Nicaragua	4	4	2	5	3
Panama	3	4	2	3	5
Trinidad	0	0	0	5	2
South America	*16*	*43*	*9*	*44*	*37*
Argentina	0	2	0	5	2
Bolivia	0	14	0	7	3
Brazil	0	6	0	10	18
Chile	0	1	0	1	0
Colombia	2	9	3	10	4
Ecuador	4	4	0	5	3
Guyana	0	0	0	0	3
Peru	5	5	3	6	4
Venezuela	5	2	3	0	0
Tropical and Southern Africa	*20*	*29*	*11*	*42*	*40*
Benin	0	0	0	0	3
Botswana	0	0	0	0	2
Cameroon	0	0	0	5	5
Central African Rep.	0	1	0	0	2
Ethiopia	0	1	2	4	0
Ghana	0	3	2	2	1
Ivory Coast	5	4	4	4	4
Kenya	0	4	1	3	1
Malawi	0	0	0	2	2
Mozambique	0	3	0	0	0

example, 90 percent of the collaborators who grew the progeny trials in 1976 found that mean yields of the 10 best progeny were significantly better than the mean of the local checks. The superiority of yield in the progeny was generally 20 percent or greater. Commercial hybrids were included as checks in many progeny trials. The best progeny were generally earlier (1 to 4 days), shorter in plant height, and slightly better in

International maize trials, *continued.*

Region and nation	1975 Progeny trials	1975 Exp. var. trials	1976 Progeny trials	1976 Exp. var. trials	1976 Elite trials
Nigeria	6	3	2	11	7
Senegal	0	0	0	0	1
Swaziland	0	0	0	1	0
Tanzania	9	6	0	5	3
Togo	0	0	0	1	1
Uganda	0	0	0	0	3
Upper Volta	0	0	0	0	2
Zaire	0	4	0	3	0
Zambia	0	0	0	1	3
Mediterranean/Mideast	*9*	*10*	*4*	*12*	*15*
Algeria	0	1	0	0	0
Egypt	5	4	2	4	6
Iraq	0	0	0	1	0
Iran	1	2	0	0	0
Saudi Arabia	0	0	0	1	0
Sudan	0	0	0	1	1
Turkey	3	2	2	4	2
Yemen, A.R.	0	1	0	1	6
Asia	*27*	*26*	*16*	*36*	*44*
Afghanistan	0	0	0	1	1
Bangladesh	0	2	0	5	3
India	12	5	6	7	6
Indonesia	0	1	0	0	0
Khmer	0	1	0	0	0
Malaysia	0	0	0	1	1
Nepal	0	7	2	4	18
Pakistan	6	4	4	4	7
Philippines	5	3	4	6	4
Sri Lanka	0	0	0	5	2
Thailand	4	3	0	3	2
North America	*0*	*0*	*0*	*1*	*2*
Canada	0	0	0	1	0
USA	0	0	0	0	2
Total	*138*	*174*	*85*	*219*	*205*

disease resistance and lodging resistance. These traits should appear in the 1977 experimental varieties.

Requests for seed increase

Even before results of the 1976 trials were available, 17 governments asked CIMMYT for supplemental seed from the 1975 experimental varieties, with intention to increase the seed for demonstrations on farmers' fields. Such a step generally precedes release of a new variety. CIMMYT has never previously had such widespread response from one year's maize trials. Multiplication seed was ordered by Dominican Republic, Grenada, Jamaica, Costa Rica, El Salvador, Guatemala, Honduras, Brazil, Colombia, Ivory Coast, Zaire, Egypt, Tunisia, India, Nepal, Pakistan, Turkey.

1977 International trials

The distribution list for 1977 maize testing will again approximate 500 trials including 87 progeny trials, 208 experimental variety trials, and 188 elite variety trials.

Beginning in 1977, maize populations have been divided into two groups, and only one group will produce progeny for international testing each year. This schedule will permit one full year to retrieve the trial data both north and south of the equator.

FLOW OF NEW GERM PLASM

Each year raw germ plasm newly arriving at CIMMYT or drawn from the bank is tested, and the superior materials are added to the back-up pools.

Agro-climatic characteristics considered in classifying maize gene pools.

Maturity range	Altitude (m)	Latitude	Temperature*	Days to silking	Duration of crop growth (days)
Tropical lowland					
early	0-1600	0-30° N-S	25-28°C	Up to 50	About 80
medium	0-1600	0-30° N-S	25-28°C	50-60	About 100
late	0-1600	0-30° N-S	25-28°C	60-	About 120
Tropical highland					
early	1600-	0-30° N-S	15-17°C	Up to 70	About 120
medium	1600-	0-30° N-S	15-17°C	70-95	About 160
late	1600-	0-30° N-S	15-17°C	95-120	About 240
Temperate-subtropical					
early	0-1600	30-40° N-S	20-22°C	Up to 60	About 120
medium	0-1600	30-40° N-S	20-22°C	60-75	About 150

*Mean of main growing season.

Similarly, the superior progenies in the back-up pools are moved into the advanced populations.

Introduction nurseries

Over 2000 materials newly arrived in Mexico from national programs were planted in observation nurseries during 1976. The best will be moved directly into the back-up pools in 1977. A few will be further improved in the breeding nurseries before they are incorporated. New materials are especially needed for earliness and disease-insect resistance.

Flow from the bank

In the summer of 1976, 278 bank accessions of early tropical character were evaluated at three sites (Poza Rica, Tlaltizapan, Obregon) in an effort to identify widely adapted materials that could be added to the early tropical gene pools. Fifty accessions were chosen on the basis of their performance across sites. They will be further improved in 1977 through reselection in the breeding nursery before being incorporated into the pools.

Early tropical pools

To upgrade the early tropical pools for yield, lodging resistance, insect and disease resistance, they were crossed in 1975 with a mixture of families from advanced populations having matching grain type. The best early progenies from these crosses were selected from F2's in 1976 and used to reconstitute the tropical early pools.

Temperate pools

Four additional gene pools for temperate regions were developed in 1976 by recombining inbreds, hybrids, and varieties of broad genetic base originating from widely located temperate areas. The additional pools are temperate early white dent, temperate early yellow flint, temperate early yellow dent, and temperate intermediate white flint.

Improving wide adaptation in pools

All back-up pools were grown in 1976 under a procedure to improve wide adaptation. Tropical pools were planted at two sites (Poza Rica, Obregon), temperate pools at three sites (Poza Rica, Tlaltizapan, Obregon), and highland pools at two sites (El Batan, Toluca). Superior families were identified at each site by an interdisciplinary team. The process was repeated at several stages of plant development. Finally, the best plants were tagged at each site, within families superior at all sites.

At harvest the best ear was chosen among the selected plants for each pool and each site, to reconstitute the pool. Exceptions were made: ears found greatly superior at only one site were also retained, to provide superior recombinants for the future. This procedure is expected to provide a faster approach to wide adaptation, without sacrificing site-specific adaptation.

GERM PLASM BANK

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

Collection and storage

The 12,000 items in the CIMMYT bank were gathered from 46 countries mainly by an agency of the Mexican Ministry of Agriculture during the 1940's and 1950's. Over 90 percent of the collection consists of the species *Zea mays* L. The collection also contains near relatives including *Zea mexicana, Zea perennis,* and *Tripsacum* species (a relative of maize).

The bank is held in concrete chambers at a temperature of 0 degrees C. There are over 18,000 labelled storage tins of 2-liter and 4-liter capacity containing 40 tons of seed. The tins are arranged on steel shelving like library stacks.

A duplicate seed supply for the CIMMYT collection (500 grams per item) is being deposited for long term storage at the U.S. National Seed Storage Laboratory.

Regeneration

Fresh seed was grown for over 8000 bank items between 1969 and 1975. In 1976 fresh seed for another 276 accessions was added to the bank, 112 items grown in Mexico and 164 by the national maize program of Peru which offers climatic conditions more suitable for some floury germ plasm. Over 90 percent of the bank now consists of seed less than 7 years old.

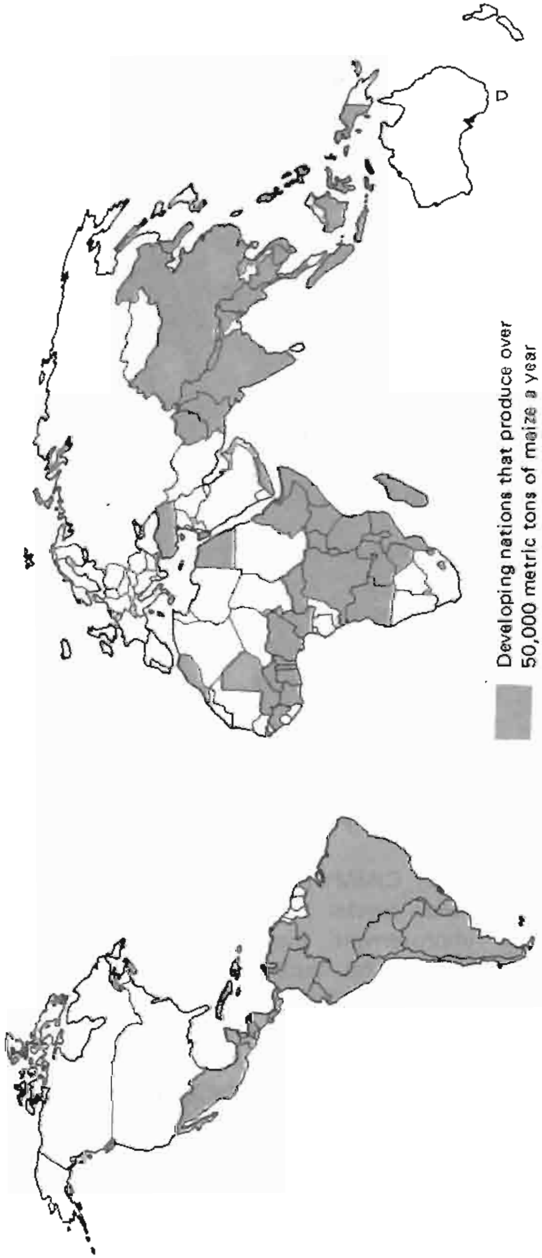
Classification and cataloging

Over 8000 of the bank items have been documented for agronomic characteristics, and 3000 of them tested in replicated yield trials. A catalog on computer is in preparation giving name of each accession, country of origin, agronomic information, current quantity of seed, location of storage tin, etcetera. Collaborators on the catalog include the U.S. National Seed Storage Laboratory and the International Board for Plant Genetic Resources.

Shipments to clients

CIMMYT offers free samples of seed from the bank to all research organizations. From 1966 to 1975 the bank made 588 shipments to 80 countries, representing almost 25,000 seed items. During 1976 there were 59 shipments totalling 2412 seed items to 27 countries.

CIMMYT continues to fulfill the role of caretaker of the world's largest maize collection.


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

Selections made in dozens of countries are multiplied in Mexico and redistributed.

SPECIAL RESEARCH PROJECTS IN MEXICO

When CIMMYT staff encounter a problem in maize which they believe needs special attention apart from the broad program of population improvement, they handle it in a special project. The scientist then confines his studies to one or several chosen populations. Any usable conclusions from the special project will later be applied to all populations. This procedure is a measure of economy.

CIMMYT now works on five special projects: for shorter maturity (days of growth from seeding to maturity), shorter plant height, wider adaptation, drought tolerance, and greater plant efficiency for the tropics.

Shorter maturity

Many tropical maize-growing countries seek varieties which ripen earlier to fit a brief rainy season, or to fit a tight cropping sequence (for example, the three-crop rice-rice-maize rotation in one year in southeast Asia).

More than one approach is being tried to develop very early maturity populations. In one, earliness is approached by gathering short-season maizes from all over the tropical world, intercrossing some of them for a number of generations, and selecting progeny with both shorter maturity and good yield.

One population being worked by this approach is a combination of three maizes from widely separated areas: (1) an Indonesian material which matures in 80 to 85 days in Indonesia; (2) a maize grown by the Guajira Indians in northeast Colombia, maturing in 80 days under Colombian climate; (3) a maize from the lowlands of Honduras-Nicaragua which flowers there in 40 days and matures in 72 to 80 days. All three acquired their short-season character from the pressure of short rainy seasons in their present homeland. After 2 years of intercrossing at CIMMYT, this Indonesian-Colombian-Honduran mixture was harvested in less than 90 days at Poza Rica, and showed good plant type. Already the population is earlier than any commercial variety used in Middle America.

A second approach to shorter maturity is much slower: mixing early maize from the lowland tropics with early materials from the higher latitudes or higher elevations. Excellent short-season materials are available from the temperate regions of the USA, Canada, and elsewhere, but they are vulnerable to tropical diseases, and disease resistance must be bred into them before they can contribute satisfactorily to a tropical variety. Possibly, in the long run, the tropical x temperate approach may produce the best results.

A third approach involves the crosses of early tropical types with intermediate and late maturity tropical varieties plus a long range procedure of gradual selection for earliness in the resulting segregating mixture.

Reduced plant height

During 13 generations starting in 1968 CIMMYT has shortened some varieties of tropical maize by 1.5 meters, to the approximate height of 'corn belt' maize. A special project is now continuing selection of shorter height to determine how far the shortening process can proceed without adversely affecting yields, and to see what happens to other characteristics as height is reduced By the end of 1978 scientists anticipate that generally applicable conclusions can be drawn.

So far, shorter plant height has reduced lodging, and the shorter plants tolerate higher plant population. These are gains. Standard yield trials will await still further shortening.

Wider adaptation

In 1977 CIMMYT makes its 10th cycle of crosses in a maize population drawn from many climates (for example, northern Canada, equatorial Brazil, and the southern tip of Argentina). Ten years ago the cold climate materials would not set seed in the lowland tropics, and vice versa, because of sensitivity to differing day lengths, temperatures, and diseases. Today the mixture sets seed in all maize growing climates. In the winter of 1976-77 selections from this mixture grown in Canada, Colombia, Hungary, and South Africa were combined in Mexico for still another international test. Natural selection for wide adaptation continues.

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

More efficient tropical plants

Physiological studies at CIMMYT during 1970-75 concluded that tropical maize produces about as much dry matter as the corn belt (temperate climate) plant, but the grain yield is lower, caused not by heat and humidity, but by inefficiency of the plant (it devotes more energy to fodder and less to grain).

Scientists are investigating two approaches to improvement of efficiency. The first is to cross tropical x temperate germ plasm to combine the better yield distribution of the temperate material and the better disease and insect resistance of the tropical material. Three populations which contain varying proportions of tropical and temperate germ plasm are currently being exposed to lowland tropical environment for selections.

The other approach is to select within the tropical material for a temperate-type morphology (plant architecture). Scientists are investigating the possibility that the larger tassel of the tropical plant may dominate the development of the ear or that the excessive leaf area above the ear in tropical material may reduce the grain-producing efficiency of the plant.

To test this hypothesis CIMMYT scientists are selecting for smaller tassels and a reduced leaf area above the ear in three advanced populations. After some more generations of selection and recombination the resultant materials will be retested along with the original population to determine if smaller tassels or less leaf area above the ear are characters associated with more efficiently yielding plants.

Drought tolerance

In drought studies, CIMMYT physiologists conducted a test in 1976 to determine whether families within a population have different degrees of tolerance for drought. Scientists are using two criteria to measure drought response. First, during the vegetative stage of growth they measure the rate of cell elongation of families under irrigation (no stress) and under rainfed conditions (various degrees of stress) and select those families in which there is little change in elongation rate between the two water treatments.

Second, they look for families whose yields are good under both irrigated and stress conditions.

Some families have been identified which appear better than others in drought response. To verify this, the 10 best families for each water treatment (medium and severe water stress) were intercrossed to develop synthetic varieties and these are being evaluated under the water treatments. If a practical test to determine differences can be found, the techniques used here could be applied in other parts of the breeding program.

PROTEIN IMPROVEMENT

Protein is unsatisfactory in most maize. In a commercial maize crop, protein ranges from 9 to 11 percent of the grain weight, which is adequate for balanced human nutrition if all of it could be utilized. But maize protein is low in lysine and tryptophan, two essential amino acids. Because of inadequate lysine and tryptophan the body can utilize only half the protein in normal maize. Lysine is typically 2 percent of protein in normal maize, whereas 4 percent would be needed to permit use of all the protein.

Scientists at CIMMYT and elsewhere have been working for a decade on the problem of poor quality maize protein.

Maize protein can be improved by introducing various genes but the added genes bring undesirable effects which have not yet been fully corrected.

One breeding approach is through opaque-2 mutant gene (the name comes from the appearance of the kernel), but opaque-2 maize has serious defects: yield drops because the opaque-2 maize contains a soft endosperm which weighs less than the endosperm of normal maize; most consumers of maize are reluctant to accept opaque-2 maize as a food because of its appearance; adequate disease and insect resistance has not been obtained in the quality protein maize.

Since 1969 CIMMYT breeders have been selecting opaque-2 populations with modified hard endosperm, normal appearance, resistance to ear rots, and higher tolerance for stored grain insects. This is a slow process.

Continued progress in 1976 was indicated by the following:

(1) CIMMYT now has developed 29 gene pools and 17 advanced populations carrying the opaque-2 gene and is selecting hard endosperm versions for most of these materials.

(2) When 23 experimental varieties carrying opaque-2 gene were tested in 1976 at seven locations world-wide, the opaques yielded as well or better than the checks, including the normal checks. Similarly, when seven elite varieties carrying opaque-2 gene were tested in 1976 at 14 locations world-wide, the opaque elites yielded as well as or better than the mean of the checks, including normal checks.

(3) Performance of the opaques in 1976 is all the more impressive

Alex Ortega uses a 'bazooka' to apply precise amounts of insect larvae to each plant.

because the experimental varieties so far available are based on selections made in Mexico before 1974, whereas selections made since 1974 show great improvement in the breeding plots in Mexico. These later selections will appear in the international variety trials over the next 1 to 3 years.

CIMMYT has entered into collaborative research with the national programs in Philippines, Nepal, Zaire, Tanzania, Ghana, Ecuador, and Guatemala. Each is developing open-pollinated opaque varieties suitable for its own agro-climates.

In highland locations, particularly in the Andean region, farmers prefer maizes that have soft endosperm and large kernels. These are called floury maize. Starting in 1975 CIMMYT crossed floury maizes with sources of the opaque-2 gene. Since the floury kernels have the same appearance as opaque-2 kernels, the ninhydrin test (chemical laboratory test) is used to select segregating kernels that contain the opaque-2 mutant gene.

A composite was formed from opaque-2 x floury-1 crosses that were made in 1974. Selected ears from this composite were shelled and the largest kernels from each ear were planted to obtain further cycles of recombination. Several more cycles will be needed to judge progress.

Scientists at Purdue University (USA) have found that the double mutant sugary-2 x opaque-2 has several advantages over ordinary opaque-2 maize; for example, hard endosperm, good digestibility, good biological value, less ear rots, and less damage from storage insects. One disadvantage is the small size of the kernels which causes lower yield.

A composite of Sugary-2 x Opaque-2 has been made and is undergoing its first cycle of recombination in 1977.

Little maize has been planted commercially with high quality protein. USA, Brazil, Colombia and Yugoslavia have released opaque-2 hybrids which are grown mainly for animal feeds. In the USA less than 200,000 hectares of opaque-2 maize is grown.

CIMMYT believes that a breakthrough on commercial use of high quality protein maize will come only when a variety carrying the opaque-2 gene, or its equivalent, shows yields and agronomic performance equalling or surpassing the existing normal varieties, and the protein quality is a bonus.

DISEASE AND INSECT RESISTANCE

The plant protection staff (pathology and entomology) work as part of an interdisciplinary team for maize. They assist in rating disease and insect damage on trials of raw germ plasm, of back-up pools, and of advanced populations. They also conduct studies of disease and insect resistance.

Insect and disease nurseries

To determine how each family of maize reacts to high levels of attacks, the plant protection scientist plants separate disease and insect nurseries for each advanced population. These nurseries are subjected to severe attacks of disease and insects.

For disease nurseries, all 250 families represented in the yield trial of each advanced population are planted in 5-meter rows. Plants in half of each row are inoculated with stalk rotting organisms; plants in the other half are inoculated with ear rotting organisms. At harvest the pathologist scores each row for disease damage, and progenies with the least amount of damage are retained for succeeding generations.

For insect nurseries, the same families are planted and artificially infested with larvae of fall armyworms and sugarcane borers. These are the most widespread and important of maize pests in Mexico and the tropics of the Western Hemisphere. At appropriate intervals after infestation a score for insect damage is determined visually for each row. Progenies showing the least damage (most resisant) are retained and the most severely damaged (most susceptible) discarded.

Under recurrent selection pressure with the uniform artificial infestation techniques which CIMMYT developed in 1976, the populations should gradually increase in resistance to these important diseases and insects.

Insect-rearing laboratory

Large numbers of insect larvae are required to infest artificially the advanced unit companion nurseries and other CIMMYT materials. An insect rearing laboratory has been established which has the capacity to produce the numbers of insect larvae required to infest the progenies to be evaluated. In the last 2 cycles of 1976 CIMMYT produced and infested in the field over 4,000,000 *Spodoptera frugiperda* larvae and over 500,000 *Diatraea sacchacalis* larvae. Also laboratory colonies of the corn earworm (*Heliothis zea*), southwestern corn borer (*Diatraea grandiosella*), and neotropical corn borer (*D. lineolata*), were initiated. As more efficient rearing techniques for these species develop, maize materials will be evaluated and selected for resistance to them.

Collaborative research

Starting in 1974 a collaborative breeding project was organized between CIMMYT and six strong national maize programs, who are jointly developing germ plasm resistant to three damaging international diseases of maize.

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

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

In 1974 CIMMYT assembled in Mexico three broad-based populations which could have general acceptance in the tropics if they carried resistance to the three diseases. The three base populations, plus 93 other heterogenous populations were crossed to sources of resistance to the three diseases.

In 1975, 4000 experimental progenies selected from these crosses were sent to the six participants, to be screened for resistance to the diseases. All plantings in Africa were lost in 1975 due to drought, thus delaying the streak virus studies 1 year. But families resistant to downy mildew in Asia and to stunt virus in Latin America were identified by the collaborators.

In the spring cycle of 1976 those families identified for resistance in

Asia and Latin America were recombined in Mexico, using seed from resistant plants identified in the diseased areas. After recombination, plants were selected and seed was again sent to the six collaborators for planting in the autumn of 1976.

Alternate cycles of a) screening and selfing the resistant families in the collaborating countries and b) evaluation in these countries with recombination in Mexico will continue for several additional years, in expectation that sub-populations will emerge which give good resistance to each of the three diseases, and possibly also to combinations of resistance for two or three diseases.

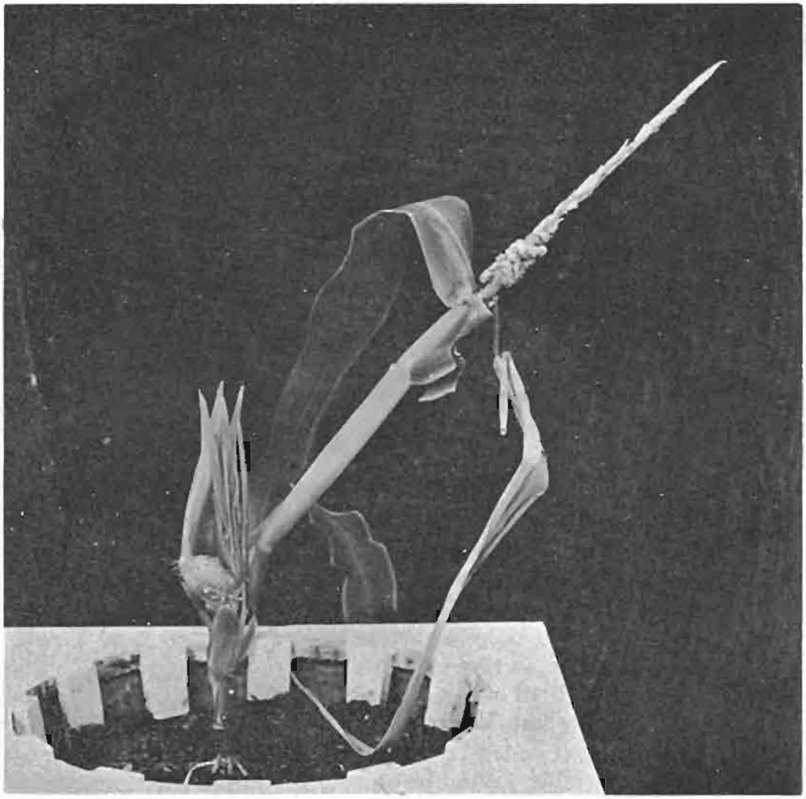
This example of 'shuttle breeding' is one of the advantages of the worldwide network of maize scientists, not feasible before the 1970's.

WIDE CROSSES

Since 1973 CIMMYT has conducted a modest program of crosses between genera (wide crosses) to investigate potential uses of alien germ plasm in maize improvement. Alien genera with desirable characteristics are crossed with maize. The immature embryo is excised (cut out from the seed) and grown in a medium to prevent the embryo from breaking down. Where possible, progeny are examined to see if they possess desired characteristics, and are used as parents for further crosses.

In 1976 over 10,000 crosses were made between maize and tripsacum, a wild relative of maize, and seven F1 hybrids were identified. The progeny were screened for resistance to fall armyworm, a pest to which maize is generally susceptible but tripsacum shows varying levels of tolerance. Some of the CIMMYT's F1 hybrids show the same level of tolerance as their tripsacum parent. Incorporation of armyworm tolerance into commercial maize would be worth millions of dollars to the world crop. CIMMYT will make further crosses to tranfer this character to maize and will continue maize-tripsacum crosses for possible transfer of other desirable characteristics.

In 1976 over 25,000 crosses were attempted between maize and sorghum. Several hybrids were identified, but the plants were not stable and chromosome loss resulted in various cells in the same root tip having different chromosome numbers. Only one hybrid reached maturity in 1976. The plant produced a terminal inflorescence, the upper portion of which was male, but no viable pollen was produced. The lower portion was female and set seed after pollination with maize. The hybrid then produced four lateral ears, one of which set seed after pollination with both sorghum and maize. The three later-developing ears gave no seed set. Some seeds collapsed and died, and others did not develop normally, but 11 progeny plants (BC1 generation) with various chromosome numbers (aneuploids) survived and were growing in the glasshouse in 1977.



The world's first maize-sorghum hybrid, produced at CIMMYT in 1976. The plant is male sterile. Maize pollen was used to produce seeds on the terminal inflorescence and on one of four lateral ears.

Scientists have attempted maize-sorghum crosses for many decades, without success; this combination was generally considered impossible. The hybrids at CIMMYT open the possibility for using sorghum germ plasm in maize improvement. For example, one useful characteristic of sorghum is that it is notably more drought tolerant than maize. This hybridization might also prove the first step in development of a new food crop.

This progress has encouraged CIMMYT to broaden its wide cross experimentation to include attempts at a maize-millet hybrid. Work began in 1976.

MAIZE TRAINING

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

—In service training: generally 5 to 6 months

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

In-service training

The maize in-service training program is only 6 years old but already 285 participants from 44 countries have passed through the course, including 58 in 1976. The program receives about 50 trainees per year, one fourth specializing in crop improvement, and the rest in production agronomy.

In-service training is designed to develop skills in field research, production management, and laboratory techniques, to give experience on an interdisciplinary team, and to teach the relationship between improved technology and development. The typical participant has had 5 to 10 years experience in a government agency. The courses in Mexico stress learning by doing, and the discipline of working long hours under heat, humidity, and torrential rains.

One feature of production training is the layout of agronomic trials on private farmers' lands, and organizing field days for farmers. This work is performed by trainees in Veracruz State under supervision of the CIMMYT training officers and the Mexican extension service. The on-farm research helps identify the limiting factors in yield, and permits farmers at a field day to select their own technology.

Training in national programs

Starting in 1974 CIMMYT offered in-service training for officers from national programs who were preparing to give short courses for production agronomists in their own country. Eight trainers have now been trained (Ecuador-3, El Salvador-3, Philippines-1, Pakistan-1) and another Pakistani is taking this training in 1977.

CIMMYT training staff members in Mexico are occasionally lent to national programs outside Mexico where they assist with local courses. During 1976 the director of maize training in Mexico participated in short courses for production agronomists in Honduras and Panama. This local training role will be extended in 1977 to El Salvador, Nicaragua, Ecuador, and Nepal.

Academic training

During 1976 the maize program cooperated in the training of three master's degree candidates in Mexico, seven predoctoral fellows in the USA, and 13 postdoctoral fellows at CIMMYT in Mexico.

An unusual feature of academic training is the interdisciplinary advanced degree program. Such programs were under way in 1976 between CIMMYT and Kansas State University (at the M.S. level) and Cornell University (at the Ph.D. level). Teams of candidates did their thesis research together in Mexico but receive their degrees from Kansas State or Cornell. The candidates came from nine countries (Cameroon, Colombia, Honduras, Kenya, Malaysia, Pakistan, Rhodesia, USA, and Zaire).

Postdoctoral fellows serving with the maize staff in Mexico have increased from five per year during 1970-73 to 10 or more per year during 1974-77, and the number of fellows is expected to remain at the higher level through the remainder of the 1970's. At the beginning of 1977 the postdoctoral fellows in maize came from seven countries (England 1, El Salvador 1, Germany 1, Iceland 1, Japan 1, New Zealand 1, USA, 2).

Visiting scientists

During 1976 the maize program received 18 visiting scientists and 51 short-term visitors. Visiting scientists are senior crop researchers or experiment station managers who spend a week to a year at CIMMYT to become familiar with world germ plasm and CIMMYT research methods

Maize in-service trainees 1971-76.

Region and Country	1971-75	1976	Region and country	1971-75	1976
Latin America	*103*	*37*	Pakistan	13	3
Argentina	11	0	Philippines	14	0
Belize	3	2	Thailand	3	3
Bolivia	5	2			
Brazil	3	0	*North Africa and Mideast*	*14*	*3*
Colombia	5	0	Algeria	1	0
Costa Rica	1	2	Egypt	8	2
Chile	2	0	Tunisia	1	0
Dominican Rep.	4	2	Turkey	3	0
Ecuador	9	0	Yemen A.R.	1	1
El Salvador	12	8			
Grenada	0	1	*Tropical Africa*	*65*	*11*
Guatemala	9	5	Cameroon	1	0
Guyana	1	0	Ethiopia	1	1
Haiti	3	2	Ghana	6	0
Honduras	14	4	Ivory Coast	4	0
Mexico	7	3	Kenya	2	1
Nicaragua	4	4	Malawi	0	1
Panama	3	0	Nigeria	12	0
Peru	3	2	Tanzania	19	6
Venezuela	4	0	Uganda	1	0
			Zaire	19	1
South and East Asia	*44*	*7*	Zambia	0	1
India	2	0			
Japan	3	0	*Other*	*1*	*0*
Korea	0	1			
Nepal	9	0	*Total*	*227*	*58*

which may be used in their own national programs. Short-term visitors are often agricultural policymakers and administrators who spend 2 to 7 days at CIMMYT.

MAIZE COOPERATIVE PROJECTS OUTSIDE MEXICO

During 1976 CIMMYT posted 16 maize scientists to work with cooperative projects outside Mexico.

Eleven scientists were assigned to collaborate with national programs, and five with regional programs.

A national maize program typically serves the following purposes: (1) to improve maize research in local experiment stations; (2) to test experimental varieties on local farmers' fields, thus helping to transfer technology from experiment station to the farmer; (3) to multiply seed for improved varieties; and (4) to provide additional training for local scientists. CIMMYT's assigned staff share in these activities, including the testing of germ plasm received from national programs and from Mexico, and the feedback of information on the suitability of these materials to the whole network of maize scientists.

These cooperative arrangements between CIMMYT and national programs are part of CIMMYT's world-wide research effort, and also serve national food production campaigns.

The following countries now participate in cooperative arrangements:

Country	*Start of CIMMYT arrangement*	*CIMMYT assigned staff 1976*	*Approximate maize crop (tons)*	*Donor**
Pakistan	1968	1	700,000	USAID/Ford
Egypt	1968	1	2,500,000	Ford
Zaire	1972	4	500,000	Zaire
Nepal	1972	1	800,000	USAID
Tanzania	1973	2	800,000	USAID
Guatemala	1976	2	600,000	USAID

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

Participation by CIMMYT in each national program may continue 5 to 10 years, subject to mutual agreement among the cooperating country, the donor, and CIMMYT.

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

Typically a regional program will sponsor: (1) an annual workshop among maize scientists of the region to review their past year's research and make plans for the following year; (2) circulation of annual nurseries to be grown by all cooperators in the region, followed by exchange of trial data; (3) visits of local scientists to observe research in neighboring countries; and (4) continuing consultation by CIMMYT scientists posted in the region.

In 1976 CIMMYT maize scientists assisted the following regions:

Region and headquarters	*Number of cooperating countries*	*1976 population (millions)*	*Maize crop (tons)*	*CIMMYT assigned staff 1976*	*Donor*
Central America and Caribbean (Mexico)	9	34	2,200,000	2	IADB
South and Southeast Asia (India)	15	1300	16,000,000	1	UNDP
Andean (Colombia)	5	65	2,400,000	2	CIDA

Prior to 1974 CIMMYT attempted to monitor the international maize trials of these governments by the travel of CIMMYT staff from Mexico. But the volume of consultation made it impossible to provide adequate service in this manner.

Regional programs require no construction of new headquarters, and no acquisition of land. Where possible CIMMYT staff are attached to other international centers or to strong national programs.

Naturally, cooperative programs vary widely according to the wishes of the governments which sponsor them. Therefore, notes below will report on the circumstances and recent developments in each program.

Pakistan National Maize Program

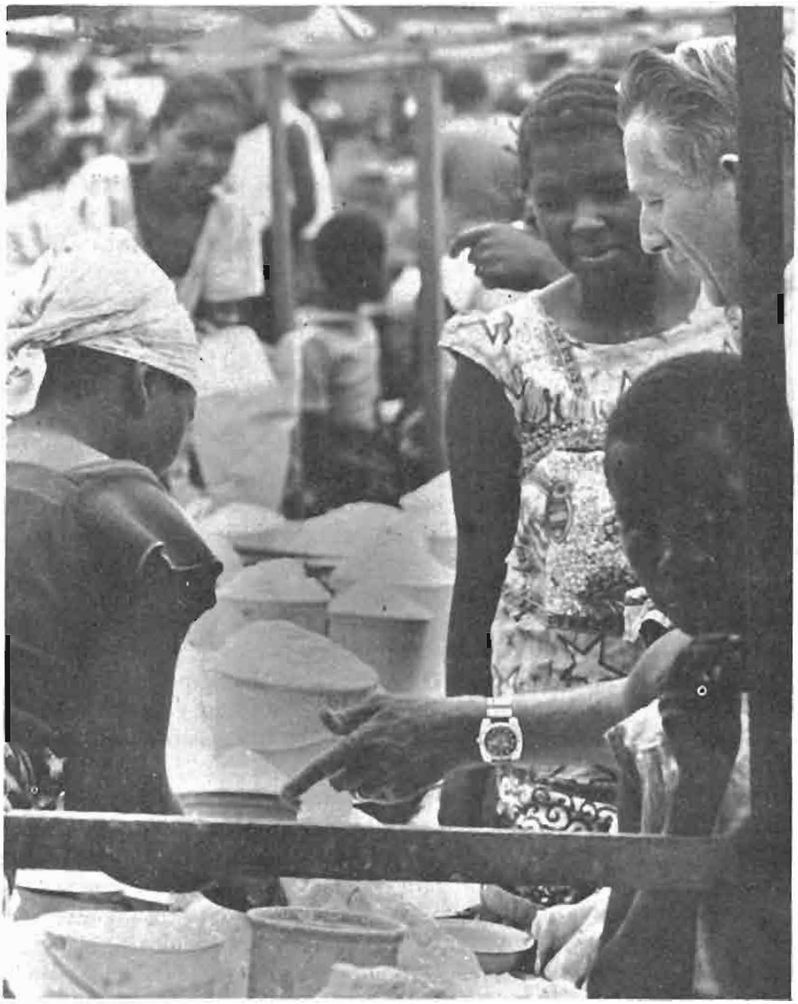
CIMMYT collaboration with the Pakistan national maize program has entered its ninth year in 1977. During this period CIMMYT has continuously posted one or two maize scientists to Pakistan research stations. Maize is the No. 3 food crop (after wheat and rice), supplying a Pakistani population of 76 millions, which is increasing 2.9 percent a year.

Eleven Pakistani maize scientists received training in Mexico during 1972-76, including three during 1976. One recent trainee was an extension leader preparing to serve as training officer for the Pakistan extension service. In addition, two Pakistanis completed M.S. degrees in maize research in the U.S. and one Pakistani is still completing his Ph.D. there.

Pakistan receives and grows CIMMYT international trials for maize progeny, experimental varieties, and elite varieties. Most CIMMYT germ plasm has too long a growing season for Pakistan's climatic zones, but Pakistan is selecting earlier materials from within the CIMMYT shipments.

CIMMYT methods for developing experimental varieties have been adopted by Pakistan.

This strengthened maize breeding program in Pakistan has released to local farmers a number of improved open-pollinated varieties, now widely grown, and several Pakistan varieties have proved superior when tested in neighboring Asian countries.



In the Lubumbashi market, Tom Hart, CIMMYT team leader in Zaire, asks about the price of maize flour.

During 1977 one CIMMYT agronomist continues to work in the Pakistan research service, assisting with training courses for the extension service, and consulting on maize trials on private farmers' lands.

The average yield of maize in Pakistan has gradually increased by 20 percent during the last nine years but this falls short of the population growth of 30 percent in the same period.

A Pakistani economist collaborating with the CIMMYT economics program has completed a farmer survey to study why the majority of farmers do not apply the recommended technology.

CIMMYT's cooperation with the Pakistan maize program is sponsored by the Agricultural Research Council of Pakistan.

Egypt National Maize Program

Egypt is making a determined effort to reduce its food deficit which has required imports of 1.5 to 2.5 million tons of grain per year during the 1970's. Population has now passed 38 million, and grows at 2.3 percent a year.

Maize, wheat, and rice are the three largest grain crops of Egypt, in order of area.

CIMMYT has maintained one maize scientist in the Egyptian program since 1968.

During 1975-76 Egyptian maize researchers identified shorter and higher yielding open-pollinated varieties, organized 60 on-farm trials, and conducted an economic survey of 160 farmers.

Fourteen young Egyptian maize scientists received training in Mexico during 1970-76, including two each year in 1975 and 1976. Two senior Egyptian maize scientists spent half of 1976 as visiting scientists in Mexico and USA.

Despite these efforts, the increase in maize yields over the last decade has not kept pace with a 25 percent increase in population in the same period, and the government continues to look for a more rapid increment in grain production.

Zaire National Maize Program

Zaire's 26 million people are primarily maize eaters consuming also some wheat and rice. As a food-deficit country, Zaire has been importing all of its wheat, much rice, and 160,000 tons of maize, and paying for it with copper exports.

During 1972-76 Zaire utilized its own funds to finance a four-man scientific team from CIMMYT to help develop a national maize program. The annual maize crop of 500,000 to 600,000 tons represents two thirds of the national grain production, and the low average maize yield (about 700 kg/ha) offers substantial opportunity for improvement.

During 1972-76, 20 young Zairian university graduates were sent to CIMMYT for one cropping season of training and seven Zairians were sent for higher degrees at agricultural universities in the USA.

From this group, a nucleus staff for the Zaire National Maize Program has been organized.

Zaire participates in international maize nursery trials shipped from Mexico, Kenya, Nigeria, and Thailand. The best of the experimental varieties from Mexico have been widely tested on private farmers' fields. Three elite varieties have now been multiplied for general use in Zaire. Beginning in 1977, a steady flow of new varieties should be available, each showing some improvement in yield or quality.

At the end of 1976 CIMMYT reduced the CIMMYT scientists in Zaire from four to two, reflecting the growing strength of the young but competent national staff.

Tanzania National Maize Program

Like most countries in tropical Africa, Tanzania eats more maize than other cereals. It is a food deficit country, partly because a semi-arid climate has caused local grain production to fluctuate from 1.0 to 1.5 million tons a year during the 1970's. With a population of 16 million growing 2.7 percent a year, the government found it necessary to import more than 250,000 tons of maize per year in 1974 and 1975.

CIMMYT has agreed to station two maize scientists in Tanzania since 1973 to assist the national maize program. Twenty-one young Tanzanian university graduates have been sent to Mexico for one season of maize training during 1973-76, six of them in 1976. And four Tanzanians have been sent to U.S. agricultural universities for advanced degrees.

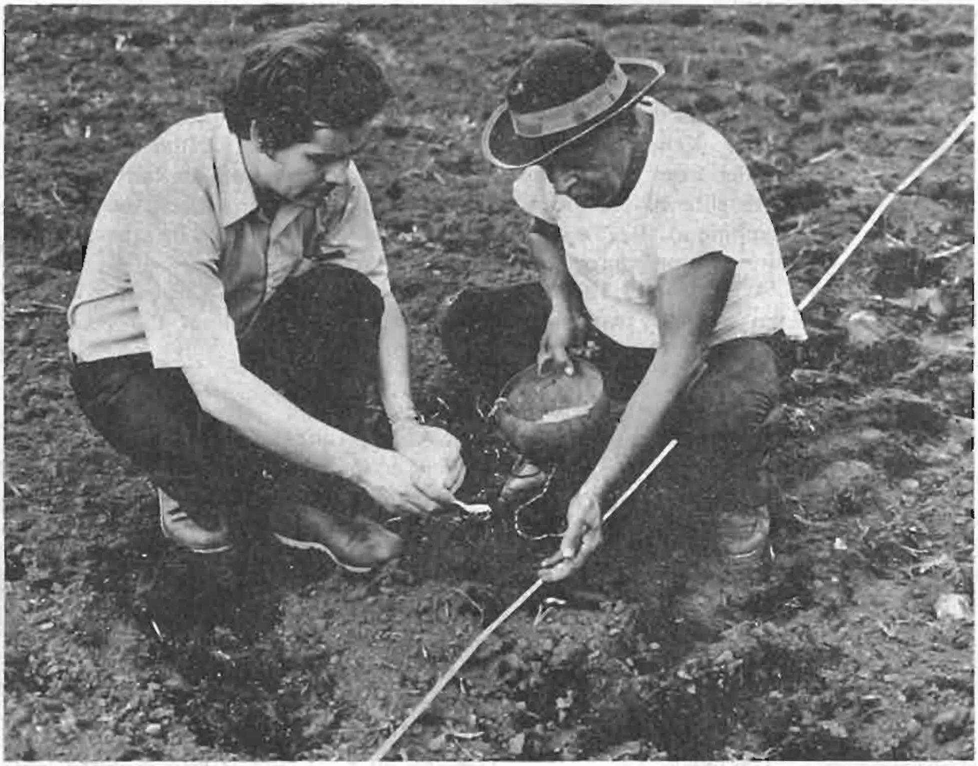
The Tanzanian maize breeding program, assisted by CIMMYT, is located at Ilonga Station 200 kilometers west of Dar Es Salaam. Here scientists have identified several experimental maize varieties which outperform the varieties in commercial use. Foundation seed for one new variety was delivered to the Tanzania seed program at the end of 1976, to be multiplied, and several more varieties will be ready for seed increase in 1977.

Two donors, World Bank and USAID, have pooled US$30 million to support a 7-year maize production program concentrating on 950 ujamaa-type villages (cooperative production units).

A training program for maize extension workers has been organized at Mbeya research station, using the CIMMYT-introduced on-farm trials as the means of communicating with farmers. CIMMYT staff from Mexico participated in a 'train the trainers' course in Tanzania in September 1975, as a forerunner of the present training plans.

It appears that pieces are falling into place for a sustained production program during the remainder of the 1970's, in which any new maize technology developed with assistance from CIMMYT will be given immediate use in the national production scheme.

CIMMYT's work in Tanzania is part of a joint IITA-CIMMYT effort, in



Roberto Soza, left, CIMMYT regional agronomist, planting a trial in a farmer's field in Panama.

which IITA is responsible for overall crop improvement, with emphasis on legumes.

Nepal National Maize Program

Nepal is one Asian national program which has been feeding itself. But food production per capita has gradually declined during the 1970's because grain production plateaued (about 3.5 million tons a year) whereas population has been rising 2.3 percent a year, and passed 13 million in 1976.

CIMMYT first posted a maize scientist to Nepal in 1972.

In 1976 Nepal invited several international organizations to assign staff to collaborate with local agricultural services, including IRRI for rice (local crop 2,500,000 tons), CIMMYT for maize and wheat (maize 800,000 tons, wheat 300,000 tons) and the International Agricultural Development Service (to assist cropping systems on the cereals and other crops).

Eight Nepali maize scientists have received training in Mexico during 1971-75, and they now constitute the nucleus of Nepali collaborators who grow CIMMYT's international maize nurseries, breed local varieties, and place trials on private farms.

Guatemala National Maize Program

Starting in 1976 CIMMYT assigned two maize scientists to collaborate with the Guatemalan national maize program. This program seeks to expand and stabilize the national maize crop which has fluctuated unpredictably between 600,000 and 1 million tons a year during the 1970's. Average maize yields below 1000 kg/ha suggest that early progress is possible.

Guatemala reorganized its agricultural research institute in 1975, strengthened the budget and staff, sent many agricultural officers for advanced study, organized a 1-year internal course for new research staff, and began massive testing of new maize varieties on farmers' fields.

Guatemala participates in CIMMYT's international maize testing program. Past trials indicate that some experimental varieties are well adapted to the Guatemalan lowlands where the larger part of the Guatemalan crop is grown; but improved maize materials adapted to the Guatemalan highlands (above 1500 meters) are yet to be developed.

Breeding efforts in Guatemala include both open-pollinated varieties and hybrids. An effort toward protein improvement is conducted in association with the Institute of Nutrition for Central America and Panama.

Regional program: Central America and Caribbean

In 1974 the Inter-American Development Bank gave CIMMYT a 2-year grant to collaborate with nine governments in Central America and the Caribbean for improvement of their maize crops. Starting in 1977 support was provided by Switzerland.

These nine countries had a population of 31 million people increasing at 3 percent a year. This is a food deficit area: local grain production is about 3.5 million tons a year, supplemented by imports of another million tons.

Most people in the region are maize eaters. Maize represents two thirds of local grain production, and probably contributes two thirds of total calories and two thirds of total protein in the diet.

Starting in 1974 CIMMYT assigned two maize scientists to work in this region. They spent 40 percent of their time during 1975 and 1976, consulting with maize scientists in participating countries, and meeting with agricultural policy makers. In their remaining time, they provided research and training services from Mexico.

The breeder on this team helped plan the annual research programs of the nine governments, recommended what experimental nurseries should be shipped from Mexico, advised local policy makers on the requirements for research budget, staff, and inputs; and helped organize two workshops each year among the maize scientists of the region.

The CIMMYT agronomist promoted on-farm trials for new maize varieties and conducted training courses for extension agronomists in two countries, an activity expected to expand in future years.

Training in Mexico of young scientists from this region was speeded up: 16 in 1975 and 21 in 1976. Upon returning home, these young men join the collaborators who conduct research on new varieties, and organize trials on private farms.

When these regional activities began in 1974, average maize yields in the nine countries ranged from 0.7 to 1.7 tons per hectare, mostly below 1 ton. Success of the program will be judged by the increase in yields over a period of years.

Regional program: South and Southeast Asia

CIMMYT received financial support from UNDP in 1976 to strengthen the maize improvement program in Asia for a 3-year period, 1976-79. Exchange of maize technology in this region began in 1964, through an informal arrangement between governments.

South and Southeast Asia has the largest food deficit of any region in the world.

The region produces about 16 million tons of maize in 15 countries stretching from Afghanistan-Pakistan in the west to the Philippines-Indonesia in the east. This makes maize the third ranking grain crop (after rice and wheat). Four countries of the region each produce over 1 million tons of maize a year (India, Thailand, Philippines, Indonesia).

In 1976 CIMMYT posted one of its international scientists to the region, where his efforts are concentrated on the following objectives: (1) to reinvigorate regional trials of improved maize materials selected both from national programs and from Mexico; (2) to promote trials off the experiment station, on private farms; (3) to organize an annual workshop for maize scientists of the region; (4) to arrange training for maize scientists, both within their home country and elsewhere; and (5) to consult with participating governments on any scientific problem constraining expansion of maize.

Work in 1976 was focused on eight countries: India, Pakistan, Nepal, Sri Lanka, Thailand, Malaysia, Philippines, and Indonesia.

In recognition of the calibre of some scientists working for national programs in the region, CIMMYT is requesting governments to permit these scientists to serve as short-term consultants in neighboring countries.

Regional progeny trials for maize resistant to downy mildew (a fungus disease) will be assembled and circulated by Thailand and the Philippines.

In 1977 CIMMYT anticipates that two staff members will be on duty in the region, and that the exchange of germ plasm between countries will be further broadened.

Regional program: Andean countries

The Canadian International Development Agency has provided CIMMYT with financial support for a regional maize improvement program among the five Andean countries: Bolivia, Colombia, Ecuador, Peru, and Venezuela. Initial financing is for 3 years, 1976-79. The program is jointly sponsored by CIMMYT-CIAT and CIAT provides the headquarters.

Every Andean country had an overall food deficit in the first half of the 1970's. The region as a whole produces about 6 million tons of grain and imports 3 million tons. Maize and rice are the largest local crops and wheat is the largest import.

During 1976 one CIMMYT staff scientist was posted to CIAT and from this base he assisted the participating governments in regional trials, a workshop among maize scientists, and he consulted with the five governments on policy problems affecting maize.

By the end of 1976 a CIMMYT training agronomist joined the program to help organize off-station trials of elite maize materials, and to train local scientists in that work.

A third aspect of regional collaboration concerns the breeding of improved varieties of floury maize, a preferred crop in the high Andes. This work is headquartered at Santa Catalina Station, near Quito, Ecuador, and was assisted during 1976 by two CIMMYT staff members commuting from Mexico.

Average maize yields in the five Andean countries are 1.0 to 1.7 tons per hectare. The success of the Andean program will be measured over years by the ability to raise these relatively low yields.

COLD TOLERANT SORGHUM

In December 1976 CIMMYT harvested a sorghum yield trial of historic importance at El Batan (elevation 2250 m): ten lines of cold tolerant sorghum gave mean yield of 4 tons per hectare, and the best entry yielded 8 tons. Twenty years earlier, in the mid-1950's, no variety of sorghum would flower or set seed above 2000 m, anywhere in the Western Hemisphere. Recent progress strengthens CIMMYT confidence that sorghum can become a grain crop superior to maize in the higher marginal and drier mountain areas of Central and South America, where some of the poorest population lives.

CIMMYT's sister institute, ICRISAT in India, assumes leadership and financing for this sorghum project in 1977, with CIMMYT still providing research facilities in Mexico.

East African origins

In the highlands of East Africa, farmers for centuries have grown sorghum which would flower and set seed on high plateaus. The first cold-tolerant lines in Mexico were brought from Uganda in the late 1950's. During the 1974-76 period 380 more sorghum introductions from Ethiopia, Uganda, and China were tested in Mexico, and 39 were found to be cold tolerant (100 percent seed set) and 157 partially cold tolerant (75-95 percent seed set), under low temperatures, but above freezing.

Breeding

Three thousand sorghum crosses are made each year by CIMMYT at Poza Rica, the tropical station where highland and lowland sorghums can be planted together and intercrossed. Progenies are reselected for cold tolerance and other required characteristics under both highland and lowland conditions. Breeders are seeking earlier maturity, wider adaptation, better disease and insect resistance, better protein quality, and higher yield for direct human consumption.

Earlier maturity is critical. A growing period of 90 to 115 days is required for highland areas of short rains or short frost-free seasons. So far, the earliest of the cold tolerant sorghums mature in 125 days at El Batan, and most take longer. Breeders are introducing more short season material to further compress the growing season.

Damage to sorghum by diseases and insects is minor in the Mexican highlands. But since diseases and insects are known to be severe in the East African highlands, and even more devastating in the lowlands of Mexico, breeders are introducing disease and insect tolerance/resistance into all the new lines for cold areas. Lines for resistance have been collected from Texas, Nebraska, India, and Brazil. Texas A&M University is helping screen CIMMYT materials for resistance.

Protein quality

Improvement of protein quantity and quality in cold tolerant sorghum began in 1974 when Purdue University supplied seed for six high lysine lines from Ethiopia. The Ethiopian material was excessively tall, late, and daylength sensitive. Initial crosses in Mexico shortened the plants, reduced the growing period, and introduced daylength insensitivity; progeny could then be used as parents in crosses to cold-tolerant sorghum.

Protein in most sorghum has low lysine content (2 percent of protein, similar to normal maize). In 1976 CIMMYT protein laboratory verified that the better F3 crosses using Ethiopian lines as donors, now contain 3.0 percent lysine. These lines had somewhat lower total protein. But breeders believe that normal protein content can be regained while retaining higher lysine content and yield.

International testing

Sets of 380 cold-tolerant lines were sent from Mexico to 29 locations throughout the world for an observation trial in the summer of 1975. From preliminary data, the 30 best lines were chosen. Seed was increased and distributed again to 22 international sites for yield trials in 1976. Preliminary data received in early 1977 from four highland sites in Kenya, Ethiopia, Honduras, and Mexico indicates that these cold tolerant lines gave mean yield across sites of 3.3 tons per hectare, with mean plant height of 1 meter, and mean period to flowering of 85 days. These yields compare favorably with the best commercial yields of maize in highland areas, but the average maturity period for sorghum is still four or more

Shree Singh checking for stalk-rot resistant plants to use in the cold tolerant sorghum breeding program.

weeks too late to satisfy farmers in the coldest and driest highlands. The target of shorter maturity is thus restressed.

Sorghum training and consultation

Training personnel for national sorghum programs is important for international testing. So far three scientists (El Salvador 1, Honduras 1, Ethiopia 1) have spent a cropping season at CIMMYT, participating in all aspects of sorghum breeding and production. Trainees are encouraged to select and take home the sorghum lines in Mexico which may strengthen their national program. A CIMMYT sorghum scientist has visited five national programs for consultation (Ecuador, El Salvador, Guatemala, Honduras, and Ethiopia) and also observed CIMMYT sorghum lines growing in the USA and Canada.

Road ahead

Very little sorghum is yet grown in colder regions of Latin America above 2000 m elevation, principally because of late maturity. A breakthrough for shorter season varieties is expected. Several million hectares of cropland in highland areas of the Western Hemisphere could then produce sorghum more advantageously than any other food grain.

wheat improvement

WHEAT INTRODUCTION

Wheat harvests continue to expand faster than population in developing countries. During a recent 10 years, wheat production rose 50 percent and population 30 percent.

The wheat harvest of all developing countries in 1975 reached 79.2 million tons, an all-time record. Preliminary estimates for 1977 suggest another all-time record, one reporting service forecasting 88 million tons (for the year ending mid-1977). Despite these peaks, developing countries are still importing 23 million tons or more of wheat and wheat flour each year, indicating a substantial remaining deficit in food production.

In developing countries, half the recent gains in wheat production have been achieved through increased area planted; the other half comes from rising yields. In future, the role of rising yields per hectare must be even greater, because that is the route by which most increases of food production must come. Available cropland is already fully utilized in most developing countries.

The high-yielding varieties of wheat continue to spread in developing countries. A survey in 1976 indicated that improved wheat varieties are now grown on 25 million hectares in Asia, Africa, and Latin America, or about 40 percent of the wheat area on three continents. The most recent gains for the high yield varieties have been in Latin America.

The other sixty percent

We ask ourselves: why have 60 percent of the farmers in developing countries not yet adopted the high yielding varieties? We find many

Changes in wheat production and population: 1961-65 to 1971-75.

Developing countries	1961-65	1971-75	Percent Increase
Average annual wheat area harvested (million ha)	50	51	22
Average annual wheat yield (kg/ha)	976	1211	24
Average annual wheat production (million metric tons)	49	74	50
Population (millions)	1448*	1876*	30
World			
Average annual wheat area harvested (million ha)	210	221	5
Average annual wheat yield (kg/ha)	1209	1621	34
Average annual wheat production (million metric tons)	255	362	42
Population (millions)	3160*	3831**	21

Source: FAO Production Yearbook 1975. *1963. **1973.

reasons. In some locations, political events have disrupted agriculture. In some places prevailing market prices provide no incentive to farmers, or fertilizer is not available, or credit is lacking. These are problems for government administrators, not for research scientists.

But there also are countries where improved wheat technology is still lacking. Here the monkey is on the scientist's back. For example, the vast area of acid soils in Brazil, now producing a summer crop of soybeans, could also produce a winter crop of wheat in rotation with soybeans, as soon as improved varieties of wheat tolerant to those soils have been developed. Scientific teams in Brazil and Mexico are collaborating on a breeding program, now in its third year, to combine Brazilian varieties of wheat (tolerant to low pH) with higher yielding varieties from Mexico. This is a form of shuttle research in which every second generation the research crop moves from Brazil to Mexico, then back.

Similar collaborative research in under way for selection of better resistance to the fungus disease septoria which can be devastating in Turkey, Algeria, the highlands of East Africa, and the southern cone countries of South America.

We are devising shuttle research between Mexico and other nations.

Need for horizontal resistance

Stable resistance to the three rusts remains a world-wide need. The Yaqui Valley of Mexico experienced an outbreak of leaf rust in early 1977, most severe for that area in one third of a century. The outbreak was encouraged by a series of events that allowed much land to remain uncultivated in the summer of 1976, providing a bridge of volunteer wheat plants to serve as hosts for rust spores which are usually destroyed during summer cultivation.

The Mexican government promptly sprayed 80,000 hectares of wheat with new fungicides developed in Europe and USA. This may turn out to be the largest example on record of the chemical control of a rust epidemic.

The multiline offers one option for slowing down a rust epidemic and stabilizing wheat yields at a high level.In 1976 CIMMYT staff observed a striking demonstration of the potential for the multiline. At Toluca station in Mexico a severe epidemic of stripe rust wiped out a large plot of Siete Cerros, one of Mexico's highest yielding bread wheats; but a neighboring plot of the multiline, based upon the same parents as Siete Cerros, was untouched by the attack.

Spreading new technology

Our wheat staff continues to use many methods to deliver new technology to collaborating countries.

During 1976 the international nurseries for experimental bread wheat, durum wheat, barley, and triticale were grown in more than 90 countries. This puts the new breeding progeny on display, and also provides testing

In the experimental plots at the CIANO station, Norman Borlaug, left, compares notes with Vance Goodfellow of the U.S. Crop Quality Council.

data which guides CIMMYT and its collaborators in further breeding work.

Forty more young wheat scientists from developing countries were brought to Mexico in 1976 to work for one cropping season with CIMMYT scientists. These young men and women are now back in their home countries, where they become part of the worldwide network of wheat scientists.

Members of our Mexico staff traveled to 42 countries in 1976 to see the international wheat trials, to talk with farmers, and to consult with government policy makers.

During 1976 CIMMYT posted wheat scientists in four national wheat programs (Algeria, Tunisia, Turkey, Nepal) where we shared the work of local research and training.

In 1977 we have posted staff to three regional groupings of nations which are exchanging wheat technology among neighbors. These regions are the Mediterranean and Mideast, headquartered in Egypt and Turkey; highland East Africa, based in Kenya; and the Andean countries, based in Ecuador. We find these regional programs can supplement the work of CIMMYT-Mexico by circulating regional nursery trials, organizing regional workshops for wheat scientists, and increasing local training.

In the pages which follow, our staff reports on these and other activities of the past year. —*N.E. Borlaug.*

BREAD WHEAT

The goal of CIMMYT bread wheat breeders is to develop materials that have a consistent high yield potential in the broadest possible array of environments. This objective is pursued in general, by breeding semidwarf wheats which are highly responsive to improvements in crop management, by breeding for insensitivity to daylength which tends to give wheats stable maturity characteristics regardless of location, and by breeding for broad resistance to disease.

CIMMYT conducts wheat research in two seasons each year. In the winter, wheats are grown in a dry climate at sea level in northwest Mexico. In the summer the wheats are grown in a cool moist climate near Toluca in Mexico central plateau. The movement of successive generations from one location to another and back again, exposes the wheats to sharp changes in environment, daylength, and disease organisms, and allows breeders to identify well-adapted lines.

In addition, wheats are artificially inoculated with rusts —the most important diseases of wheat world-wide— in each season to ensure that only lines with good resistance reach advanced generations. Testing lines at various stages of development at dozens of locations around the world provides an additional measure of disease resistance and adaptability.

Because the rust organisms are capable of frequent and sudden change in their virulence, the resistance of a new wheat variety may be effective for only a few years. But for stem rust, several decades of breeding have concentrated so many resistance genes in Mexican wheats that they seem to be approaching a stable type of resistance. The level of resistance to leaf rust and stripe rust in Mexican wheats, however, does not compare to that for stem rust. In recent years, CIMMYT has placed more emphasis on breeding for resistance to leaf and stripe rust, as well as for resistance to septoria leaf blotch an important disease in certain areas.

Selected spring bread wheat varieties bred by CIMMYT-INIA or predecessors, released in Mexico, 1950-76.

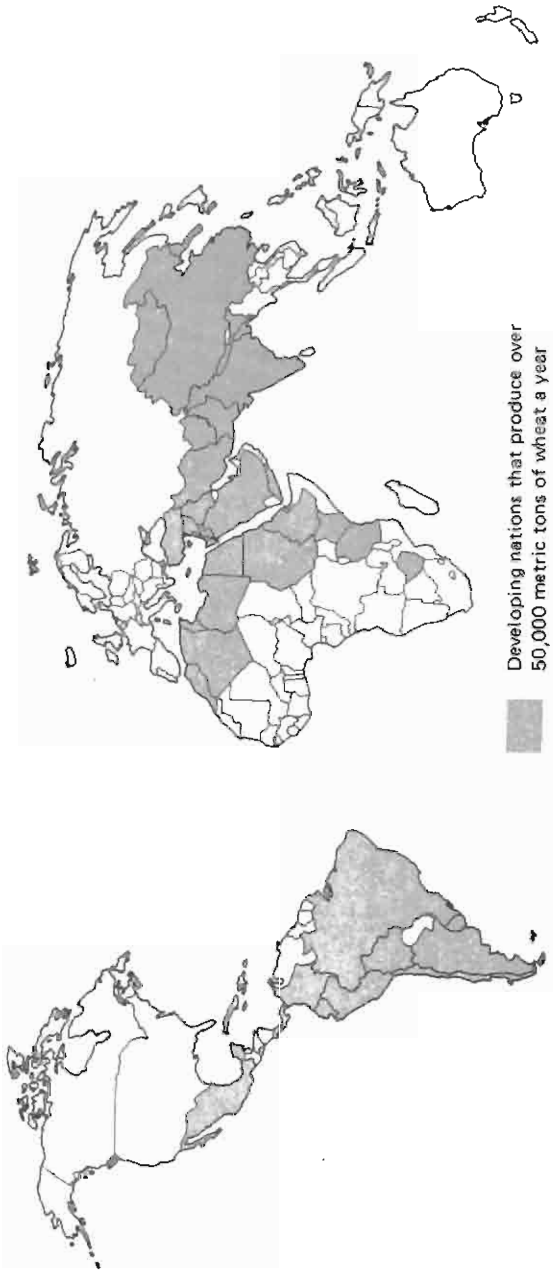
Year of Mexican release	Variety name	Year of cross	Yield potential* kg/ha	Plant ht* cm	Disease rating in Mexico 1976** Stem rust	Leaf rust	Stripe rust	Septoria
1950	Yaqui 50	1945	3500	110	TMS	20MS	10MS	MR
1960	Nainari 60	1958	4000	110	10MS	5R	0	-
1962	Pitic 62	1956	5370	100	100S	60S	80S	MR
1962	Penjamo 62	1956	5870	100	50MS	0	80S	MR
1964	Sonora 64	1957	5580	85	20MS	70S	80S	S
1964	Lerma Rojo 64	1958	6000	100	30MR	80S	80S	S
1966	INIA 66	1962	7000	100	5MR	100S	80S	S
1966	Siete Cerros	1967	7000	100	TMS	20S	100S	S
1970	Yecora 70	1966	7000	80	TR	100S	100S	S
1971	Cajeme 71	1966	7000	80	TR	100S	100S	S
1971	Tanori 71	1968	7000	90	20MR	80S	60S	S
1973	Jupateco 73	1969	7000	95	TMR	80S	60S	MR
1973	Torim 73	-	7000	75	TMR	20MS	40S	S
1975	Cocoraque 75	1969	7000	90	TR	TR	20MR	MR
1975	Salamanca 75	-	7000	90	TMR	20MS	20MS	S
1975	Zaragoza 75	-	8000	90	0	30MS	80S	S
1976	Nacozari 76	-	7500	90	0	TMR	10MR	S
1976	Nacozari 76	-	7500	90	0	TMR	10MR	S
1976	Pavon 76	-	7500	100	0	TMR	10MR	MS
1976	Tesopaco 76	-	7500	105	10MS	20MS	20MS	MR

*Measured at experiment stations in Mexico, irrigated under high soil fertility, and essentially disease free. **All varieties were resistant to all three rusts under Mexican conditions at time of release. R — resistant; S — susceptible; 0 — no rust; MR — moderately resistant; MS — moderately susceptible; 20MS — moderately susceptible type lesion on 20 percent of plant surface, balance of surface is lesion-free; TMS — moderately susceptible type lesion in trace amount, balance is lesion-free; TR — resistant type lesion present in trace amount, balance is lesion-free.

Variety releases

Three new CIMMYT-INIA wheats were released by the Mexican government in 1976: Nacosari, a two-gene dwarf with white grain; Pavon, a one-gene dwarf with white grain; and Tesopaco, a one-gene dwarf with red grain. All three are resistant to the races of stem rust, leaf rust, and stripe rust existing in Mexico in 1976.

Argentina—Buck Nandu
Egypt—Sakha and Sakha 8
South Africa—Elrina and Liesbeck
Tanzania—Tanzania Kororo
USA (California—Portola and Yecora Rojo
Lebanon—Haramoun and Sunnine


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

Yield testing

About a thousand advanced lines were yield tested in northwest Mexico during 1976. Of these, 205 were selected for their high yield, rust resistance, and good agronomic characters and included in the 10th International Bread Wheat Screening Nursery. This nursery has been sent to 150 locations around the world.

Six advanced lines, including the line that became Pavon, yielded 500 to 900 kg/ha more than Jupateco, the most widely planted commercial variety in northwest Mexico, which yielded 8700 kg/ha.

Disease resistance

Results from the Ninth International Bread Wheat Screening Nursery show that the increased emphasis on breeding for resistance to leaf rust, stripe rust, and septoria during recent years is paying off. In this multilocation test, 45 lines had a low average coefficient of infection by stripe rust, 55 had a low coefficient of infection by leaf rust, and 51 had a low coefficient of infection by septoria. Only 17 percent of the 386 lines in the 9th IBWSN were highly susceptible to septoria.

Multilines

Several years ago, varieties derived from the Mexican cross 8156 (known as Siete Cerros and Super X in Mexico)were grown on 13 million hectares in five continents. A large portion of these varieties were grown in countries stretching from North Africa to India. In recent years, the area planted to the 8156 cross has declined as new races of rusts have arisen and because of susceptibility to septoria.

Nevertheless, the vast plantings of the 8156 cross testifies to its suitability for farmers in many countries. The productive germ plasm of the 8156 cross could continue to be used if its current vulnerability to disease could be eliminated.

Since 1971, CIMMYT has been developing lines based on the 8156 cross that could be used in multiline varieties which would have stable disease resistance. A multiline variety is a mixture of lines that have one parent in common and that resemble that parent in height, maturity, grain color, etc. But each line derives genes for disease resistance from different parents. Thus when the prevailing rust virulence in an area changes, only a small percentage of the plants in a field planted to a multiline variety are likely to be susceptible. Through this mechanism the typical 'brushfire' effect of a rust outbreak is damped. Over time, the susceptible component of the multiline variety would have to be replaced and a new multiline variety issued.

CIMMYT is producing and testing a large number of lines that can be used to constitute multiline varieties. The choice of which lines to use must, however, be made in the country where the multiline will be released.

In 1976, over 200 crosses were made between varieties of the 8156 parentage and sources of resistance from Argentina, Australia, Canada, Colombia, Ecuador, India, Kenya, Rhodesia, North Africa, and USA. F1 plants that show resistance to two or three rusts are topcrossed or double crossed so that the resulting lines each have genes from two sources of resistance.

Preliminary results from the Fourth International Multiline (8156) Nursery show that 35 of the 215 lines were resistant to leaf rust in India, Pakistan, Egypt, and Mexico. Forty lines were resistant to stripe rust in India, Pakistan, Chile, and Mexico. Eleven of the lines were resistant to both rusts at all locations.

To test the principle of the multiline, 12 multiline composites consisting of 3 to 11 components, were planted in yield trials in northwest Mexico. About half of the multiline composites yielded as well as Siete Cerros under disease-free conditions. Several of the composites yielded more or less than the average of their components which were grown separately for comparison. These results underscore the need to conduct local tests to determine which line should be used in compositing a multiline variety.

When disease infection is heavy, multilines are expected to substantially outyield Siete Cerros. This was demonstrated in 1976 in Toluca where stripe rust killed Siete Cerros but left neighboring plots of the 8156 multiline composites unharmed.

In 1976, the Fifth International Multiline (8156) Nursery, consisting of 92 lines, was distributed to 30 locations.

Spring x winter wheat

Spring wheats and winter wheats (wheats that require a period of low temperatures to induce flowering) have, historically, been bred and improved as separate groups. Each group, however, has certain genes that might improve the characteristics of the other, if they were intercrossed. For spring wheats, the winter wheat germ plasm might enhance drought resistance, and resistance to septoria, powdery mildew, stripe rust, and leaf rust. For winter wheats, spring wheat germ plasm might improve stem rust resistance. Both types might receive better yield potential and a wider range of maturity characteristics from the other.

CIMMYT is engaged in a large-scale program of crossing spring wheat with winter wheats. At the Toluca station winter wheats planted in November are vernalized naturally (flowering is induced) by cold weather in December. Yet the weather is warm enough in January to permit planting of spring wheats, so both spring wheats and winter wheats flower in May and June allowing about 1500 crosses to be made each year.

About half the F1 seed is sent to Oregon State University (USA) where the F1 plants are crossed again to winter wheats to extract winter types. At CIMMYT the F1 plants are crossed to spring wheats to extract spring types. After testing in several locations in Oregon, the winter progeny are tested in other winter wheat areas through the International Winter x Spring Wheat Screening Nursery. The spring progeny eventually are tested in spring wheat areas through the International Bread Wheat Screening Nursery.

Some F1 seed is also shared with breeders in Turkey and India.

In 1976, over 700 spring x winter F1 crosses were evaluated in northwest Mexico. Over half had good agronomic type and resistance to

Making pollinations in front of the CIMMYT headquarters building.

stem and leaf rust, and these were sent as F2 seed to 100 cooperators world-wide. These scientists will make their own selections from the segregating populations.

Wheats for the humid tropics

Although wheat is not generally well suited for humid tropical climates, several countries are interested in growing wheat during their 'winter' season —the period of lowest temperature and humidity, as a means of reducing imports of wheat and flour.

The chief shortcomings of wheat in hot, humid climates are poor tillering (production of secondary stems) and susceptibility to *Helminthosporium sativum,* a fungus.

Tests at Poza Rica, Mexico, a hot, humid location on Mexico's Gulf coast have shown that some CIMMYT germ plasm is able to tiller adequately there but that resistance to the disease is rare. To find sources of resistance, 5000 entries from the world collection of spring wheat were grown in Poza Rica in 1976. Eighteen entries were resistant or tolerant. They will be used in the crossing program.

In addition, four F1 crosses involving the variety Horizon, which was previously found to be *Helminthosporium* resistant, were grown at Poza Rica. All the crosses were resistant and seed has been sent for selection to Cameroon, Zambia, Assam (India), Philippines, Dominican Republic, Costa Rica, Nicaragua, and Guyana.

Cooperative program with Brazil

Wheat in Brazil is grown under heavy attacks of septoria and severe aluminum-toxicity. CIMMYT is cooperating with Brazilian breeders to combine Brazilian wheats' resistance to septoria and aluminum toxicity with the high yield potential and fertilizer-responsiveness of Mexican wheats. In 1976 more than a thousand top and double crosses were made in northwest Mexico involving Mexican and Brazilian wheats. Most of the F2 progeny is grown and selected in Brazil. Part, however, is sent to other nations where septoria is important.

International nurseries and trials

Since 1964, CIMMYT has annually distributed a group of 50 varieties as the International Spring Wheat Yield Nursery. In 1976, the 13th nursery in this series of replicated yield trials was sent to 125 locations in 66 countries.

CIMMYT also distributes a crossing block. This is a group of varieties, each of which is one of the world's best sources for one or more characteristics. Seed of 300 entries was sent to 50 locations in 1976 so that breeders can evaluate them and use them in crosses if they wish.

Two regional screening nurseries are coordinated by CIMMYT. The Regional Disease and Insect Screening Nursery serves countries from Morocco to India. The Latin American Disease and Insect Screening

Nursery tests the disease resistance of experimental wheat lines in countries from Mexico to the south.

A trap nursery of commercial wheat varieties is grown throughtout the Mediterranean to Mideast regions to monitor changes in the vulnerability to rust of varieties farmers are growing.

DURUM WHEAT

Durum wheat is the preferred cereal in many countries near the Mediterranean where it is eaten as couscous and 'Arab' bread and in large areas of India where it is used for chapatis.

Dwarf durums were first produced at CIMMYT over a decade ago. Although the first dwarf durums were hampered by excessive sterility, dwarf durums released by national programs in recent years have largely overcome this problem and potential yields have risen rapidly. Durum varieties bred in Mexico have been released in Algeria, Cyprus, Iraq, Lebanon, Saudi Arabia, Tunisia, and Turkey.

Higher yield

Yield trials in Mexico and internationally during the last two years have shown that the durum variety Mexicali 75 is setting a new standard for durum yields and adaptability. and that semi-dwarf durums can equal the best bread wheats in yield. Mexicali was the highest yielding durum in the 6th International Durum Yield Nursery as well as being among the top five entries at 21 of the 38 locations, more than any other durum. Based on preliminary results from the 7th IDYN, Mexicali is the highest yielding durum and among the top five entries at 11 of the 26 locations, once again more than any other durum.

In yield trials at Ciudad Obregon Mexico in 1976, Mexicali was among the top five entries in 11 of the 16 trials. A number of advanced lines, however, yielded even better than Mexicali. Half of these lines had Mexicali in their pedigree. Mexicali is being used often in new crosses to combine its high yield potential with better grain quality, better disease resistance, and better straw strength.

The crosses 21563-AA x Fg and Gta-21563 x AA have also produced lines that have been outstanding in several years of trials.

Mexicali did not give outstanding yields in a rainfed trial in the Mexican high plateau in 1976. Although moisture was generally adequate, stripe rust and 'Take-all,' a root rot caused by *Ophiobolus graminis*, were severe. In this trial Cocorit performed better than Mexicali, but the highest yielding entry was Beagle, a triticale.

Disease resistance

A comparison of rust resistance ratings of durum lines in Mexico, with ratings made on the same lines in major durum producing nations reveals

Durum varieties released in Mexico between 1950 and 1976.

Year of Mexican release	Variety name	Year of cross	Yield potential* kg/ha	Plant ht* cm	Disease reaction** Stem rust	Leaf rust	Stripe rust	Sept. tritici	Test weight kg/hl	Pigment ppm***
1941	Barrigon-Yaqui	-	4000	130	0	TS	70S	R	75	4.5
1960	Tehuacan 60	1954	4200	150	0	10MR	20MS	R	81	5.5
1965	Oviachic 65	1960	7000	90	40MS	30S	5MR	S	81	7.2
1967	Chapala 67	1961	7000	85	0	10MS	10MR	MS	-	4.0
1969	Jori C69	1963	7700	85	0	TR	5MS	S	81	3.7
1971	Cocorit 71	1965	8300	85	0	5MR	5MS	MS	81	3.6
1975	Mexicali 75	1969	8600	90	0	TR	5MR	S	78	5.8

*Measured at CIANO experiment station, at high rates of fertilizer with irrigation, and in the absence of diseases. **In Mexico, 1976. R — resistant, MR — moderately resistant, MS — moderately susceptible, S — susceptible. Figures before letters indicate percentage of infection. ***Carotinoids.

sharp differences. With few exceptions, lines showing complete resistance to rusts in Mexico are susceptible abroad. Races of rust in regions that produce large amounts of durums are more virulent to durum lines than the races present in Mexico where little durum is grown commercially. In breeding for resistance to rust, CIMMYT scientists will have to be guided by resistance data from countries where durum is an important crop. For stripe rust, however, ratings made in Mexico are a more reliable indication of durum performance abroad.

Comparison of ratings made in Mexico for septoria and *Fusarium* have been hindered by the lack of reliable ratings for these diseases on Mexican semi-dwarf durums from elsewhere in the world.

Broader genetic base

During 1976, about 6000 crosses were made. Over half of these crosses were made with varieties or lines that are not genetically related to Mexican durums.

The program of crossing durums with bread wheats to increase the genetic variability of durums was continued. Crosses were made between durums and spring bread wheats, winter bread wheats, and F1 spring x winter bread wheats. These should improve durum's cold tolerance, disease resistance, tillering ability, and spike length.

Drought tolerance

The yields of 54 durum lines and varieties were compared with and without drought stress. Scientists attempted to relate traits such as total dry weight, harvest index, grain number, kernel weight, days to flowering, and leaf permeability to high yield under drought. Only harvest index

—the ratio of grain weight to the weight of the above-ground plant— was highly correlated with yield. Semi-dwarf plants which tend to have high harvest indexes had higher yields than tall durums under both well-watered and drought conditions.

Durum quality

The cereal technology laboratory began using a new quick test in 1976 for determining whether grain will produce noodles which have a desirable yellow color and which will not disintegrate when cooked. The new test avoids the time-consuming procedure of making spaghetti. A sample of wet gluten (protein) obtained by washing 5 grams of semolina, is formed into a ball and placed on a glass sheet. After 30 minutes the color of the gluten is evaluated visually. The water used to wash the gluten from the semolina activates lipoxidase, an enzyme in semolina that breaks down pigment. Since content of both pigment and lipoxidase differs from variety to variety, this test gives a good indication of what spaghetti color will result from the interaction of the two factors. The test also allows gluten strength to be rated based on the degree that the ball spreads in 30 minutes.

In 1976, over 100 lines that yielded as well as Mexicali or better were rated for durum quality. Thirty of them had excellent gluten color combined with strong or medium strong gluten.

TRITICALE

Triticale results from crossing wheat with rye. Although such crosses were first made a century ago, improvement of triticale as a crop did not begin until the 1950's. Since then researchers in Europe and North America have labored to make triticales competitive with other cereals. CIMMYT has worked on triticale since its founding in 1966. The research is conducted cooperatively with the University of Manitoba in Canada.

Many formidable problems that faced CIMMYT's triticale breeders a decade ago have been overcome, and the best triticales yield on a par with the best bread wheats. Triticale is planted commercially in Hungary, Spain, Argentina, China, Canada, and the USA and is being tested for use by farmers in several developing countries.

Higher yield

Infertility was a major cause of low yields until the late 1960's. Typically, only a small proportion of the florets (flowers) in the triticale spike became fertilized and produced grains. In 1968 a triticale line was found that had a high degree of floret fertility. Since then the line, called Armadillo, has been used extensively in crosses. All advanced hexaploid triticales (those resulting from crosses between durum and rye) now have

Armadillo or a derivative of Armadillo in their parentage. Good floret fertility combined with longer spikes has permitted yields of the best triticales to challenge those of the best CIMMYT bread wheats. In trials at Ciudad Obregon, Mexico, in 1976, the best triticales yielded 7500 kg/ha just 5 percent less than the best bread wheats. Eight years ago yields of the best triticales were less than half those of the best bread wheats.

Grain quality

Triticale kernels are often shrivelled, a liability that is reflected in low test weight (weight per unit volume). The best triticales have test weights of 72 to 76 kg/hl compared with over 80 kg/hl for the best bread wheats. Progress in improving the test weights of triticales has not been rapid. Even when two triticales that have high test weights are crossed, few of the progeny retain the high test weight. Some lines with over 78 kg/hl have been found, nevertheless. For industrial quality, however, it may not be essential for triticale to equal bread wheat in test weight, especially if whole grain flour is used.

In the early years of triticale improvement high yielding lines usually

Mohan Kohli, triticale breeder, counting spikelets.

had low test weight. Now, however, many advanced lines combine yielding ability with adequate test weight. In 1976 trials, nine lines that yielded over 7000 kg/ha had test weights of over 72 kg/hl.

Evaluations of 264 high yielding lines in 1976 showed that 80 percent had test weights of over 70 kg/hl. In 1974, only 75 percent of 122 lines evaluated had test weights over 70 kg/hl.

Earliness

Among triticales of tall or normal height, breeding for early maturity is not difficult. Attempts to combine short stature and high yield potential with earliness have not generally succeeded until now. At present most high yielding and dwarf triticale lines are medium or late maturing.

Lodging resistance

The increasing resistance of triticales to lodging (the tendency of plants to fall over near harvest) has contributed significantly to rapidly rising yields.

Dwarfing genes from wheat have been extensively used to reduce the height —and therefore the lodging tendency— of triticale lines. Progeny that have one or two dwarfing genes are not as reduced in height as wheats bearing the same genes. Progeny with three dwarfing genes have inadequate floret fertility. Similarly, a dwarf triticale line, UM 940, which successfully transmits short stature to progeny, also transmits a high degree of sterility.

Crosses between triticale and a dwarf rye called Snoopy have rarely given vigorous fertile progeny although Snoopy produces sound progeny when crossed with other ryes.

Lodging resistance in triticales has been achieved by combining a moderate reduction in height with stronger stems. The best lines in the triticale program, such as Beagle, are equal to the bread wheat Jupateco in

Top yielding triticale germ plasm developed by CIMMYT since 1967.

Year in advanced trials	Identity	Sonora Nursery* Yield kg/ha	Sonora Nursery* Test wt kg/hl	Sonora Nursery* Plant ht cm	ITYN** Year	ITYN** Yield kg/ha
1967-68	Bronco X224	2356	64.4	150	1969-70	2578
1968-69	Arm. T909	3100	65.8	125	1970-71	3272
1969-70	Badger PM122	4492	68.5	125	1971-72	3274
1970-71	Arm. X308-14Y	5490	65.4	125	1972-73	3506
1971-72	Cinnamon	5550	66.8	100	1972-73	3409
1972-73	Maya II x Arm.	6300	70.0	90	1973-74	4200
1973-74	Yoreme	7000	71.0	90	1973-74	4400
1974-75	Beagle	7500	68.0	110	1974-75	4480

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

height, maturity, and yield. Beagle has been crossed with many two-gene dwarfs in an attempt to reduce its height while maintaining high fertility.

Daylength response

Genes that CIMMYT triticales received from Mexican bread wheats have made them insensitive to daylength. This insensitivity means that the growth duration of a triticale line is about the same regardless of the length of day in the locality in which it is planted. Insensitivity to daylength broadens the adaptability of cereal varieties. In cool areas outside the tropics, however, triticales from Mexico often flower before they have sufficiently tillered (put out extra stems). Breeders from USA and Canada have been cooperating with CIMMYT to introduce a broader range of maturity patterns into CIMMYT's triticales.

Protein

Since 1973 when yields of the best triticales first closely approached those of the best bread wheats, the protein content of the best triticales has held at about 13 percent. The content of lysine in triticale protein rose from 2.8 percent in 1968 to 3.4 percent in 1973 and has remained at that level since then. Lysine is a commonly limiting amino acid in cereal protein.

Baking quality

The flour yield of triticale lines has ranged from about 52 to 70 percent since 1974. But in 1976 tests, 95 percent of the lines had higher than 60 percent flour yield.

Baking tests showed that many triticale lines are capable of producing bread loaves with volumes up to 700 cubic centimeters (Yecora, a bread wheat, produces loaf volumes of 765 cubic centimeters).

For cookie-making, some triticale lines provided flour that was more suitable than soft bread wheat flour. Tortillas made from triticale flour were equal in quality in tortillas made from wheat flour. Chapatis made from triticale meal kept moist longer than chapatis made from bread wheat flour.

Results from trials made since 1974 suggest that triticale will find widest acceptance in chapatis, tortillas, cookies, and types of bread other than commercial sandwich bread.

Disease resistance

Triticales continue to show strong resistance to the virulences of leaf rust and stem rust present in northwest Mexico. In the cool, high altitude stations of El Batan and Toluca, Mexico, triticales were resistant to both stem rust and leaf rust but bacterial leaf blight was severe on some winter-planted triticale lines. Snow mold, caused by *Fusarium nivale* was also a serious disease at Toluca.

Results from the Third Triticale Disease Resistance Nursery indicate that triticales have good resistance to stem rust, leaf rust, and stripe rust.

Under a heavy infection of bacterial blight in Turkey, most lines showed adequate resistance.

Winter triticales

Winter type triticales are needed for areas of the world where cereals are planted in the autumn and flower in the spring. In such areas, spring type triticales would be damaged by cold and frost during the winter and, if they survived, would flower in cold weather which would reduce seed set.

CIMMYT is making crosses between its spring triticales and winter triticales developed in Europe and USA. The winter triticales are unsuitable for commercial production in Mexican conditions because they are tall, susceptible to lodging, largely sterile, and susceptible to disease. The crosses are made at CIMMYT's Toluca station where the December weather is cold enough to induce flowering in winter types yet the January weather is warm enough to allow spring types to be planted. Under this planting pattern the two types flower at the same time and large numbers of crosses can be made.

Winter-type progeny of these crosses are shorter, have higher fertility, better seed development, earlier maturity, and more rust resistance. Spring-type progeny have better root development, improved resistance to certain diseases and possibly better drought resistance.

Improvement in winter types is progressing slowly because of defects of the winter parents and because only one crop can be grown each year. Winter progeny cannot be tested for cold tolerance in Mexico so they are sent to cooperating scientists in Europe, South America, and USA for screening.

Farm trials

In northwest Mexico, trials on irrigated farmers fields, managed by farmers, have shown that farmers' normal practices are adequate for producing yields from triticales that approach those of the best bread wheats. Under farm conditions, however, some triticales tend to lodge more than shorter wheats. If the farmer makes his last irrigation too early, late-maturing triticales will suffer. Weed control can be more of a problem in triticales. Some triticales such as Yoreme and Navojoa are not good competitors with weeds such as wild oats and reed canarygrass.

Trials have also been made in the Mexican high plateau region near CIMMYT headquarters. In this area, shallow soil, poor land preparation, and erratic rainfall have caused germination problems in triticales. Rainfall at harvest time has caused sprouting in the head in some triticales. Since most triticales are late maturing they are often subject to frost damage in areas that have short growing seasons.

Fertilizer response

Triticales have not generally been as productive as dwarf bread wheats under high rates of fertilizer. Trials with zero to 300 kg/ha of nitrogen in

1976, however, showed that 10 triticales were equal to or better than high yielding bread wheats and durums at every fertilizer level. Since lodging still is a problem in triticales, breeders expect that even better fertilizer responsiveness will be achieved when the tendency to lodge is further reduced.

Forage triticales

Some triticales have the ability to produce large amounts of dry matter even when repeatedly clipped or grazed. Trials have been conducted to test the ability of triticale strains to produce forage and, after regrowth, grain. Oats, a crop commonly used for forage and grain, was included in the trials for comparison.

Enrique Rodríguez, left, barley breeder, rating the grain of freshly harvested lines.

Generally, the more often triticales are cut for forage, the lower the ultimate grain production is. In contrast, frequent cutting increases the ultimate grain production of oats. Without clipping, the best triticale yielded 8900 kg/ha of grain and 16,000 kg/ha of straw, a low protein forage, compared with the best oat variety which yielded 3200 kg/ha of grain and 18,000 kg/ha of straw. With one clipping the best triticale yielded 7000 kg/ha of grain and 900 kg/ha of high protein (26 percent) forage. The best oat variety, with one clipping yielded 3600 kg/ha of grain and 650 kg/ha of high protein forage. But with four clippings the best triticale yielded 3600 kg/ha of grain and 1600 kg/ha of high protein forage while the best oat variety yielded 5000 kg/ha of grain and 3000 kg/ha of forage.

Broad adaptation

The six International Triticale Yield Nurseries which have been grown since 1970 provide evidence of the broadening adaptation of triticales to diverse environments. These nurseries consist of about 20 advanced triticales and are grown at several dozen locations around the world. In the Sixth International Triticale Yield Nursery, grown at 45 locations, the five highest triticales averaged 4500 kg/ha compared with 4000 kg/ha for Tanori, the bread wheat check, and 3700 kg/ha for Cocorit, the durum check.

National programs

Several nations have vigorous programs for testing triticales prior to possible release for commercial production. Ethiopia, for example, has set up a pilot program with nearly 2000 farmers to promote commercial production of triticale. In national trials in Kenya in 1976, triticales outyielded bread wheats and durums by 30 percent. India has an agressive breeding program aimed at producing triticales for hilly areas of North India. Mexican triticale germ plasm is being used by Indian breeders. In Brazil, triticale is being evaluated in acid soils. Triticales appear to have better tolerance to aluminum toxicity than most wheats. In Chile trials are showing that triticale can equal wheat yields while producing more protein.

BARLEY

Barley is perhaps the toughest of the cereal crops. It produces grain under conditions prohibitive to other cereals. Barley, as a crop, has several notable attributes. It grows fast, often faster than weeds. It matures quickly, an asset in areas that have short growing seasons. And it tolerates low rainfall. Although most of the world's barley (87 million hectares) is used for cattle feed and for making beer, the portion that is used for food is grown by some of the world's most impoverished peoples. Barley is a staple food near deserts and in high plateaus in areas of North Africa, Mideast, India, Pakistan, Nepal, China, Korea, and the Andean Region of South America.

Few improved food-crop barley varieties exist. CIMMYT is developing barleys for human consumption that have stable high yields and good nutritive value.

Barley varieties that are eaten by people tend to be low yielding, susceptible to disease, and narrowly adapted —that is, they perform poorly outside their home locality. Barleys that have been bred for cattle feed or beer-making have better yields, but their kernels must be dehulled before people can eat them. Varieties used in beer, moreover, have been bred for low protein content. CIMMYT's barley breeders are gradually overcoming the flaws of food barley.

Wider adaptation

The Second Elite Barley Yield trials provided evidence that broader adaptation is possible in barleys. An advanced line from CM67-Mona was among the highest yielding five entries at 10 out of 17 locations worldwide. The insensitivity of this line to daylength (both its parents are insensitive) largely accounts for its adaptability. Varieties that are sensitive to daylength do not grow well when they are planted north or south of their native environment.

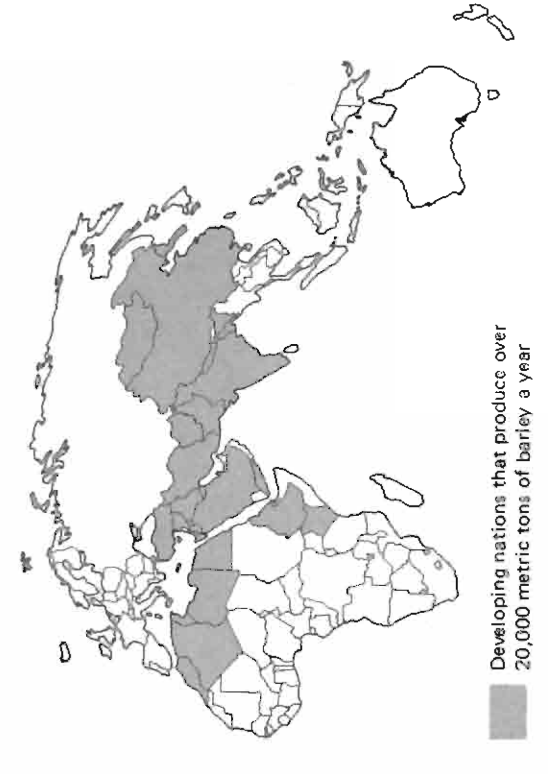
More and more daylength-insensitive lines are now moving into advanced generations. CIMMYT's barleys are grown in the winter near sea level in Northwest Mexico at a latitude of 27 degrees N while in the summer they are grown at 2200 meters elevation in central Mexico at a latitude of 19 degrees N. By moving successive generations of barley between these two markedly different environments, lines that are not adaptable can be identified and discarded.

Disease resistance

The Fourth International Barley Observation Nursery, containing 300 barley lines, was sent to 60 locations around the world in 1976. The IBON gives breeders information on the resistance of their lines to a broad range of barley diseases in many environments. The first three observation nurseries showed that most lines tested in the early years of the CIMMYT barley improvement program were susceptible to several diseases. But a few lines and varieties had strong resistance and these were placed in the crossing block where they could be used as parental sources of scald resistance. The first lines resulting from crosses involving scald-resistant parents are in the fourth IBON.

CIMMYT pathologists conducted tests in 1976 which permitted several sources of resistance to loose smut to be identified. This work should speed the incorporation of smut resistance genes in high yielding barleys.

Although rusts of barley are not major diseases in Mexico, sources of


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

rust resistance are being used in new crosses. These sources were identified by CIMMYT pathologists in North Africa and the Mideast where barley rust outbreaks are common. The degree of rust resistance of new lines will be tested through international trials. Resistance to soil problems is being studied in cooperation with Brazilian and Mexican researchers. In Brazil, scientists are growing CIMMYT barley lines in soils high in aluminum. CIMMYT breeders will use lines that survive and yield adequately as parents in crosses designed for areas of the world where aluminum toxicity is severe.

In Mexico, CIMMYT and national scientists began looking for lines highly resistant to salinity in 1977. Barley tolerates salinity better than most cereals, but the scientists hope to find lines with far above average ability to grow in saline soils. The trials will be conducted in a saline area near the sea in northwest Mexico.

Earliness

The first yield trials with early barley lines were conducted in 1976. A number produced over 4000 kg/ha in less than 95 days. This is 10 to 20 days earlier maturity than most commercial varieties. The most notable line was HjaC4715 x olli which yielded 4730 kg/ha in 92 days compared with Puebla, a commercial variety which yielded 4880 kg/ha in 118 days. These trials used moderate fertilizer rates (120 kg/ha N and 60 kg/ha P) and only two irrigations in a rainless desert where wheat usually gets four to five irrigations.

Quick-maturing barleys would be advantageous where the growing season is short because of brief rains or early frosts. Also, such barleys might allow farmers that grow two food crops a year to squeeze in barley as a third crop.

Hull-less grain

At the start of CIMMYT's barley program hull-less barleys were an important goal. Through the frequent use of 'naked' barleys such as Godiva and lines from Nepal and Ethiopia, hull-less barleys have become commonplace among CIMMYT lines. In 1976 about 40 percent of early generation lines were hull-less.

Straw strength

Resistance to lodging —the tendency of the crop to fall over near harvest— is another objective that has been largely achieved. Breeders have used barleys from the USA and Mexico to improve lodging resistance. Barleys have also been shortened to reduce the tendency to lodge in areas where fertilizer and irrigation is used. Lines in advanced generations now have a high degree of lodging resistance.

High yield

Replicated yield trials in 1976 showed that a number of advanced barley lines can yield well over 6000 kg/ha with only three irrigations (four to five irrigations are commonly applied to wheat in northwest Mexico where the trials were conducted). In trials where Mexicali 75, a high yielding durum variety, was used as a check, some barley lines exceeded the yield of Mexicali by up to 15 percent.

International testing

Two large international barley trials were distributed by CIMMYT in 1976. The Second International Barley Yield Nursery was sent to 45 locations. At each location 24 CIMMYT advanced lines will be tested.

The Fourth International Barley Observation Nursery, with over 300 entries, was sent to 60 locations. This nursery is primarily aimed at providing broad information on the disease resistance of early generation lines.

Winter x spring crosses

During 1976 CIMMYT asked other barley breeders for seed of winter barleys as the first step toward a program of crossing winter barleys with spring barleys. Winter barleys are types that must be exposed to a cold period to induce flowering. Winter barleys are planted in the autumn, survive winter as seedlings and resume growth in the spring. Spring barleys are grown in areas or seasons in which the weather is too mild to induce flowering in winter barleys. Since winter and spring barleys have evolved in different ecological zones they are quite distinct genetic pools. Through interbreeding each pool becomes a rich source of additional genetic variability for the other pool.

Winter barleys from USA, Turkey, Korea, and eastern Europe were planted in CIMMYT's Toluca station in late 1976. The weather at Toluca is cold enough to induce flowering in winter barley yet spring barley can be planted early in the year and large numbers of crosses can be made. Part of the F1 seed will be sent to cooperating winter barley breeders so that winter barleys can be selected under their conditions. CIMMYT will develop spring barleys from the crosses.

By using appropriate parents, breeders believe winter barley x spring barley crosses will lead to both winter and spring types that have higher protein content and better disease resistance. The progeny of such crosses are likely to have better cold tolerance and a broad spectrum of maturities.

DEVELOPMENT OF NEW GERM PLASM

Some wheat varieties have unusual characteristics that could raise or stabilize farmers' yields if the genes for the characteristics could be added to varieties that yield well and are widely adapted.

Often however varieties with special desirable characters have many undesirable ones as well. One breeding program at CIMMYT is aimed at painstakingly transferring special characters into lines that have generally good agronomic features. Such lines can then be used as parents to make numerous crosses to improve high yielding, widely adapted varieties.

New sources of dwarfing

Most of the world's semi-dwarf wheats derive their short height from genes of the Japanese variety Norin-10. To broaden the genetic base of dwarf varieties CIMMYT has been making crosses with the varieties Tom Thumb and S948A1, two varieties whose genes for short height are different than those of Norin-10. Tom Thumb and S948A1 have been used in backcross programs to produce short progeny from old tall varieties such as Santa Elena, Chris, INIA, CIANO, and Bonza. These varieties have numerous desirable features, but tallness places a low ceiling on their yield potential.

Yield trials in 1975 and 1976 have shown that the dwarf advanced backcross lines outyield their tall parents. These lines are being incorporated in the bread wheat breeding program.

Other varieties such as Pitic, Penjamo, Lerma Rojo, Jupateco, Cocorit, and Mexicali are now being crossed with S948A1 to reduce their height.

In addition, a new source of dwarfing, Hisumi, was used for the first time in 1976. Hisumi is a dwarf winter wheat which may prove valuable as a source of short stature in the CIMMYT program for crossing winter wheats with spring wheats.

Protein improvement

A number of varieties produce grain that has unusually high protein content or protein quality. These varieties, however, tend to be susceptible to rusts, to have incompletely filled kernels, and to have poor spikelet fertility. CIMMYT breeders are making crosses with agronomically superior varieties in hopes of producing high-protein progeny with few deficiencies.

These varieties have been crossed, and often backcrossed, with agronomically superior varieties in hope of producing high protein progeny with few deficiencies. Several lines have been produced that have high protein content (15 to 19 percent), or good protein quality, or both. But these lines retain one or more deficiencies such as weak steams, incompletely filled kernels, susceptibility to rusts, and poor spikelet fertility. Additional crosses will have to be made to eliminate these weakness before the lines can be used in the bread wheat breeding program.

Resistance to rusts

Certain varieties such as Yaqui 50, Bonza 56, and Era have remained resistant for a decade or more in spite of the continual changes in the virulence of rusts. Through backcrossing, breeders have started transferring

Ricardo Rodríguez, left, supervises the breeding of uncommon characteristics in wheat.

the stable resistance of these old varieties to varieties that have better agronomic features.

Crosses between Era and daylength-insensitive varieties will be in the F3 generation of the second backcross in 1977. At that time, the daylength insensitive progeny can be selected and further crosses made to combine rust resistance and daylength-insensitivity with improved plant type.

Breeders have also begun crosses intended to combine, or pyramid, the genes from various sources of stable resistance into one line.

Larger spikes

Grain yield is in part affected by the number of spikelets (grain bearing structures) a variety has on each spike as well as by the number of grains each spikelet contains.

The progeny of some crosses produce 35 to 41 spikelets per spike in northwest Mexico compared with 20 to 24 spikelets per spike for normal varieties. These progeny are late maturing and attempts to select for earlier maturity cause the number of spikelets per spike to decline.

Crosses aimed at increasing the number of grains per spikelet have resulted in one progeny with 8 to 14 grains per spikelet (most commercial varieties produce 3 to 4 grains per spikelet). These lines are early maturing, but do not tiller well (tillering is the ability to produce secondary stems). Some other crosses which have more than six grains per spikelet are high tillering as well as early maturing.

Lines from two crosses combine 12 to 14 spikelets per spike with more than six grains per spikelet.

In the high plant density of commercial fields the number of spikelets per spike and the number of grains per spikelet tends to decline. Only when these lines are in advanced generations and placed in yield tests can the influence on yield of more spikelets and more grain per spikelet be measured.

Branched spikes

The spikes of most wheats consist of spikelets arranged along a central axis —the rachis. Some wheat however have a branched rachis. Potentially a branched rachis has room for more spikelets and thus might lead to higher yields.

Trials in 1975 and 1976 have shown that several branched bread wheat lines are capable of equalling Cajeme and Jupateco in yields. Some branched durum wheat lines yield at the same level as Cocorit but not as well as the newer durum variety Mexicali.

While these results are encouraging evidence that the branching characteristic is being combined with agronomically sound plant type, the performance of individual lines has been erratic from one year to the next. Before branched wheats can be brought into the general breeding program, stable, high yielding lines must be found.

Triticale

Triticales are generally taller than semi-dwarf bread wheats. Their tallness is a disadvantage under intensive farming conditions, because the tendency of the tall plants to lodge (topple over) increases in fields that have abundant moisture and high fertility. Breeders are making intensive efforts to produce short triticales that could be used as sources of dwarfing in the triticale breeding program. Breeders are incorporating genes from the bread wheats S948A1, Tom Thumb, and Norin 10 into triticales, while trying to avoid the shrivelled grain and poor spikelet fertility that often accompany dwarfing genes.

Intergeneric crosses

During 1976 breeders made over 5000 pollinizations in attempts to make crosses among barley, wheat, oats, and rye. In addition attempts were made to cross wheat with various grasses such as *Elymus, Agropyron* and *Aegilops.*

To make these crosses breeders use EACA to suppress barriers to alien pollen and giberellic acid and 2,4-D to stimulate fertilization and development of the seed endosperm and embryo.

While a number of the crosses yielded seeds which germinated when planted, cytological examination will be necessary to confirm that the plants are true intergeneric hybrids.

WIDE CROSSES

The progress in improving triticale (wheat x rye) as a crop suggests that other wide (intergeneric) crosses could become more than mere laboratory curiosities. For this reason CIMMYT has been investigating crosses between genera.

Crosses of barley and wheat

Crosses of barley and wheat, using barley as the female parent, have given a number of weak F1 plants. These plants suffer from chromosomal sterility and attempts to induce seed set through treatments with colchicine have failed. Using wheat as the female might reduce the problem of chromosomal sterility, but it would also decrease the number of F1 hybrid plants obtained.

Research in Britain indicates that certain genes in wheat tend to prevent fertilization by rye pollen and it appears that these genes may also block fertilization by barley pollen. But because of CIMMYT's experience in large-scale crossing of wheat and ryes to produce triticales, a number of bread wheat and durums have been identified which have good crossability with rye. Crosses between barley and 40 such wheats, however, have so far uncovered only one which produced large amounts of seed.

Attempts are also being made to overcome crossability barriers by applying various chemicals to the ovaries of the wheat parent.

Crosses with grasses

Wheats that can be fertilized fairly successfully with rye pollen also appear to be receptive to pollen of certain species of *Agropyron* and *Elymus.* Using wheat as the female parent, crosses with *Agropyron junceum* and *Elymus arenarius* have been successful.

In addition, vigorous and apparently fertile hybrids have been produced by fertilizing *Agropyron elongatum* with pollen of either bread wheat or durum.

Crosses between one unidentified accession of Agropyron and barley have been easily made. Possibly such crosses might be used as a bridge for combining barley and wheat.

Agrotriticums —fertile progeny from crosses between wheat and *Agropyron elongatum*— have been derived mostly from old tall wheats from temperate areas. As a result agrotriticums are extremely late maturing and have poor agronomic type. Nevertheless they have a high percentage of fertile florets and they produce plump grains. Since fertility and grain plumpness are weak in many triticales, agrotriticums might offer a means of improving them. Crosses have been made between agrotriticums and wheat and between agrotriticums and triticale to improve the agronomic type of the agrotriticums and to assess their potential for rectifying weaknesses in triticale.

PHYSIOLOGY

Physiological measurements in relation to yield Various physiological measurements were made on 114 varieties and lines of bread wheat, durum, and triticale and related to yield. Harvest index —the ratio of the weight of a plant's grain to the weight of the entire plant excluding roots— was once again the best overall predictor of yield. For triticale, however, total dry matter was a better indicator of yield than harvest index. Other measures that were closely correlated with yields were, for bread wheat, grains per fertile spikelet, grains per ear, and total dry matter; and for durum wheat, grains per fertile spikelet. In another study 27 characters were measured on 150 plants from each of 10 F2 populations. In later generations yield of the progeny of these plants will be examined in relation to the characteristics measured in the F2 generation. The physiologists' goal is to find characters that can be easily measured on widely spaced F2 plants and that reliably indicate the yield of advanced generations derived from that plant. Such characters would allow breeders to reduce the number of lines that have to be carried from one generation to the next.

Drought resistance

The effects of drought were compared in 108 varieties and advanced lines of bread wheat, durum, triticale, and barley grown in well-fertilized soil. Drought was simulated by making the last irrigation just 45 days after planting.

The bread wheat Ciano 67 gave the best yield, 4080 kg/ha. This variety was among the best performers in the previous year's drought trials. Cleopatra, which yielded well in previous drought trials, ranked only 52nd in this year's trials.

Harvest index, maturity, total dry matter, and grain number per ear were closely correlated with grain yield. Crop characteristics measured on the same varieties and lines grown with adequate irrigation were not good indicators of the yields produced under drought conditions.

Preparing plots for planting at El Batan.

Another drought trial was conducted with 21 barleys. To simulate late-season drought, the fields were irrigated only at planting and 25 days later. Only two of the barleys yielded significantly more than the bread wheat check variety, Cleopatra. But because these barleys matured over 20 days sooner than Cleopatra, their yield per day was 49 and 45 kg compared with 28 kg for Cleopatra.

Long spikes in short days

The growth of the spike before flowering affects how many flowers form. A long spike produces more flowers and hence has more potential sites in which grain might form. Pysiologists are looking for varieties that are more sensitive to daylength during the brief spike formation phase than in the long vegetative phase. Growing such plants in the winter when the days are short would extend the spike formation phase relatively more than the vegetative phase. Consequently, the spike would have longer to grow and develop, yet the overall time needed for the plant to reach maturity would not be greatly increased.

Trials in which 46 lines were grown under controlled daylengths revealed that seven of the lines had the desired response, and three lines had a strong opposite response. These lines will be studied in future trials.

Fertilizer and yellow berry

Yellow berry is the name for the portion of some durum kernels which, when milled, makes poor quality semolina. Yellow berry tends to decrease when high rates of fertilizer are used, but some varieties tend to have more yellow berry than others. To find parents for possible use in crosses to reduce yellow berry, several durum varieties and lines were grown under two fertilizer levels. Hercules had the lowest yellow berry percentage, but it also was low yielding. Since low yield and low yellow berry percentage are significantly associated, two higher yielding durums, Gediz and Jori 'S', which had low yellow berry percentage,might be better parents.

SLOW RUSTING

In most cereals, varieties' resistance to rust diseases is conferred by race-specific genes. These genes give the varieties resistance to specific races of rust. If a new virulent race appears the variety's resistance may be ineffective thus permitting a rust outbreak to occur. Some varieties, however, seem to have genes that are not race specific and which slow the production of rust lesions. Such varieties continue to yield satisfactorily over many years despite changes in rust races.

CIMMYT pathologists are looking for such slow rusting lines so that these genes, which may work additively, can be accumulated and used in crosses with high yielding varieties that have race specific resistance.

Previously the tall varieties Yaqui 50 and Bonza 55 were identified as being slow rusters. In 1976, several other varieties including Torim 73, a dwarf variety, were confirmed as slow rusters.

These varieties and advanced bread wheat lines which show slow rusting ability are being included in the crossing program to enhance the rust resistance of new crosses.

CHEMICAL CONTROL OF RUST

During the 1975/76 season in northwest Mexico a systemic fungicide was tested against leaf rust in a large scale experiment. Yecora, a susceptible variety, was planted in a 30 hectare field and 13 hectares were sprayed once with Indar from an airplane. At harvest the sprayed area yielded about 7000 kg/ha, 15 percent more than the unsprayed areas. This yield increase was more than enough to cover the cost of the chemical and aerial application.

INTERNATIONAL TRIALS

In 1976 collaborating scientists in 96 nations planted over 1575 trials of wheat, triticale, and barley nurseries distributed by CIMMYT. A nursery consists of a set of varieties or lines, sometimes as many as 270. Identical sets are sent to scientists in numerous locations. The results reveal the adaptability of each entry to dozens of different ecological conditions as well as the breadth of disease resistance of the entry. The information derived from 1 year of testing at so many locations could not be equalled by decades of testing at one location.

CIMMYT's international testing program has grown from cooperative wheat testing organized in North and South America in the late 1950's. When the Rockefeller Foundation program in Mexico received its first trainees from outside the Americas in the early 1960's the idea of worldwide tests developed. The First International Spring Wheat Yield Nursery in 1964/65 was the beginning. Other types of nurseries have followed. Nurseries are sent out annually in triticales, durums and barleys as well as bread wheats. Some nurseries consist of F2 seed, others contain released varieties, still others have seed of generations between F2 and released varieties. Certain nurseries are replicated, others are not.

The nurseries are also a mechanism for distributing germ plasm. Any entry in any nursery can be used as the local breeders sees fit. He may use an entry as a parent for making crosses with local varieties, or make selections from the entry, or multiply the entry for direct release to farmers.

A not insignificant benefit of the nurseries is that they foster contact and cooperation among scientists in nations with wide social and political differences.

In 1976, 96 countries received nurseries. The total weight of the nurseries, shipped by air, was 4500 kilograms.

MILLING AND BAKING LABORATORY

The milling and baking laboratory evaluates the grain of bread wheat, durum, and triticale for industrial quality, that is, their suitability for making bread, tortillas, chapatis, cookies, macaroni, and other products. These tests help plant scientists breed and select lines with good grain quality.

Bread wheat, durum, triticale and barley nurseries distributed by the International Nurseries Program, 1976.

	Bread Wheat	Durum	Triticale	Barley
North America	*64*	*20*	*44*	*11*
Canada	16	2	11	4
USA	48	18	33	7
Latin America	*186*	*59*	*127*	*41*
Argentina	24	19	24	3
Bolivia	2	-	4	8
Brazil	34	9	28	2
Chile	16	9	15	3
Colombia	2	-	3	-
Costa Rica	4	1	1	-
Cuba	1	-	1	-
Dominican Rep.	4	-	1	-
Ecuador	13	3	11	6
El Salvador	1	-	1	-
Guatemala	9	-	4	2
Guyana	3	-	1	-
Honduras	2	-	1	-
Jamaica	2	-	1	-
Mexico	36	9	13	7
Nicaragua	4	1	3	-
Paraguay	7	-	1	1
Peru	17	7	13	8
Puerto Rico	1	-	-	-
Uruguay	3	1	-	1
Venezuela	1	-	1	-
Europe	*59*	*46*	*59*	*15*
Albania	-	1	-	-
Austria	1	6	1	-
Belgium	2	-	-	-
Bulgaria	2	4	3	2
Czechoslovakia	2	-	-	-
Denmark	-	-	-	1
England	5	2	2	-
Finland	2	-	1	1
France	3	2	8	-
Germany	2	1	2	1
Greece	2	2	1	1
Hungary	2	-	4	-
Ireland	1	-	-	1
Italy	1	7	1	-
Malta	1	-	-	-
Netherlands	6	1	1	2
Norway	3	-	3	-
Poland	2	4	8	1
Portugal	4	3	2	1
Romania	3	3	2	1

	Bread wheat	Durum	Triticale	Barley
Russia	3	1	1	-
Spain	5	6	6	2
Sweden	2	1	6	-
Switzerland	-	-	4	-
Yugoslavia	5	2	3	1
Africa	*124*	*63*	*80*	*32*
Algeria	12	16	10	5
Cameroon	4	1	2	-
Egypt	18	12	8	6
Ethiopia	9	8	13	1
Ghana	3	1	2	1
Kenya	10	7	11	4
Lesotho	2	-	1	-
Malawi	2	-	1	-
Mali	3	1	-	-
Morocco	1	1	1	1
Nigeria	7	2	3	2
Senegal	2	-	1	1
Somalia	3	1	2	2
Sudan	8	1	5	-
Tanzania	3	-	2	-
Tchad	2	-	-	1
Tunisia	8	7	2	4
Uganda	1	1	2	-
Zaire	2	-	1	-
Zambia	9	1	2	1
Other	15	3	11	3
Mideast	*84*	*68*	*44*	*32*
Cyprus	3	5	2	5
Iran	17	9	6	5
Iraq	8	7	6	2
Israel	10	4	5	-
Jordan	9	11	5	5
Libya	4	4	2	2
Saudi Arabia	3	3	2	2
Syria	8	9	4	3
Turkey	16	12	10	5
N. Yemen	4	2	2	1
S. Yemen	2	2	-	2
East Asia and Oceania	*138*	*50*	*97*	*35*
Afghanistan	8	1	3	2
Bangladesh	5	2	3	4
China	24	2	6	2
India	29	26	31	8

continued

Bread wheat, durum, triticale and barley nurseries, *continued.*

	Bread Wheat	Durum	Triticale	Barley		Bread Wheat	Durum	Triticale	Barley
Indonesia	1	-	1	-	Sri Lanka	4	-	-	-
Japan	4	-	2	1	Thailand	2	1	1	-
S. Korea	9	-	5	7	Australia	11	2	12	1
Nepal	7	2	9	4	New Caledonia	3	-	-	-
Pakistan	25	11	21	5	New Zealand	3	2	2	1
Philippines	3	1	1	-					

Kernels from 25,000 bread wheat plants of the F3 and F4 generations were evaluated in 1976 for gluten strength by the use of the micro-pelshenke test, after being selected for seed type.

The crossing block, observation lines, and the high yielding material with high test weight (weight of the grain per unit volume) were evaluated for milling, protein content, mixogram, alveogram, sedimentation, and baking.

Winter wheat was evaluated for the above characteristics and also for cookie-making quality. Many winter lines were found to have good quality characteristics which will help to improve the grain quality of spring material.

Among lines from the special protein improvement project, many had protein levels up to 15.9 percent and good quality characteristics.

In durums the number of lines with good spaghetti color and good cooking quality has increased due to the screening in early generations.

From 468 triticale lines tested in 1976, 81 percent had a test weight of 70 kg/hl or more. Because the material has been selected for higher test weight and more plump grain, the flour yield has increased, and only 5 percent of the samples tested had a flour yield lower than 60 percent. Some lines had up to 72 percent flour yield. Many triticale lines had a loaf bread volume up to 700 cc in comparison with the bread wheat Yecora which has a loaf volume of 765 cc. Results from most of the lines were quite satisfactory for the preparation of tortillas and chapatis. Some triticale lines provide flour that is better for cookies than the soft bread wheat used for making this product.

In 1976 six trainees from Peru, Ecuador, Colombia, Brazil, India, and Ethiopia spent an average of 3 months learning the techniques in the milling and baking laboratory.

WHEAT TRAINING

Since 1966 over 300 wheat scientists have received in-service training in Mexico. During 1976, 39 young scientists from 22 nations were trained.

The training program lasts 3 to 9 months. It aims to develop skill in field and laboratory techniques, to give experience in working on an interdisciplinary team, and to improve understanding of agricultural development in relation to wheat production.

Farm trials

In 1976 the curriculum for production (agronomy) trainees was modified to give them more experience in deriving recommendations from sound on-farm trials.

The trainees helped CIMMYT agronomists and economists survey the grain farmers of the high plateau in the vicinity of CIMMYT headquarters. They gathered information on costs of inputs and prices of grains from farmers and dealers. They asked about farming practices. They collected data on rainfall and frosts.

From this information the region was divided into three agro-climatic zones and appropriate farm trials were designed for each zone.

Origin of wheat in-service trainees, 1966-76.

	1966-76	1976		1966-76	1976
Latin America	*73*	*13*	Yemen	3	0
Argentina	12	0			
Bolivia	2	0	*Africa, South of the Sahara*	*33*	*6*
Brazil	17	2	Ethiopia	9	2
Chile	6	1	Kenya	6	1
Colombia	4	1	Malagasy	1	0
Dominican Republic	1	0	Nigeria	11	2
Ecuador	9	1	Somalia	1	0
Guatemala	5	1	Tanzania	3	0
Honduras	1	1	Zaire	1	0
Mexico	3	2	Zambia	1	1
Panama	1	0			
Paraguay	3	1	*South & Southeast Asia*	*67*	*9*
Peru	8	2	Afghanistan	13	2
Uruguay	1	1	Bangladesh	14	6
			India	5	1
North Africa & Near East	*145*	*8*	Nepal	4	0
Algeria	38	3	Pakistan	31	0
Cyprus	1	0			
Egypt	7	1	*Other countries*	*23*	*4*
Iran	8	0	France	1	0
Iraq	4	0	Hungary	1	0
Jordan	3	0	Korea, South	6	1
Lebanon	4	0	Poland	3	0
Libya	4	0	Portugal	1	0
Morocco	17	0	Romania	2	0
Saudi Arabia	1	0	Spain	2	0
Sudan	3	0	USA	4	3
Syria	4	0	USSR	3	0
Tunisia	22	0			
Turkey	26	4	*Total*	*341*	*39*

Based on the survey, the trials were developed to test better methods for barley production (barley is the major cereal of the region) and to provide a comparison with wheat and triticale. The trainees installed, managed, and harvested the trials, analyzed the results, and prepared recommendations.

The principles and techniques learned in this series of trials should help the trainees develop trials in their home countries that will rapidly produce information useful in formulating realistic recommendations.

Variety trials

As part of the farm demonstration in the high plateau, trainees set out trials of wheats and triticales to test their performance under low and erratic rainfall and short growing season.

These trials emphasized the need for earlier maturing triticales. Some early-maturing triticales were selected from the trials and will be tested again in 1977. One wheat, Tesopaco, was early enough and yielded well.

National training programs

The CIMMYT training staff helped Ecuador set up a national training program in 1976. Two Ecuadorians who were CIMMYT trainees during 1975 form the nucleus of the program.

A CIMMYT training officer helped the ex-trainees develop a curriculum and helped analyze current research in Ecuador to plan simple farm-level trials.

The Ecuadorians conducted a 3-month training course for 20 extension agents who work with small grains. CIMMYT communications and economics staffmembers provided guest lectures during parts of the course.

Ecuador has now started an in-service training program within its research institute and hopes to provide training in a wide array of subjects.

CIMMYT expects to aid more national training programs in the future and has increased the size of its training staff to be freely able to respond to requests for assistance.

WHEAT COOPERATIVE PROJECTS OUTSIDE MEXICO

During 1976 CIMMYT posted seven wheat scientists to work with national wheat programs, and four to work with regional wheat programs. A national wheat program typically serves to improve wheat research in local experiment stations, to test experimental varieties on local farmers' fields, to multiply seed for improved varieties, and to provide additional training for local scientists. CIMMYT's assigned staff share these activities.

The following countries participated in cooperative arrangements during 1976:

Country	Start of CIMMYT arrangement	CIMMYT assigned staff 1976	Approximate wheat crop (tons)	Donor*
Pakistan	1965	1	7,000,000	USAID/Ford
Tunisia	1968	1	1,400,000	Ford
Turkey	1970	1	16,400,000	Rockefeller
Algeria	1971	3	2,900,000	Ford
Nepal	1976	1	300,000	USAID

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

Participation by CIMMYT in each national program may continue 10 years or more, subject to mutual agreement among cooperating country, donor, and CIMMYT.

A regional wheat program represents another form of shared effort between CIMMYT and its collaborators. In three parts of the world wheat growing countries have entered into cooperative arrangements to improve their wheat crop. Regional groupings generally comprise neighboring countries in which wheat is a major crop, grown under similar climatic conditions, exposed to similar diseases, and benefiting from continuous exchange of technology. Typically a regional program will sponsor: (1) an annual workshop among wheat scientists, (2) circulation of uniform nursery trials, (3) visits by local scientists to observe wheat research in neighboring countries, and (4) consultation by one or more CIMMYT scientists posted in the region.

At the close of 1976 CIMMYT wheat scientists were stationed in the following regional programs:

Wheat region and headquarters	Number of cooperating countries	1976 population (millions)	Wheat crop (tons)	CIMMYT assigned staff 1976	Donor
Mediterranean and Mideast (Egypt)	15	225	30,000,000	2	Netherlands
East Africa (Kenya)	6	70	1,000,000	1	Canada
Andean Region (Ecuador)	5	65	300,000	1	Canada

These cooperative programs vary according to the needs of the sponsoring governments.

Pakistan national wheat program

CIMMYT posted a wheat scientist to Pakistan in 1965, and has maintained a staff member there intermittently for the past 12 years. In 1976 the current resident scientist completed his assignment, and a replacement is being recruited in 1977.

Wheat is the number 1 cereal crop in Pakistan, where the population of 76 million is increasing 2.9 percent a year.

During the past decade the CIMMYT training program has brought 31 young Pakistani scientists to Mexico for one cropping season of experience in wheat research and production.

These scientists now make up the core of the Pakistani wheat program. Pakistan sent all supervisors of its wheat research to CIMMYT for observation of one harvest period; and more than a dozen Pakistan wheat scientists went to U.S. universities for advanced academic studies. This body of trained manpower was the foundation of subsequent progress.

The wheat program in Pakistan has released more than a dozen new varieties during the past decade; some Mexican varieties, some reselections from Mexican crosses, and some crosses made in Pakistan by the competent young staff.

During this decade of CIMMYT-Pakistan collaboration, the average yield of wheat has risen by 50 percent, and national production of wheat has risen by 80 percent (comparing 1961-65 with 1971-75).

It is the judgment of both the Pakistan government and of CIMMYT that the present average yield of 1250 kg/ha could be doubled over the next 25 years by a vigorous research program and by policies which create the necessary incentives for farmers.

Tunisia national wheat program

Tunisia imported as much as 400,000 tons of grain a year during the first half of the 1970's, but may have reached self-sufficiency in 1976 for the first time in a decade.

National population will pass 6 millions in 1977, increasing at 2.5 percent a year.

CIMMYT wheat scientists were posted to Tunisia starting in 1968, and during the past 9 years 22 young Tunisian scientists have spent a cropping season in the Mexico training program. Several Tunisians were sent to U.S. universities for advanced degrees. Out of this young staff has come the following progress:

(1) Several new bread wheat varieties have been released, together with recommended practices and the production of bread wheat has doubled.

(2) New varieties of durum wheat have been released which now cover 50 percent of durum land, and proved substantially superior to the previous commercial varieties. Appropriate production practices have been researched and introduced.

(3) A 2-year rotation of wheat and medicago (forage legume) has been introduced from Australia and proven adapted under local conditions, providing more grazing to sheep than the previous year of 'weed fallow' between wheat crops. The medicago practice is spreading, not only in Tunisia, but also to countries of the Mideast.

(4) Limited work has been completed on barley improvement and in

triticale testing. More can be expected from these crops in the next decade.

(5) These activities led to a cereal crop of about 1.4 million tons in 1976, compared with 800,000 tons a decade earlier. Credit must go partly to weather, partly to national policies, and partly to excellent research. Tunisia was the bread basket of the Roman empire and it is again exporting to Rome.

Expatriate wheat scientists in Tunisia are now reduced from a high point of five in the early 1970's, to a single CIMMYT staff member in 1977, but other CIMMYT staff pay short visits.

Turkey national wheat program

Turkey's 40 million people are wheat eaters, and their numbers have been increasing at 2.6 percent a year.

The country experienced violent fluctuations in its food deficit in the first half of the 1970's, requiring annual imports which ranged from 100,000 tons to more than a million tons and cost the government up to US$200 million a year.

CIMMYT assigned two wheat scientists —one breeder, one pathologist— to work with the Turkey national wheat program from 1970. The CIMMYT pair combined forces with a team of scientists from the Rockefeller Foundation and Oregon State University (USA), who were studying better methods of moisture conservation for Turkey's semi-arid Central Plateau.

Twenty-four young Turkish wheat scientists received training in Mexico during 1970-76 and 15 were given academic training to the M.Sc. level.

In the first half of the 1970's the Turkey researchers released new varieties of spring bread wheats for the lowlands, winter wheats for the highlands, and barley (which is Turkey's second ranking food crop, producing over 3 million tons).

By 1976 the Minister of Agriculture was able to report a record grain harvest of 16 million tons, attributable in part to good weather, part to greater use of fertilizer and insecticides, part to better cultivation practices, part to better research.

When the Minister visited CIMMYT-Mexico in the mid-1970's, he predicted that the achieved average bread wheat yields of 1.3 tons per hectare could be doubled within another decade or two.

CIMMYT withdrew its staff from the Turkish national program during 1976 and now provides visits to Turkey by staff from the Mediterranean regional program, and from Mexico.

Algerian national cereals program

In 1976 Algeria produced an all-time record cereals crop —estimated at 2.9 million tons— achieving approximate self-sufficiency of food grain for the year. This good harvest followed a decade of food deficits when grain imports ranged 0.7 to 1.7 million tons a year, and the cost of imported food rose as high as US$250 millions in one year.

Algeria's population of 17 million (1976) has been growing 3.2 percent a year.

Starting in 1971 CIMMYT assigned a team of wheat scientists to assist the Algerian national program. FAO and Caisse Centrale of France also provided technical staff.

The 'Project Cereal' in Algeria was initiated in 1971, employing 13 technicians and a director who held the engineer degree. An ambitious training program during 1971-76 sent more than 50 Algerians abroad, including 38 for short in-service training at CIMMYT-Mexico, and the

Mike Prescott, CIMMYT regional pathologist, discussing the harvest with a Turkish farmer.

others for advanced academic study in France, India, Australia, USA, Italy, and ALAD-Lebanon. Six Algerians are still taking advanced degrees outside their country in 1977. In addition, many Algerians were given travel opportunities to visit cereal programs and international centers. This training program enabled Algeria to upgrade and strengthen its cereal staff now numbering 200. New high yielding varieties were released for durums and bread wheats. Algeria began testing the 2-year wheat-medicago (forage legume) rotation which was adapted from Australia. Triticales and barley from CIMMYT received wide testing. Research on tillage practices and weed control developed improved methods. These steps paid off in the 1976 harvest.

In 1977 CIMMYT has three staff on post in Algeria, a breeder and two production agronomists.

Nepal national wheat-maize program

CIMMYT assigned a wheat agronomist to Nepal for the first time in 1976. (Background information on Nepal's grain production is given in the maize section of this report).

CIMMYT gave training in Mexico to five young Nepali wheat scientists during 1971-76, and these now make up part of the staff which tests the annual wheat and barley nurseries from Mexico, conducts local breeding, and places trials on private farmers' fields.

The recently accelerated Nepal food production program involves a number of international organizations: IRRI for rice, CIMMYT for maize and wheat, the International Agricultural Development Service for farming systems.

New developments of interest to all upland areas of Asia are expected to follow.

Mediterranean and Mideast Region

Since 1973, a unique disease warning system has been operating with cooperation of cereal growing countries stretching from Morocco in the west to Pakistan-India in the east.

Two CIMMYT pathologists are assigned to the project, one headquartered in Egypt, the other in Turkey, both able to make rapid trips to observe new outbreaks of wheat-barley diseases. The project operates as follows:

International wheat-barley trials are distributed each year as (1) a trap nursery, and (2) a disease and insect screening nursery.

A trap nursery consists of small plots of the principal commercial varieties of wheat-barley grown in the region. This trial is grown by cooperators in most countries of the region, permitting observation by the pathologists of the diseases which attack each variety, the extent of damage, and and virulence of pathogen involved. If an existing commercial variety is seriously damaged in the trial, early warnings can be issued to governments that this variety will need replacement in future years.

A disease screening nursery consists of small plots of experimental lines of wheat-barley, gathered from national programs of the region and from international wheat centers like CIMMYT. These trials are likewise exposed to the prevailing wheat-barley diseases. By monitoring when diseases strike, and the intensity, the pathologists are able to identify breeding materials which carry strong resistance to each disease. This information is distributed to cooperating governments. By selecting resistant wheats in the 'hot spots' (locations with virulent forms of pathogen), the pathologists are probably identifying multiple-gene resistance, and may thus help produce future varieties with effective commercial life longer than 5 years.

Testing is so widespread that it is possible to map the movement of epidemics and even the newer races of pathogens, as they cross national boundaries. Ultimately, it may be possible to predict when a new race of rust will reach each country of the region, and thus warn the government when to release substitute varieties. More information on weather systems is needed before prediction is possible.

Laboratory identification of the races and virulence of rust is performed for this project by collaborators in Netherlands, Yugoslavia, and Egypt.

Two training courses for collaborators were held in 1976 in India and Pakistan, with CIMMYT staff participating.

This project is shared among many organizations, including the Cairo regional office of FAO and the International Center for Agricultural Research in Dry Areas.

East African regional wheat program

Starting in 1976 CIMMYT assigned one wheat breeder to the East African highlands where he works with national programs and ultimately will develop an informal organization between governments for the exchange of wheat technology.

This evolving operation is headquartered at the Kenya National Plant Breeding Station, Njoro, elevation 2300 meters, about 200 kilometers northwest of Nairobi, near Nakuru.

The activities for this regional program include: consulting visits by the CIMMYT staff member to wheat growing countries of the region; an annual workshop for wheat scientists of the region; regional nursery trials combining the best experimental materials within the region and exotic materials from international centers like CIMMYT; and a high-elevation summer wheat station where nations of the Mediterranean region can advance their most promising experimental wheats an extra generation each year. In addition, stem rust and stripe rust resistance is identified for worldwide use.

In 1976 consultations began with six countries which together produce more than 1 million tons of wheat: Kenya, Ethiopia, Tanzania, Zambia, Malawi, and Lesotho. Regional nursery trials will be offered to these and other East African countries in 1977. Training is also planned for individuals from 12 nations.

The high altitude summer wheat nursery was grown at Njoro station in 1976, approximately June-October, and the opportunity to gain an extra generation in research was utilized by eight nations: Algeria, Tunisia, Egypt, Jordan, Lebanon, Syria, Turkey, and Iraq. Seasonal turnaround time is so tight between the Mediterranean winter crop and the East African summer season that CIMMYT found it necessary to send a staff member as a courier to pick up and return the seed for each country participating in the summer nursery.

Andean regional wheat program

Five countries of the Andean region (Bolivia, Colombia, Ecuador, Peru, and Venezuela) produce 300,000 tons a year of wheat, but import 2,000,000 tons of wheat and flour, an indication of food deficit in this region (FAO Yearbooks, 1970-75).

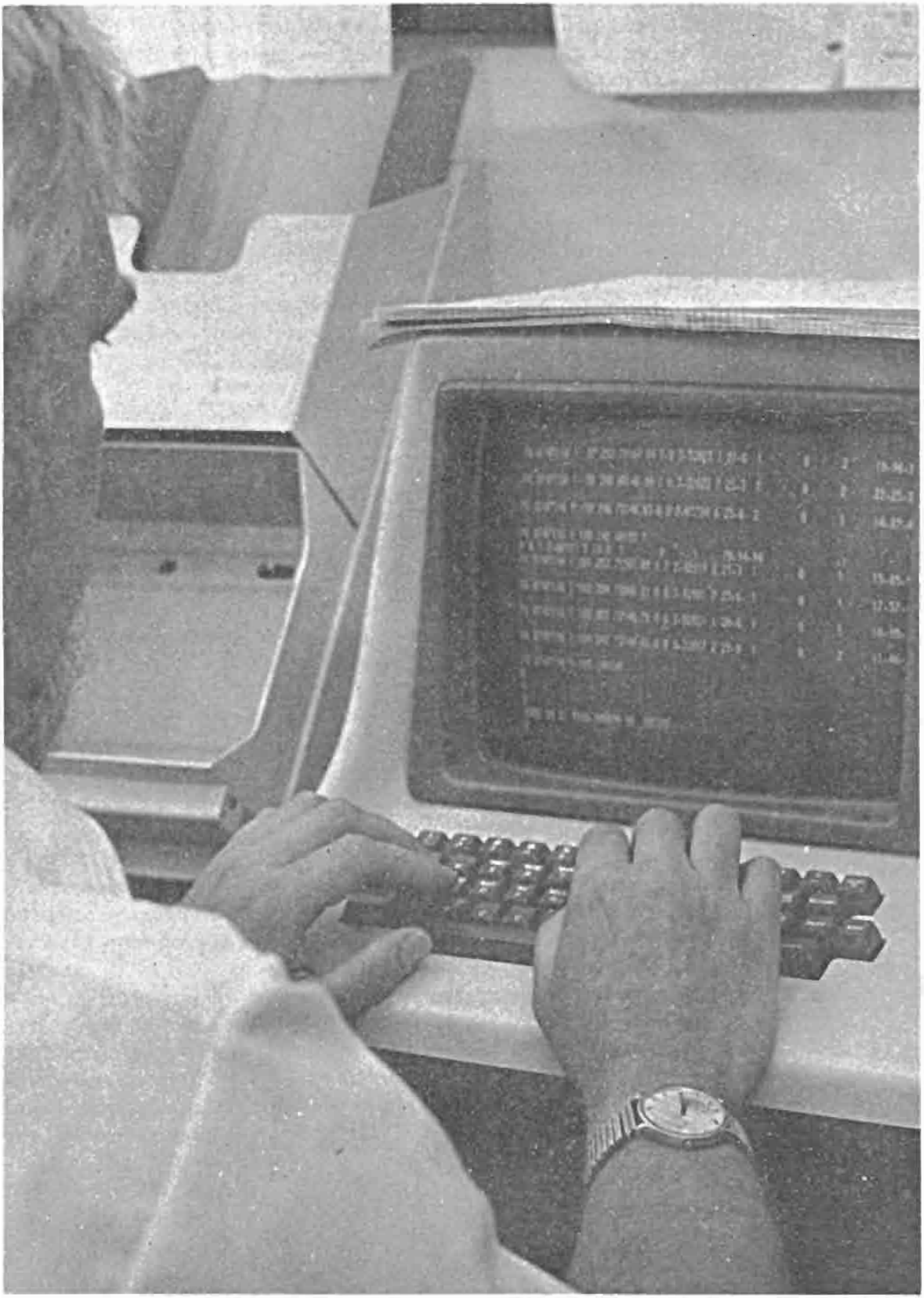
These circumstances influenced CIMMYT to post one wheat breeder to Ecuador, starting in 1976, to work with national wheat programs of the region. the Andean countries also produce 400,000 tons of barley per year, and import another 100,000 tons. Researchers generally handle wheat and barley together.

The projected Andean wheat program includes: (1) consulting by the CIMMYT breeder with five governments; (2) an annual workshop among wheat scientists of the region; (3) regional nurseries grown by collaborators of the region, including a regional disease and insect nursery similar to the early warning system around the Mediterranean; (4) arranging additional training for wheat scientists; and (5) occasional visits by the CIMMYT breeder to wheat crops of the five southern countries —Brazil, Argentina, Uruguay, Paraguay, and Chile.

During the decade 1966-76 CIMMYT provided one season of training in Mexico to 25 young scientists from the Andean countries, and 40 scientists from the southern cone countries. This established many CIMMYT contacts in the present wheat-barley research staffs, and explains the origin of many of the collaborators who are growing CIMMYT nurseries.

A workshop for regional wheat scientists is planned for 1977; the first regional nurseries will be circulated; and five more trainees from the Andean countries will undergo CIMMYT training.

supporting services



ECONOMIC STUDIES

The economics section supports CIMMYT's efforts to help nations develop and diffuse new maize and wheat technology. It does this by working with scientists and policy makers to make new technology and policy more consistent with farmers' circumstances, by joining with CIMMYT maize and wheat staff in their training programs, and by providing information which the maize and wheat staff can use in setting priorities.

Developing farmer-adapted technology

A major contribution of CIMMYT's adoption studies was to add credibility to the argument that new technology must truly fit the needs of farmers. Within CIMMYT, the studies encouraged agricultural scientists and economists to collaborate on research on new technologies. Studies aimed at identifying the natural, biological, and economic circumstances of maize and wheat farmers have been undertaken in several countries and more studies are under way.

In these studies, indigenous economists work closely on farm level research with the biologists of national cereals programs. The biological scientists contribute their special knowledge of important agro-climatic factors and of critical crop management operations while economists bring their concern for farmers' goals and limitations, markets, and competing activities along with knowledge of survey techniques and data analysis. The CIMMYT economics section has helped organize the studies, offered counsel, and shared in financing.

Evidence from farmers' fields has resulted in new orientations in research and extension work within national programs. Several examples can be given of how farm-level research has influenced the activities of crops programs.

—In Zaire, it was discovered that intercropping of maize is dominated by two strategies. One is to plant maize and cassava simultaneously. The other is to plant cassava about 3 months after maize. Having established the importance of these mixtures, maize researchers included them in their experimental and demonstration work.

—In Pakistan collaborative research involved extension staff as well as members of the maize program. Farm-level research made it possible to identify the characteristics of representative farmers. These characteristics then set the standard for the selection of sites for on-farm trials and demonstrations.

—At CIMMYT, collaboration with the wheat training program led to information on the distribution of small grains on Mexico's high plateau and on the techniques —especially with respect to seeding method and planting dates— used by small grain farmers. This information was then used in designing and locating on-farm trials and demonstrations of small grains conducted by the trainees. An additional consequence was that trainees became better aware of the elements that should influence site selection, treatment levels, and experimental designs.

—In Kenya, to encourage collaborative farm-level research in eastern Africa, CIMMYT deputed a full-time economist under a grant from the U.N. Development Programme. Farm-level research in collaboration with Kenyan maize specialists has shown the importance of a short-season maize variety for the farmers of the area studied.

These experiences are not meant to be exhaustive. They serve as examples of the kinds of information, and of its utility, provided by farm-level studies. Each study has, of course, yielded other insights of value in the development of new technology.

Similar studies are progressing in Tunisia, Egypt, Kenya, Ethiopia, Tanzania, Ecuador, and Peru. In each, economists are cooperating with local scientists. The economists are associated with schools of agriculture in Egypt, Tanzania, and Tunisia and with government research institutions in Ethiopia and Ecuador. In Peru, the researcher is a full-time CIMMYT consultant.

Training

The economics section participates in the training of agriculturists in three ways —by working with CIMMYT's maize and wheat training programs, by helping regional programs in their special training sessions, and, more generally, by preparing materials on economic issues of special interest to agronomists. The aim is to bring to the attention of agriculturists the myriad of forces, other than biological or natural, which influence farmer decision making. If the efforts of the biological scientists are to be successful, these forces should be incorporated in research on technologies, in making recommendations, and in demonstrating recommendations.

In 1976 CIMMYT published a manual, 'From Agronomic Data to Farmer Recommendations: An Economics Training Manual,' in English and Spanish (and in Turkey it has been translated into Turkish). While prepared for general use, the manual also serves to orient training in regional programs and at CIMMYT. It identifies issues —the cost of all labor, the on-farm cost of fertilizer, markets for product, and so forth— which farmers typically consider in deciding among farming strategies and gives checklists and simple rules-of-thumb for their treatment. Economics training at CIMMYT and in regional programs features these concepts. Beyond that, procedures for gathering related data and for evaluating the results of trials from the point of view of the farmer are described and demonstrated to CIMMYT trainees. This takes the trainees to markets for inputs and products, to credit agencies, and to farmers in search of information.

Crop research priorities

Priorities within CIMMYT are established by the two major crop programs, maize and wheat, along with CIMMYT's central administration. Economics contributes to their deliberations with information and analysis on relevant topics.

LABORATORY SERVICES

The protein laboratory and the plant nutrition and soils laboratory provide analyses to all the CIMMYT crop programs, as a central service.

Protein quality laboratory

During 1976 the protein laboratory analyzed approximately 13,000 maize endosperm samples for protein and tryptophan. Protein is determined by automated nitrogen analyses and by the conventional micro-kjeldahl procedures. Tryptophan and lysine are the two limiting amino acids of maize endosperm proteins. The content of both amino acids is highly correlated in the endosperm protein. Measuring tryptophan gives an indirect but rather precise indication of the level of lysine whose determination is more laborious and expensive.

The President of Mexico, Luis Echeverria, addressing the CIMMYT staff during CIMMYT's 10th anniversary celebrations in September 1976.

Approximately 3500 whole kernel samples of more advanced maize materials were evaluated for protein quality in 1976 using the dye-binding capacity (DBC) procedure. Since the high correlation between lysine and tryptophan found in endosperm maize protein does not hold when analyzing whole kernel maize, the DBC procedure is used to estimate indirectly the lysine content in the protein.

For the floury maizes of the Andean region (Colombia, Ecuador, Peru and Bolivia) into which opaque-2 gene has been introduced to improve their nutritional quality, the ninhydrin test has been used to evaluate the free amino acids, which are found in the opaque-2 kernels in higher quantity than in the normal floury kernels. In 1976, using the qualitative ninhydrin test, the laboratory identified opaque-2 segregates in seeds of 850 families and the selected seeds were later planted in the field. Tryptophan and protein are later determined in the progeny of these materials.

Analysis for protein content and for protein quality using the DBC procedure were performed on 5400 barley samples, 3800 triticales, 1300 wheats and 250 sorghum samples. On the most promising materials selected by the previous colorimetric methods, approximately 700 lysine analyses were determined more precisely by ion exchange chromatography. Complete amino acid analyses were performed on approximately 200 selected samples from the various programs.

Laboratory training

CIMMYT has provided assistance to several countries in establishing their own quality laboratories to give service to their breeding programs. The CIMMYT laboratory has trained personnel from national programs in chemical protein evaluation. Five trainees spent different periods of time in Mexico during 1976 (Ecuador 1, Guatemala 1, India 1, Kenya 1, and Peru 1).

During 1976 technical personnel from the protein laboratory visited several quality laboratories in Latin America where former CIMMYT trainees are working in the improvement of cereal protein quality.

Plant nutrition and soils laboratory

The plant nutrition and soils laboratory does chemical analyses to evaluate samples of soil, water, plant tissue, and grain. During 1976 the laboratory analyzed 8011 samples of grain, stems and leaves, from which 6530 samples were tested for nitrogen by the macro-kjeldahl procedure, in order to evaluate the materials from the wheat and triticale nitrogen and herbicide trials. In the nitrogen trials, CIMMYT agronomists try to determine the nitrogen fertilizer uptake efficiency of different varieties, while in the herbicide trials, different herbicide treatments are studied for their effect on the grain protein.

From the maize agronomy program 2100 samples, including grain, stems, leaves and cobs were analyzed for nitrogen, to study the genetic variability for uptake of nitrogen from the soil and to determine the amount of nitrogen that is translocated into the grain. In addition, stem sugar levels were studied in wheats and triticales to determine the yield limiting factors under optimum agronomic conditions in the Yaqui Valley. Using the Anthrone method, 1738 samples were analyzed for total sugar sugar content in plant tissue.

Approximately 700 soil samples were evaluated to provide information to the agronomists about the effectiveness of the routine fertilizer practices. These samples were analyzed for pH, organic matter, nitrogen, calcium, magnesium, potassium, phosphorus, zinc, manganese and copper, depending on the information required by CIMMYT scientists. To determine the amount of nitrate present in the soil profile before sowing and after harvesting, 1300 soil samples were analyzed for nitrates.

EXPERIMENT STATION MANAGEMENT

CIMMYT has conducted research at six stations in Mexico during 1976 and 1977. Two are under Mexico's National Agricultural Research Institute (INIA), and four under CIMMYT. Some characteristics of these stations:

Station	*Elevation*	*Latitude*	*Hectares used by CIMMYT*
CIANO-INIA	Sea level	27° N	162
Navojoa-INIA	Sea level	27° N	5
El Batan-CIMMYT	2240 m	19° N	44
Toluca-CIMMYT	2640 m	19° N	69
Poza Rica-CIMMYT	Sea level	20° N	42 (twice a year)
Tlaltizapan-CIMMYT	940 m	18° N	31 (twice a year)

The four stations operated by CIMMYT are fully developed, with land fenced, levelled, provided with field roads, equipped with drainage and irrigation facilities, and crop buildings.

Summer experimental land on the high plateau remains inadequate to accommodate the winter crops moving back and forth from sea level. CIMMYT has rented 12 hectares each summer since 1974.

At El Batan station, root development problems are occurring in wheat. The station management is seeking to correct the problem by application of sulphur during winter fallow to increase the availability of soil micronutrients and lower the soil pH.

El Batan station is testing new herbicides to identify chemicals compatible with both maize and wheat, because some herbicides previously applied to maize do not allow rotation of land with wheat.

At Toluca station a shortage of irrigation water has been corrected with a deep well.

At Poza Rica station, a flood control wall along the Poza Rica River, built after a flood in 1975, stood up well during high water periods of 1976.

Since 1973 experiment station managers from 10 countries have received training at CIMMYT stations in Mexico for periods of two weeks to two months. Twelve training participants during 1976 came from: Bangladesh 5, Costa Rica 3, Egypt 1, El Salvador 1, Malaysia 1, and Thailand 1. CIMMYT also provided a short course in Nepal for five persons concerned with station management.

The head of CIMMYT's experiment stations spends a period each year as consultant to national programs, which in 1976 included a month in India, Bangladesh, Nepal, and Guatemala. Training and consultation in station management has so increased in volume that CIMMYT plans to add a training officer to the experiment stations in Mexico.

STATISTICAL SERVICES

CIMMYT took delivery of its own Nova-3 computer in 1976, replacing borrowed hardware. The new machine analyzed the international maize trials for 1976 satisfactorily and promptly, producing the tables directly from the computer without intermediate typing.

Sorghum experiments conducted in Mexico, in cooperation with ICRISAT in India, were analyzed by the computer in 1976, using the same statistical program as for maize.

Colorado University (USA) analyzed CIMMYT's international wheat trials in 1976, as part of a service agreement to develop the needed statistical program. In 1977 this responsibility will return to Mexico and be performed on the Nova-3. Likewise the Colorado staff have developed a computerized inventory of CIMMYT's maize germ plasm bank, which will be transferred to Mexico in 1977.

Many smaller computer tasks were completed in 1976, providing design and analysis of single experiments. These included agronomic trials by CIMMYT staff in Zaire and Tanzania, a sample survey of farmer attitudes in Tanzania, and assistance with variety trials in Guatemala.

The statistical staff in Mexico continue to assist the maize training program in El Batan by lecturing to trainees on statistical work, and preparing computerized test papers.

INFORMATION SERVICES

Eighteen new titles were published during 1976. In addition the general information booklet, This is CIMMYT, was revised and reissued. Most

Publications issued by CIMMYT 1976.

Title	Language	Pages	Press run
Bulletins and reports			
This is CIMMYT	English	48	5000
	Spanish	48	5000
CIMMYT 1974 Maize Improvement	Spanish	64	1500
CIMMYT 1974 Wheat Improvement	English	162	2500
CIMMYT Review 1976	English	117	6500
	Spanish	119	5000
Adoption of hybrid seeds and fertilizers among Colombian corn growers	English	29	1000
Diffusion of hybrid corn technology: The case of El Salvador	English	24	1000
The adoption of new bread wheat technology in selected regions of Turkey	English	27	1000
Green Revolution: The Tunisian experience	English	42	1000
The adoption of new maize technology in Plan Puebla, Mexico	English	24	1500
Maize marketing and distribution in Southern Zaire	English	20	500
From agronomic data to farmer recommendations: An economics training manual	English	51	3000
	Spanish	54	2000
Results of the 10th International Spring Wheat Yield Nursery	*	75	1000
Results of the 5th International Triticale Yield Nursery	*	58	1000
Results of the 6th International Durum Screening Nursery	*	22	1000
Results of the 1st to 4th Elite Durum Yield Trials	*	35	1000
Results of the 6th International Durum Yield Nursery	*	55	1000
Results of the 6th to 8th International Bread Wheat Screening Nursery	*	36	1000
Reprints			
Asian farmers can adopt Guatemala's low cost metal silos	English	4	1000
Current status of plant resources and utilization	English	5	500
Impediments to technical progress on small versus large farms	English	11	500
Promoting the adoption of new plant technology	English	14	500
CIMMYT Today			
The return of Medic	Spanish	16	4500
Multilines: Safety in numbers	English	12	4500
	Spanish	12	4500
Wheat x Rye Triticale	English	16	6000
	Spanish	16	5600

*English, Spanish and French.

bulletins, reports, and reprints were published in two languages (English and Spanish) or in three languages (English, Spanish, and French).

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

The Commonwealth Agricultural Bureau (UK) issued on behalf of CIMMYT Volume 2 of the Maize Quality Protein Abstracts, and Volumes 1 and 2 of Triticale Abstracts. About 650 maize scientists receive MQPA and about 400 scientists receive TA.

Mailing list

CIMMYT's general mailing list for publications was reviewed during 1976 and now contains 4500 addresses classified by interest: 25 percent wheat specialists, 25 percent maize specialists, 38 percent general agriculturalists, and 12 percent libraries; by language: half English and half Spanish; by geographic area: 8 percent Europe, 42 percent Latin America, 25 percent North America, 8 percent Africa, 17 percent Asia and Oceania.

A separate mailing list is maintained for economics publications.

Audio visuals

The permanent exhibit in the administration building continues to grow; new displays were added in 1976. The exhibit depicts CIMMYT's activities in increasing world food supply. The audiovisual section continued its support of the crop programs with art work and photography.

Visitors service

In 1976 over 8300 visitors from 57 countries were registered at CIMMYT headquarters, individually or in groups. Many others visited CIMMYT research stations away from El Batan, where no records are kept. A new development in 1976 was the large number of busloads of visitors sent to El Batan by agrobusinesses in the U.S. The Visitors Service gives these tour groups a slide lecture and brief walking tour of the headquarters.

Library services

CIMMYT's small working library (2700 volumes, 1200 serials) continued to offer services to the headquarters staff, postdoctoral fellows, and 100 training fellows. There were 4300 individual visits to the library in 1976. The library also serves as liaison with Mexico's National Agricultural Library (180,000 volumes, 50,000 serials) which is located 10 km from CIMMYT.

1976 CIMMYT INCOME AND EXPENDITURES
(Excerpt from CIMMYT Auditors Report 1976)

	Thousand US$
Core unrestricted income	**7,600**
Belgium	50
Denmark	172
Ford Foundation	465
Germany, Fed. Rep.	338
Inter-American Development Bank	2,300
International Minerals and Chemical Corp.	40
Iran	725
Rockefeller Foundation	500
Saudi Arabia	150
UK	200
USA	2,550
World Bank	110
Core restricted income	**1,921**
Canadian International Development Agency	750
Triticale project	
International Development Research Center	63
Cold tolerant sorghum project	
UN Development Program	1,108
Quality protein maize, East African economics	
Special projects income	**3,095**
Canadian International Development Agency	475
Projects in East Africa, Andean Region	
Ford Foundation	990
Projects in Algeria, Argentina, Egypt, Pakistan, Tanzania, Tunisia, misc. training	
Germany, Federal Republic	171
Training	
Inter-American Development Bank	367
Central American maize, Latin American training	
International Agricultural Development Service	25
Nepal project	
International Development Research Center	17
Publications, training	
International Institute for Tropical Agriculture	43
Tanzania project, training	
International Potato Center	84
Mexico research	
Netherlands	263
Disease surveillance in Mediterranean-Mideast	
Rockefeller Foundation	82
Turkey project, publications, training	
U.S. Agency for International Development	270
Projects in Nepal, Pakistan, Guatemala, training	
Zaire	266
National maize project	
Miscellaneous training grants	42
Earned income (Not listed elsewhere)	**78**
TOTAL INCOME	12,694

	Thousand US$
Core operating expenses	**9,228**
Wheat program	1,738
Maize program	1,475
Economics	276
Laboratory services	370
Experiment station operations	1,085
Statistical services	135
Conferences and training	1,011
Information services	379
Administration	996
General operations	935
Indirect costs	304
Capital acquisitions	315
Addition to working capital	200
TAC review	9
Special projects expense	**2,722**
TOTAL EXPENSES	**11,949**
Reimbursements to donors and unexpended balances	**745**
Total expenses, reimbursements and unexpended balances	**12,694**

Se dio término a la impresión de este libro el 20 de junio de 1977 en los talleres de Ediciones Las Américas. Tiro: 6,500 ejemplares. Impreso en México.

ISSN 0304-5463

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