CIMMYT

1970 – 71 REPORT

ON MAIZE AND WHEAT IMPROVEMENT

Annual Report
1970 - 1971

Centro Internacional de Mejoramiento de Maíz y Trigo
International Maize and Wheat Improvement Center

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CIMMYT is an autonomous international research and training institution which has evolved from crop improvement work begun in México nearly 30 years ago. The Government of México is a participating sponsor and provides part of the land and facilities.

Financial support for general operating expenses and special programs as reported herein came from the Ford Foundation, the Government of Canada, the Inter-American Development Bank, The Rockefeller Foundation, the United Nations Development Program, and the U.S. Agency for International Development. CIMMYT conducts research and training on wheat and maize, and is an international center for scientists concerned with the improvement of production of these crops everywhere in the world, with emphasis on developing countries.

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JOSE A. MIRANDA M., Farm Foreman at Toluca
RAFAEL TRUJANO S., Farm Foreman at El Batán

Introduction

This annual report carries the story of CIMMYT through 1971. Previous reports ended in midyear. Therefore, it has been necessary to report some activities over an 18-month period.

The years 1970 and 1971 were extraordinary years for the Center and its collaborators. CIMMYT's new headquaters, laboratories and dormitory facilities at El Batán, 45 kilometers from Mexico City, were inaugurated on September 21, 1971. Several new research stations were added to CIMMYT facilities, with financing by the Rockefeller Foundation. Norman Borlaug was awarded the Nobel Peace Prize and CIMMYT shared with IRRI the UNESCO Science Prize. Both the maize and wheat program reported solid steps forward in their research in México and in their outreach programs outside México. CIMMYT financing reached a total of US$6.6 million for 1971, with several new donors.

Central Headquarters Facilities

CIMMYT's central headquarters facilities, consisting of offices, laboratories, greenhouses, a guest house with six twin bedrooms, a cafeteria, a dormitory with 60 single rooms, and 10 apartments for postdoctoral fellows, were inaugurated on September 21, 1971. This complex of buildings is located on a 43-hectare farm for field research and training, generally known as "El Batán," near the town of Texcoco about 45 kilometers from Mexico City and near the Center for Research, Education and Extension of the Mexican Ministry of Agriculture at Chapingo. The CIMMYT facilities were built on land procured by the Government of México and the buildings were provided by the Rockefeller Foundation at a cost of approximately US$3.5 million, including all services such as water, drainage, streets, electricity and telephones, and most of the new furnishings and laboratory equipment.

Substation Development

In addition to El Batán at 2,200 meters elevation, which is used for both maize and wheat research, CIMMYT has now acquired three other substations in México with the help of the Ministry of Agriculture and the Rockefeller Foundation. These substations are strategically located in different climates to facilitate: (1) the development of high-yielding, widely adapted, disease- and insect-resistant varieties and germ plasm complexes of maize and wheat; (2) research on agronomic practices most desirable for maximum yields of such varieties; and (3) the training of young men in breeding and production techniques over a wide range of environmental conditions. One substation is located near Poza Rica, Veracruz State; another at Tlaltizapán in the State of Morelos; and a third near Atizapán in the Valley of Toluca, State of México.

The station at Poza Rica consists of 45 hectares of excellent experimental land and is being used principally for research with maize in the lowland humid tropics. Half of the area was acquired for CIMMYT by the Ministry of Agriculture and the other half was purchased by CIMMYT.

The farm at Tlaltizapán was provided to CIMMYT by the Mexican Ministry of Agriculture and contains approximately 42 hectares, of which 30 are usable for experimental purposes. This substation is located at 940 meters above sea level in a "dry" climate. Almost any variety of corn can be grown to maturity at this station during the long, warm winter dry season (8 months) and it is an excellent location for the interhybridization of a wide range of germ plasm complexes, as well as a good area for breeding for insect resistance.

The third farm, recently acquired in the Valley of Toluca, is at about 2,640 meters elevation and is used mainly for wheat research during the summer months. Its cool, humid climate at that time of year is conducive to the development of the common diseases of wheat and is excellent for screening for disease resistance. It also provides the breeders an ideal place to advance their breeding materials another generation in a two-crops per year system. This farm, consisting of approximately 80 hectares of excellent level land, was purchased directly by CIMMYT with funds provided by the Rockefeller Foundation. Some of the land is used by the International Potato Program in cooperative work with the Mexican National Institute of Agricultural Research (INIA) and other national and international agencies.

CIMMYT continues its winter wheat research in cooperation with INIA at the CIANO station near Ciudad Obregón, Sonora State. This station of 100 hectares was established in 1955 under the cooperative program between the Ministry of Agriculture and the Rockefeller Foundation, which operated for many years in the improvement of the basic food crops of México. The farmers of Sonora recently added another 140 hectares to this station, which will further facilitate research in the worldwide CIMMYT-INIA wheat and triticale programs based here.

Aside from its contribution for the central facilities at El Batán, the Rockefeller Foundation granted CIMMYT US$527,000 for the development of the substations mentioned above. These funds were used for construction and equipment, land leveling, roads, irrigation systems and other services needed to develop these farms into efficient field research stations. Although in certain areas additional land and equipment is needed, CIMMYT, in general, now has excellent basic facilities for carrying out its work.

Special Awards

On November 12, 1970, the 1970 UNESCO Science Prize was awarded to CIMMYT and IRRI for their outstanding work in the development of widely adapted, fertilizer responsive, insect- and disease-resistant varieties of wheat and rice which have contributed greatly to the increase of food production in the lesser developed areas of the world. The prize was first established in 1968 and includes US$3,000 and a gold medal. It is awarded every other year in recognition of outstanding contributions to the technological development of a developing member state or region. Selection is made by the Director General based on recommendations from a jury composed of scienitsts from five member nations.

About a month later, on December 10, 1970, the Nobel Committee awarded the Nobel Peace Prize to Dr. N. E. Borlaug for his leadership in the development and utilization of wheat varieties in México, India, Pakistan and other countries of the developing world. This is not only a tremendous honor to Dr. Borlaug, but as Dr. George L. McNew pointed out in an editorial in *Bio Science,* "it flows like an invigorating breeze from the mountain tops across the face of all biology." It clearly indicates that the foundation for peace is enough food for all.

These prizes have brought great recognition to the work that CIMMYT seeks to promote. They have been a source of immense pride and satisfaction to CIMMYT staff, the Board of Directors, the foundations and other donors who have so generously supported the work of the Center.

Wheat and Maize Progress

On the research front, the triticale plant has now been dwarfed by conventional breeding, using dwarfing genes transferred from bread wheats. The problem of partially shriveled triticale grain is not yet solved. CIMMYT launched a new wheat production and research program in Algeria during 1971 with four CIMMYT staff members in residence; and the maize program has negotiated a new national production campaign in Zaire (formerly the Congo), West Africa, to be staffed in 1972 by three CIMMYT members in residence. The expansion of outreach programs is placing a strain on available CIMMYT staff with previous international experience.

Finances

The total funding for CIMMYT during 1971 reached US$6.6 million, including US$2.6 million for recurring headquarters activities, US $2.1 million for capital expenditures on the headquarters and substations, and US$1.9 million under special bequests in which the donor specified the purpose. Despite this generous support, CIMMYT's recurring budget was almost US$1.0 million short of its carefully laid 1971 plans, as approved by the Trustees.

The United States Agency for International Development became a full financial partner in CIMMYT's core budget in 1971, joining the Rockefeller and Ford Foundations. A special grant of US$2.5 million for five years was provided by the Canadian International Development Research Center for expansion of CIMMYT's triticales work. Continued support of the United Nations Development Fund was used to finance the special work on maize varieties with high protein content.

Toward the end of 1971 the new Consultative Group in support of the international agricultural centers held its first pledging conference, and it appears at this date that CIMMYT's future financial income should become more secure. The Consultative Group was organized jointly by the World Bank, the UNDP and the FAO.

Staff Changes

CIMMYT's professional staff in México increased to 37 in 1971, from a previous year level of 28, and the CIMMYT staff assigned outside México remained constant at 13. However, there were numerous shifts.

On December 31, 1971, Dr. E. J. Wellhausen relinquished his position as Director General of CIMMYT after 28 years of scientific service with the Rockefeller Foundation in México. He will continue promoting agricultural development in the tropics under the auspices of the Rockefeller Foundation. Mr. Haldore Hanson, formerly Ford Foundation Representative in West Africa, became CIMMYT's second Director General on January 1, 1972.

México City,
March 1, 1972.


(Photo: Centre National Pedagogique Agricole, Algeria)

WHEAT

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INTRODUCTION

The objective of the CIMMYT wheat program is threefold:

1. To help governments develop wheat improvement programs and to supply germ plasm, technology and training of national scientists for those programs, in order to benefit the largest possible number of farmers, especially in developing countries.
2. To increase the efficiency of grain production, as measured by yield per unit area and by lowered cost of production, in order to help the wheat grower achieve a greater net income, and to ensure an adequate food supply at economical prices for entire populations.
3. To improve the nutritional quality of wheat, especially protein quality.

Assistance to developing nations emphasizes promotion of wheat production programs, combining modern crop production technology with policy that permits its implementation. In some developing nations, especially where there is a shortage of trained and experienced wheat scientists, CIMMYT assigns several of its staff members to work with host country scientists in research and production programs for several years. In other cases, a CIMMYT staff member spends one to several weeks in a country working with the scientists of the host country, and with government planners and officials in developing research and production programs.

A GENERAL PERSPECTIVE

The Green Revolution made further advances on several fronts during the past year. Considerable progress was attained in varietal improvement and varietal diversification in many of the countries with which CIMMYT collaborates. Diversification provides more protection against outbreaks of epidemic diseases.

India harvested its fourth consecutive record wheat crop with a total production of 23.3 million tons, 3.2 million tons more than the excellent 1970 crop (Table W1). Most of this production increase resulted from increased use of improved varieties and technology in wheat producing areas, accompanied by a significant increase in areas where the new technology had penetrated only peripherally. Much of the area sown to high-yielding varieties two years ago was Kalyansona (Cross 8156). During 1971, the area covered by Sonalika, Chhoti Lerma and Safed Lerma (varieties developed through reselection of Mexican materials by Indian scientists under Indian conditions) greatly increased. Seed of newer varieties, UP301 (from a Mexican cross) and Lal Bahadur (an Indian cross), is also becoming available in large quantities. This will further diversify resistance.

The diversity and scope of the wheat breeding program in India is one of the best in the world. Several very promising wheats developed from crosses made in India between Indian and dwarf varieties are now in the final stages of testing. The variety Hira, a new three-gene dwarf variety, has been released for irrigated conditions. Narbada 4, a bread wheat variety, and A9-30-1, a durum variety, were released for the dryland areas of central India.

India's gross agricultural product attributable to wheat during the last four years has increased US$2.96 billion above the pre-dwarf record year of 1965. This created a tremendous impact on the demand for agricultural and consumer products.

In Pakistan, the new variety Chenab 70, developed from C271 x Willet dwarf-Sonora 64, was grown this year on a significant commercial area. On the average, its yields surpass those of Mexipak (Cross 8156), the main commercial variety. It should cover much of the wheat area in 1971-72. Other new varieties, such as Nayab, Khushal and Barani 70, will help diversify disease resistance next year. Despite these research advances, 1971 production in Pakistan may be lower than for 1970. Primarily, this has resulted from the unsettled political situation and shortage of fertilizer at planting time.

Nevertheless, the last four years show an increased gross agricultural product for wheat of about US$930 million above Pakistan's pre-dwarf record year of 1965.

TABLE W1. Wheat production (millions of metric tons) in Pakistan and India from the record 1964-65 crop year through 1970-71, showing percentage change from 1964-65 and annual percentage change.

	1964-65	1965-66	1966-67	1967-68	1968-69	1969-70	1970-71
PAKISTAN							
Production	4.6[1]	3.7[2]	4.3[2]	6.7[3]	7.2[3]	7.3	6.5[4]
Percentage change from 1964-65	—	—19.6	— 6.5	45.7	56.5	58.7	41.3
Percentage annual change	—	—19.6	16.2	55.8	7.5	1.4	—11.0
INDIA							
Production	12.3[1]	10.4[2]	11.4[2]	16.5	18.7	20.1	23.3[4]
Percentage change from 1964-65	—	—15.4	— 7.3	34.1	52.0	63.4	89.4
Percentage annual change	—	—15.4	9.6	44.7	13.3	7.5	15.9

[1] Very favorable weather, the 1964-65 crop set a production record for the pre-Green Revolution era.
[2] Drought year.
[3] Data from annual reports of Accelerated Wheat Improvement Program in West Pakistan.
[4] Estimated production for Pakistan but official for India; production data for other years from official government sources.

The coordination developed in the wheat breeding program throughout the former province of West Pakistan has continued despite the creation of new provinces in the area. Hopefully, this cooperation will not be affected by changes in the political and budgetary structure.

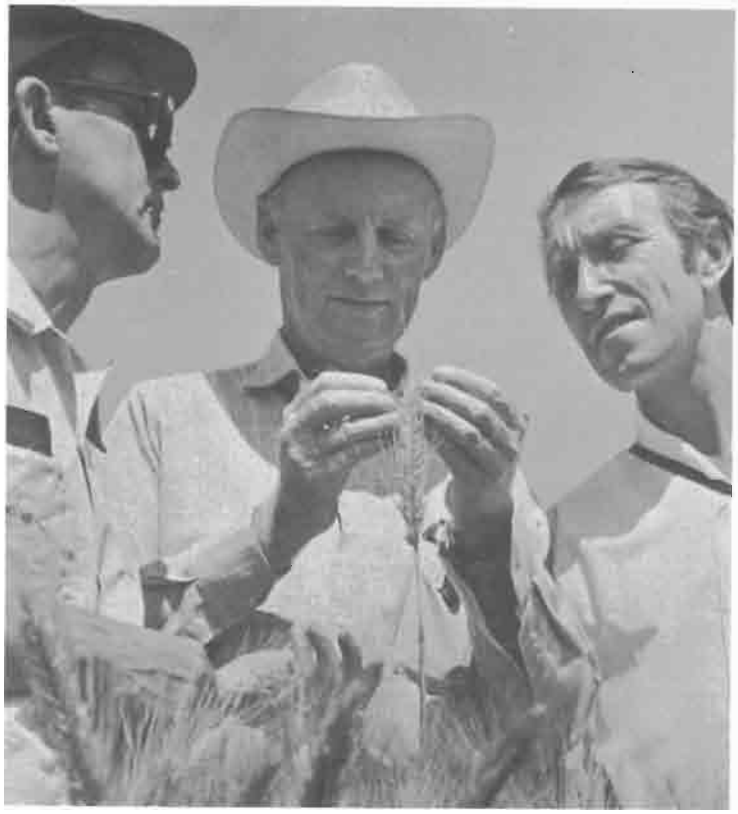
Turkey's wheat production of 13 million tons — 3 million tons more than last year — set a record. A new expanded research program started in 1970 is making rapid progress in identifying lines for the coastal fall-sown spring wheat region and the more severe conditions of fall-sown winter wheats on the Anatolian Plateau.

Afghanistan reports yield increases in its irrigated areas, but due to the second consecutive year of severe drought, production in rainfed areas declined significantly and much of the area was a total loss.

In Iran, production of Inia 66 has continued to spread rapidly and a good harvest is predicted. Some of the rainfed areas suffered yield losses from the unusually dry year.

Morocco's combined production of durum and bread wheats was an estimated 2.21 million metric tons with yields of more than 1.23 tons per hectare. Production in Tunisia has increased, but figures are not yet available for total production during the current year. In Morocco and Tunisia, three experimental lines appear to be superior to the Mexican varieties (Inia, Tobari and Siete Cerros) now being grown widely in commercial production. These lines were identified from the many Mexican lines received in the past few years. They possess better resistance to leaf blotch (caused by *Septoria tritici)*, a severe disease in the higher rainfall areas, than the current varieties. One variety, designated Utique, was derived from Cross II-22429 (Tobari "S"-Tezanos Pinto Precoz x Lerma Rojo-Andes$_{E}{}^{3}$). The second and third lines, named Zaafrane and Soltane, are from Cross II-19975 (Sonora 64-Klein Rendidor). Much breeding material is being developed and screened for increased resistance to *Septoria tritici* and *Erisyphe graminis* in the Tunisian, Moroccan, Algerian and Turkish programs.

This year Algeria launched its first expanded wheat production program, mainly built around Mexican varieties, technology developed in México and programs of collaborating neighboring countries. About 140,000 hectares of high-yielding varieties were sown this year, compared with 5,000 hectares in 1970. Despite the great shortage of trained personnel, success in the rapid expansion of production of new varieties and new production technology has been phenomenal. A good harvest was reaped although figures are not yet available on total production.



A new triticale line is examined by Dr. Oscar Brauer (left), director of the National Institute for Agricultural Research, Mexico, Dr. K.W. Finlay (center) of CIMMYT and Dr. J. Hulse of the International Development Research Center, Canada.

Among Latin American countries, Brazil has launched a very aggressive production program which has increased production from approximately 300,000 tons in 1966 to an estimated two million tons in 1971. This has largely resulted from the dynamic research program and stimulating economic policies of the government.

CIMMYT RESEARCH

CIMMYT's research efforts are devoted to helping interested developing nations produce better varieties. CIMMYT does not create varieties *per se* since this task remains with the national programs. CIMMYT seeks better agronomic practices, physiological practices, yield increases, disease resistance and industrial quality of advanced wheat lines. These developments are distributed to national programs. CIMMYT becomes a catalyzer, transmitting information, sending wheat materials and assigning a limited number of staff members to collaborate with and help some national programs.

Despite record yields in the main wheat production areas, México in 1971 was slightly deficient in wheat for the first time since 1956. This resulted from a significant reduction in wheat acreage in favor of oilseeds, particularly safflower and flax, in response to an increase in price for these crops. This indicates clearly how sensitive cereal crop production is to economic policy.

In the INIA research program in México, considerable progress has been made in the past year in varietal development, multiplication and release. Six new varieties which will be grown on a considerable commercial acreage in 1971-72 were released by the *Instituto Nacional de Investigaciones Agrícolas* (INIA) of the Mexican Ministry of Agriculture. These included Nuri 70, Yecora 70, Saric 70 and Cajeme 71. These bread wheats were all derived from Cross II-23584 (Ciano "S" x Sonora 64-Klein Rendidor/8156), formerly known as Bluebird 1, 2, 3, and 4, respectively. A fifth bread wheat, Potam 70, was derived from a cross of Inia "S"-Napo (Cross II-22402). The sixth, a soft pastry wheat (Vicam 71) from Cross II-22398 (Inia "S"-Napo), was released. In addition, another soft wheat variety Tanori 71), from Cross II-25717 (Sonora 64-Ciano "rec"-Inia 66), was named.

The durum program has expanded rapidly. Jori 69 was grown on about 5,000 hectares in 1970-71 with good results. A new variety (Cocorit 71) which is superior in performance to Jori was identified. These two varieties show promise of being well-adapted to North Africa, but because of their susceptibility to *Septoria* and mildew, their production will be restricted to zones of moderate rainfall. The genetic pool of the durum program has been rapidly diversified and enlarged during the past three years. With this modification, it is expected that lines will be produced which can be successfully grown in North Africa, the Near East, the Middle East, México, Argentina and Chile.

A major shift in emphasis is being made toward improving the bread and durum wheats for resistance to *Septoria tritici, Septoria nodorum, Giberella* sp., and *Erisyphe graminis.* It will take three to four years to develop high-yielding varieties with adequate resistance for the high rainfall areas of the Mediterranean region, Brazil and Argentina.

Progress in the triticale breeding program continues to be encouraging. Many lines have now been identified that combine good fertility, earliness under short days, good agronomic type, including short straw and resistance to a number of diseases, and having very promising nutritional properties. The principal defect is its partially shrivelled seed. However, some improvement in this characteristic has been identified in a few lines, too.

In July 1970, Dr. Fred Elliott of Michigan State University, in feeding trials with meadow voles, identified some triticale lines of the CIMMYT program which exhibited very high nutritional value. Protein efficiency ratings (PER) were similar to those for egg protein. These findings of high nutritional value support the earlier findings of Dr. Evangelina Villegas, head of the CIMMYT Protein Quality Laboratory, who identified many triticale lines with high protein and high lysine content. These discoveries have opened new horizons for this manmade cereal. Also, toxic substances which killed voles fed them were found. It indicates the need for immediate, expanded research on this species to develop varieties which will compete with other cereal crops. A vole laboratory designed to support the nutritional aspects of all the breeding activities is being developed at CIMMYT's new headquarters.

The international nurseries program continues to expand. Sixty-three countries receive seed under this program and various tests and nurseries are grown at more than 100 locations. Much valuable information useful for guiding plant breeding programs is being developed by the international nurseries.

In the training program, 41 trainees from 20 countries successfully completed the course in the past year. Applications continue to outnumber the positions available with present facilities.

Several new physiologic studies have been started to determine which physiologic and morphologic characteristics are most important in producing high yields. Agronomic tests continue to be conducted on the wheats and triticales.

During the last two years, an excellent service to monitor disease development in the region from Morocco to India has been developed. This is modelled on a similar system developed in India. Dr. Eugene Saari, who was closely involved with the Indian Disease Surveillance Project, has taken the lead in organizing this system in cooperation with plant pathologists and breeders in the countries of this region. In one of these international regional nurseries, the Trap Nursery, all leading commercial varieties of the cooperating countries are included. The nursery is grown in collaboration with national program scientists. It provides a medium for establishing epidemiology and race shifts in disease populations. All cooperating country program scientists are encouraged to place their advanced promising lines in a second nursery. This nursery is grown in locations with disease histories of high intensity. Lines entered are assessed for scope of disease resistance and adaptability. Also, materials are distributed to form the basis of increased intercountry assistance. Lines with desired resistance are put into breeding programs of interested countries and CIMMYT.

Dr. Glenn Anderson was transferred from India to CIMMYT headquarters in July 1971. He now serves as Associate Director of the Wheat Program. This move will enable the Director to increase his activities and assistance in the programs of Guatemala, Colombia, Ecuador, Perú, Chile, Bolivia, Paraguay, Brazil, Uruguay and Argentina. Dr. Anderson will coordinate CIMMYT activities in the Asian and African programs.

The increasing interrelationship of country programs is good. This mutual assistance can speed the development of materials and provide increasing insurance against disease and insect losses.

MEXICO

THE JOINT CIMMYT-INIA PROGRAM

Commercial Production

The 1971 wheat crop set a record in yield per hectare in México although total production decreased because of shifted acreage sown to winter oilseed in the major wheat area of northwestern México (Figure W1). Probably some grain imports will be required to meet consumption demand.

Diseases were not a problem in México and the incidence of the rusts, with the exception of leaf rust *(Puccinia recondita)* in the coastal areas of Sonora and Sinaloa, was very low.

The variety Inia 66, although heavily infected with leaf rust in late-sown areas of the Northwest. produced high grain test weights with little apparent adverse effect on yield. Inia 66, with the infection level at 80-90S, surpassed the yields of Azteca and Tobari, which were rust free. Light infections of *Puccinia striiformis,* a rarity in the Northwest, were observed at CIANO *(Centro de Investigaciones Agricolas del Noroeste* at Ciudad Obregon, Sonora, México) on susceptible varieties in inoculated plots. This was considered due to abnormally low temperatures in the

Wheat plots and facilities at the Centro de Investigaciones Agrícolas del Noroeste (CIANO), Sonora State, northwestern México, used by the joint INIA-CIMMYT program.

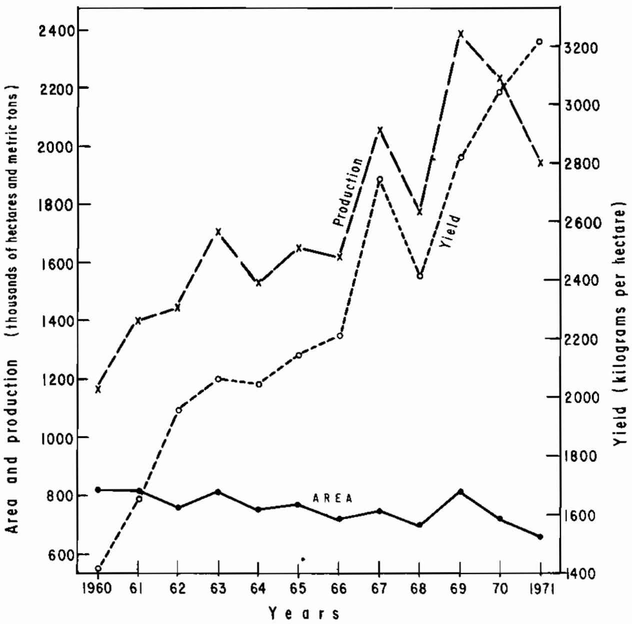


FIGURE W1. Production, yield and area of wheat in México, 1960-1971.

postflowering period. Rust development soon ceased as temperatures increased. There were no epidemics of stripe rust reported in any wheat growing areas.

Stem rust *(Puccinia graminis tritici)* was observed only in trace amounts in commercial fields of Siete Cerros in the coastal areas of Sonora and Sinaloa. There were no reports of damage from any wheat producing areas.

Last year four new varieties were named by CIANO: Nuri 70, Yecora 70, Saric 70 and Potam 70. These were increased and it is expected that Yecora 70 and Saric 70, two triple dwarf varieties, will be sown on significant acreages in the 1971-72 season. The principal commercial varieties are still Inia 66, Siete Cerros and Super X, occupying about 80 percent of the Northwest acreage. Smaller acreages of Azteca 67, Ciano 67, Bajío 67 and Tobari are still grown, but they are disappearing because of lower yield. Under good fertility practices, Siete Cerros and Super X continue to outyield Inia 66. The cultivation of Lerma Rojo 64 is again being encouraged in Sonora by industries needing a soft wheat for special products.

Although local outbreaks of aphids and armyworms were observed in the coastal area of Sinaloa and scattered fields in Sonora, they had little effect on yield.

Weeds, particularly *Avena fatua* (wild oats) and *Phalaris* (giant foxtail), continue to be key limiting factors in achieving high yields. Where adequate control measures were not taken, yield reductions of up to 50 percent were recorded. This is not a widespread problem since most farmers use herbicides and good control practices, including rotation with row crops. Still, weeds seriously reduce yields and incomes on some farms.

Varietal Development in Bread Wheats

The CIMMYT-INIA program continued its efforts to develop new, widely adapted, high-yielding lines to meet the demands of country programs in many areas of the world. Efforts emphasize widening the adaptation of varieties so that they can be grown successfully under a broad range of ecological conditions. There is a need to develop diverse genotypes with higher levels of disease and insect resistance so that the new lines and varieties have built-in protection mechanisms for these diverse areas.

Quality determinations are an integral part of the breeding program. All individually selected plants in F_2 are tested for Pelshenke values and selected for seed type. Later generations are given more complex tests, including the alveograph and sedimentation tests. Baking tests are applied in the advanced lines. Since CIMMYT cooperates with many regional programs, an attempt is made to develop crosses and lines suitable for different consumer needs. This includes red and white grain types of hard and soft wheats.

Since the derivatives of Cross 8156 have shown yield superiority under widely diverse conditions, a cooperative program with several national programs was instituted to develop a multiline of this type. The goal is to develop different multilines for different countries from this material. These multilines might differ in disease resistance, in quality and in insect resistance, but they would all have the phenotype and high-yielding capacity of Siete Cerros and Super X. The first selections from hundreds of crosses were made and these will be backcrossed as a parallel program with the regular breeding material.

New Mexican Commercial Wheat Varieties

This year a new commercial variety was named by CIANO and the National Institute of Agricultural Research. The new variety, named Cajeme 71 and formerly known as Bluebird No. 4, is a sister of the three Bluebird lines named last year. It is from Cross II-23584, Ciano "S" x Sonora 64-Klein Rendidor/8156. The cross displays a high yield potential and wide adaptation. Cajeme 71 is superior to Siete Cerros and Super X in bread-making quality and shows a higher degree of resistance to prevalent races of leaf and stem rusts in México. Compared to its sister lines, it is later in maturity and usually requires one additional irrigation. As seed supplies increase, this variety will probably replace much of the Siete Cerros and Super X now being grown.

The yield performance of Cajeme 71 in comparison with 1971 commercial varieties is summarized in Table W2. Siete Cerros is still the highest yielder, followed closely by Inia 66 and Cajeme 71. It is interesting to note that Cocorit, a newly named but still unreleased durum variety, outyielded all of the bread wheats. The yield difference is probably partly due to its longer maturity.

Promising New Bread Wheat Lines

Several very promising lines of the CIMMYT-INIA program were under test in the preliminary yield trials. A summary of the average yield performance of these lines at Ciudad Obregón, Sonora is listed in Table W3.

Several lines outyielded Siete Cerros and Inia 66. Some of the reselections of Yecora 70, for example, not only produced higher yields, but were markedly superior to Inia 66 in rust resistance and fully comparable in bread-making quality.

The line Yaqui 50_E-Kalyan^3 (Cross II-35188-5M (F_1) 6Y-0M), showed superiority in yield, but its range of adaptability may be limited by susceptibility to stripe rust and poorer bread-making qualities. A third cross, Sonora 64-Ciano 67 (reciprocal) x Inia 66, Cross II-25717-11Y-3M-1Y-0M, outyielded Inia 66 in eight trials. It is a soft wheat named Tanori 71.

Other lines and reselections will enter further yield trials and if successful in the second year, they will be candidates for future varieties.

Broadening the Bread Wheat Gene Pool

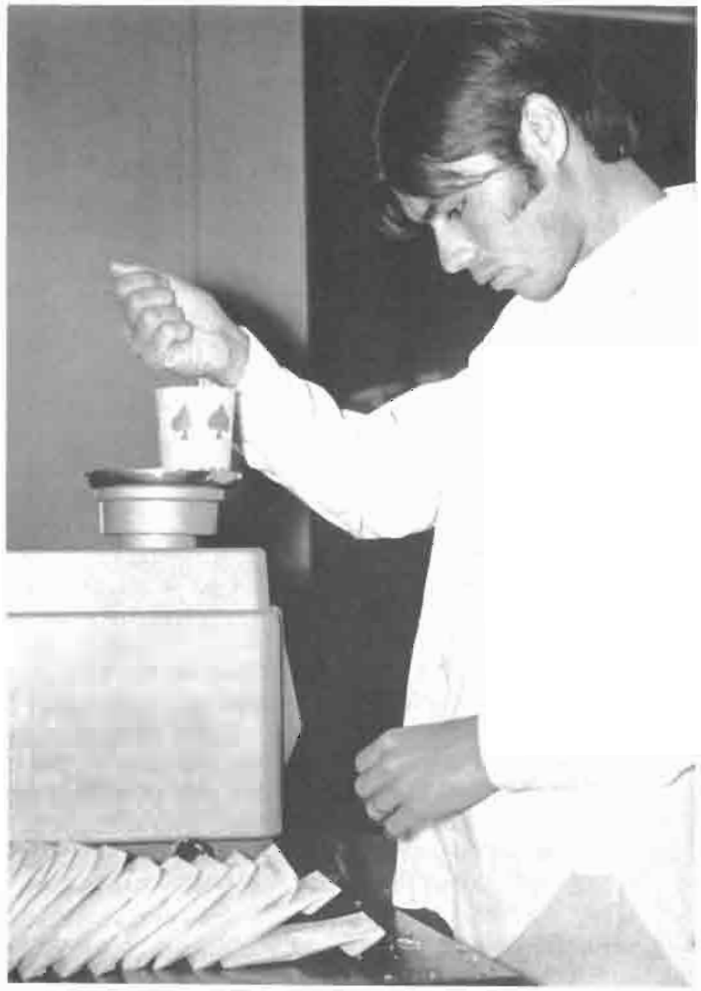
The requirements of an international program and its complex needs make broadening the germ plasm base first priority. Countries such as Morocco, Tunisia, Algeria, Turkey, Brazil and Argentina must have varieties which are resistant to *Septoria* spp. Lines such as Calidad (Tobari "S"/Lerma Rojo-Tezanos Pinto Precoz x Andes$_E$^{3}) and some of its derivatives and Pato (Tezanos Pinto Precoz-Sonora 64 x Nariño 59) are being extensively used in the breeding program as a resistance source. Other sources from different parts of the world where *Septoria* is a problem are being introduced for evaluation and crossing.

Resistance sources for scab (*Giberella* sp.), powdery mildew *(Erisyphe graminis)* and leaf

TABLE W2. Yield and performance of some commercial varieties and lines grown in yield trials during 1970-71 at CIANO, Ciudad Obregón, Sonora, México.

Variety and pedigree	Grain color	Average yield kg/ha	Test weight kg/hl	Number of replicates	Rust Reaction		
					Stem	Leaf	Stripe MV-70
Cajeme 71	Red	7613	80.1	38	0	TrMS	TrMR
Inia 66	Red	7833	82.5	53	5MR	80S	TrMR
7 Cerros	White	8007	80.0	43	20S	10MS	50S
Yecora "S" 23584-26Y-2M-1Y-0M-89Y	White	7713	81.2	14	TrMR	TrMR	TrMR
Son 64 x Cno "rec"-Inia 66 25717-11Y-3M-1Y-0M		8042	85.0	15	TrMR	20MR	TrMR
Saric 70	Red	6991	83.0	24	0	TrMS	TrMR
Yecora 70	White	7502	81.0	25	5MR	TrMS	TrMR
Nuri 70	Red	6502	83.0	21	5S	TrS	5MR
Super X	Red	7530	81.0	13	20S	5S	50S
Potam 70	Red	7100	79.5	22	0	80S	5MR
Tobari 66	Red	7306	81.3	13	10MR	TrMR	TrR
Ciano F67	Red	5234	83.0	30	0	0	TrMR
Azteca 67	Red	5908	81.3	4	TrR	0	TrMR
Bajío 67	Red	6627	82.5	3	10MR	0	
Penjamo 62	Red	7239	82.0	8	10S	5MS	30MS
Lerma Rojo 64	Red	7612	82.3	5	5MR	20S	5MS
Sonora 64	Red	6375	80.0	6	5S	30MS	20MS
Pitic 62	Red	7485	77.0	3	60S	20MS	TrMR
Jori 69*	Amber	7451		23	TrMS	0	TrMR
Cocorit*	Amber	8921		11	0	TrMR	TrMR

* New commercial durum varieties in México.



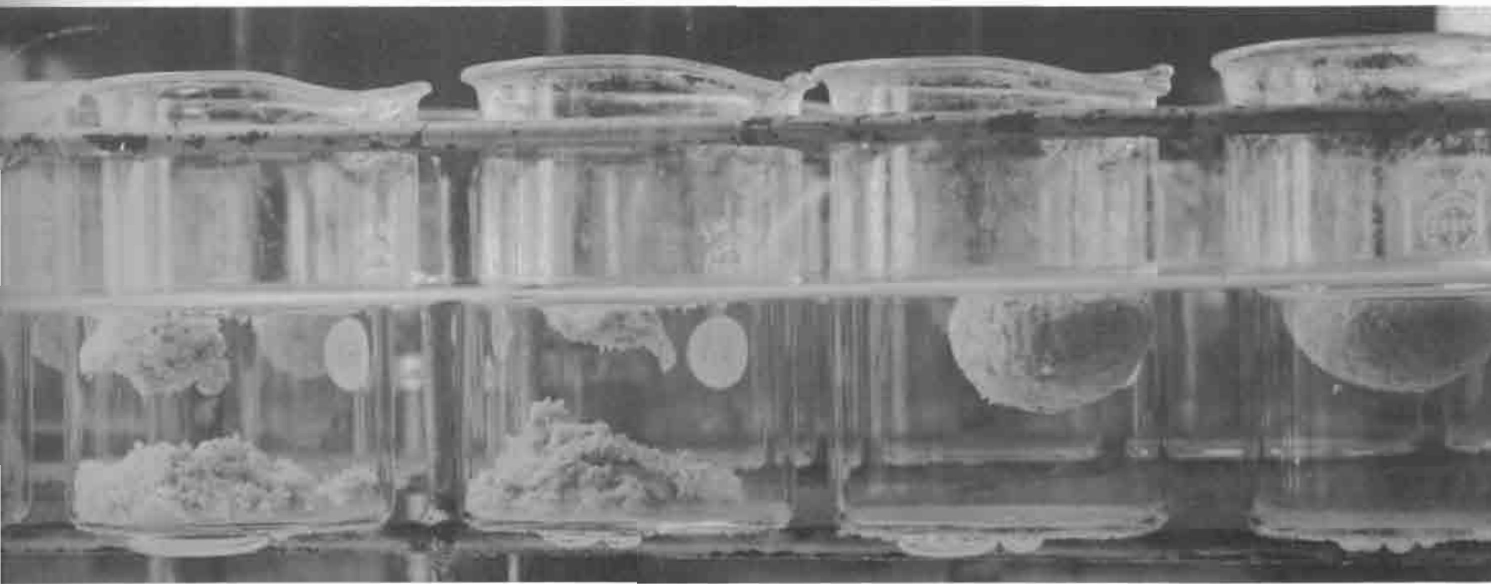
Testing Grain Quality

F_2 plants —F_3 seeds— are carefully selected in the field and immediately analized in the laboratory for type of kernel and quality of gluten.

A microsample of grain —three grams— is milled to obtain whole wheat flour.

Samples are mixed with 1.8 milliliters of a 3.2% solution of yeast and kneaded immediately to obtain a homogenous dough.

Samples are placed in beakers containing 80 milliliters of distilled water at 30°C.



Pelshenke values are expressed in the time that it takes the dough ball to disintegrate. Grain of plants with hard gluten must be vitreous and take more than 100 minutes to disintegrate. A soft gluten has a floury appearance and takes less than 100 minutes to disintegrate.

Technicians, trainees and lab assistants analyze the gluten quality of more than 10,000 lines in 15 days. With this test, about 50% of the lines are discarded.

TABLE W3. Yield averages of the most promising bread wheat lines from preliminary yield trials conducted at Ciudad Obregón, Sonora, México, 1970-71.

Variety or line	Pedigree	Yield kg/ha	Yield of highest check variety kg/ha		% of highest check
* Son 64-Cno "rec" x Inia	25717-11Y-3M-1Y-0M	7813	Inia 66	7493	104
Bluebird-Inia	26591-1T-7M-0Y-2M-0Y-(1-19Y)	7159	Super X	7117	100
Bluebird-Inia	26591-1T-7M-0Y-301M-0Y	9357	7 Cerros	9274	101
Bluebird-Inia	26591-1T-7M-0Y	9336	Super X	9597	102
Bluebird-Inia	26591-1T-7M-0Y	8242	Inia 66	7832	105
Bluebird-Inia	26591-1T-7M-0Y-132Y-0M	9138	Inia	8326	109
Bluebird-Inia	30596-1M-2Y-0M	8336	Inia 66	8159	102
Yecora "S"	23584-26Y-2M-1Y-0M-86Y-0M	9357	7 Cerros	9274	101
Yecora "S"	23584-26Y-2M-1Y-0M-302M-0Y	10137	7 Cerros	8888	114
Yecora "S"	23584-26Y-2M-1Y-0M-(6-10Y)	9753	7 Cerros	8888	109
Yecora "S"	23584-26Y-2M-1Y-0M-89Y-0M	10055	7 Cerros	8888	113
Yecora "S"	23584-26Y-2M-1Y-0M-19Y-0M	8763	7 Cerros	8294	105
Yecora "S"	23584-26Y-2M-1Y-0M-89Y-0M	7711	Inia 66	7252	106
Yecora "S"	23584-26Y-2M-1Y-0M-86Y-0M	7607	Inia 66	7252	104
Yecora "S"	23584-26Y-2M-1Y-0M-(1-5Y)-11Y-0M	8555	7 Cerros	8221	104
Yecora "S"	23584-26Y-2M-1Y-0M-(1-5Y)-54Y-0M	8586	7 Cerros	8221	104
Yecora "S"	23584-26Y-2M-1Y-0M-(1-5Y)-82Y-0M	8992	7 Cerros	8221	109
Yecora "S"	23584-26Y-2M-1Y-0M-(1-5Y)-45Y-0M	9826	Super X	8597	102
Yecora "S"	23584-26Y-2M-1Y-0M-301M-2Y-0M	9909	Super X	9597	103
$LR64^2$-Son 64	19865-58M-100Y-100M-101Y-100M	7607	Yecora 70	7575	100
Bluebird # 4 "S"	23584-26Y-2M-3Y-2M-0Y-300M-0Y	10097	7 Cerros	8888	113
Bluebird # 4 "S"	23584-26Y-1M-0Y-104Y-0M	8440	7 Cerros	8888	105
Meng-8156	H223-64-1Y-6E-1Y-1C-4Y-3C-100Y	9722	Yecora 70	9305	104
Inia 66-Cal x Inia "S"-CC	28647-67Y-1M-0Y	9253	7 Cerros	8888	104
12300 x LR64A-8156/Nor 67	30842-31R-2M-2Y-0M	9107	Yecora 70	8419	108
7C-On x Inia-B. Man.	28424-8Y-1M-1Y-0M	7940	Super X	7190	110
NP876 P62 x Cno-P62	28039-13Y-1M-2Y-0M	7950	Cajeme 71	7732	102
NP876 P62 x Cno-P62	27983-30Y-2M-0Y	7794	7 Cerros	7773	100
Bluebird-On	30388-1T-1M-4Y-0M	9597	Cajeme 71	9597	100
$Y50e-Kal^3$	35188-5M-(F_1)-6Y-0M	10347	Super X	9597	107

* Now known as Tanori 71 or Ti 71.

spot (*Alternaria* sp.) have been incorporated into the program. Breeding for these diseases and the rusts has been strengthened through cooperating programs in many countries. National programs send CIMMYT materials carrying good resistance for incorporation into CIMMYT's gene pool. Lines reported to be resistant have been received from Argentina, Brazil, Chile, Portugal, Turkey, Ethiopia, the United States and other countries where *Septoria* is indigenous and epidemic.

Incorporation of resistance to the three rust species is done under artificial epidemic in each generation. There is close cooperation with other country programs through evaluation of the screening nurseries grown in those countries. The International Rust Nursery provides much source material. For stripe rust-resistant material, there is close collaboration with Ecuador and Colombia where this disease is very severe. These materials are continually being crossed into the CIMMYT gene pool.

Insect problems are also of concern. Several varieties have been reported resistant to aphids, Hessian fly, sawfly, cereal leaf beetle, Zuni pest and wheat stem maggot. Materials from these crosses should be exploited in the F_2 generation in countries and at locations where these pests are serious.

International Testing

In addition to local tests in México, the most promising advanced lines are prepared in sets and sent to countries participating in a special screening nursery. This nursery distributes materials among cooperating programs and evaluates lines under a wide range of climatic, disease and insect conditions. An approximate measure of yield is also obtained. Formerly, two screening nurseries were assembled each year—Series "B" from Ciudad Obregón and Series "A" from Toluca. The outstanding lines were included in each nursery. In the future, the best lines from the two locations will be included in one nursery each year. Series "B" was distributed to 86 locations throughout the world. Data returned is compiled and published.

An elite trial of the most promising lines from 1970-71 preliminary yield tests at Obregón was grown at 39 locations around the and best lines to other programs and provides world. This yield test distributes the newest information on their adaptation range.

Winter x Spring Wheat Crosses

Dr. J. R. Rupert, a CIMMYT staff member, has been working at Davis, California for the past three winters on winter x spring wheat crosses. The program aims to develop germ plasm suitable for use in the high-elevation winter wheat regions of Turkey, Algeria, Iran and Afghanistan. In the initial stages, many crosses were made between winter wheats of Chile and México. A nursery of these crosses was grown last year at Ciudad Obregón, México to exploit them for suitable spring wheat types. F_2 materials have been distributed to cooperating countries to increase the germ plasm pool available. This program can be very beneficial for both spring and winter breeding programs since the intermixing of these gene pools can provide desirable genes to both.

DEVELOPMENT OF NEW DWARF DURUMS

This is the first year of expanding commercial durum wheat production in México since the 1950's. The variety Jori C. 69 was planted on about 5,000 hectares in the Yaqui Valley and the Hermosillo Coast in Sonora State. Preliminary reports indicate that it has yielded as well or better than Inia 66, the predominant bread wheat variety. The seeds of Jori 69 are very large and weigh almost 50 percent more than the seeds of Inia 66. However, the yield gain provided by this increased size of grain is not fully realized. There may be several reasons for this. Most present durum varieties have an open crown type of growth, resulting in a reduction of effective tillers per unit area. Attempts are now being made to select plant types with closed crowns. Another important factor is the rate of seeding. Durums are planted at the same rate as bread wheats. Since the seed size and weight of the durums is 50 percent greater, using the same sowing rate as for bread wheats reduces the plant population significantly. These two factors will be considered in future improvement of commercial durum yields.

The first factor can be changed by genotype selection while the second one involves simply increasing seed rate to the proper level as determined by agronomic studies.

A preliminary report of the First International Durum Yield Nursery (FIDYN) has been compiled. Table W4 gives the yield averages and disease data for 22 locations.

TABLE W4. Results of the First International Durum Yield Nursery, 1969-70. Averages for 22 locations (14 countries).

Variety or cross and origin	Yield kg/ha	Test weight kg/hl	Stripe rust	Leaf rust	Stem rust	Height cm
Crane (Mex.)	3818	78.1	1.2*	3.3*	3.9*	79.8
Brant (Mex.)	3707	77.9	2.0	3.0	4.4	76.8
Albatross (Mex.)	3657	79.5	1.6	2.1	3.2	82.3
Gerardo V-2-466 (Italy)	3633	79.3	1.8	1.4	4.3	89.5
Anhinga (S) (Mex.)	3579	81.8	1.9	3.3	1.1	101.5
Capeiti (Italy)	3218	81.1	2.5	3.8	4.6	106.5
61.130-Leeds (U.S.A.)	3200	79.5	4.9	3.8	1.0	85.2
Inia 66 (Bread Wheat) (Mex.)	3196	80.9	1.3	1.1	1.0	90.5
Local Variety	3142	79.8	2.2	4.1	2.8	108.4
Tehuacan (Mex.)	3127	81.0	2.1	2.7	3.8	125.3
S-9	3109	78.2	2.9	4.0	4.8	68.6
GA B.125 (Italy)	3105	78.4	2.3	2.5	3.9	106.7
Dur$_E$-Turg x St464-Tc^2 (Iran)	3047	76.1	1.8	3.0	4.5	85.6
Wells (U.S.A.)	3043	79.8	3.8	3.9	1.3	123.9
Castel del Monte 1 (Italy)	2962	807	1.5	2.1	4.0	91.9
Leeds (U.S.A.)	2904	82.2	3.2	4.0	1.5	127.3

* Average rust values were numerically transformed as follows: 1.0 is no disease and 10.0 represents 100 S reaction.

The top five varieties in yield carry the Norin 10 dwarfing factors. Of these, Crane, Brandt, Albatross and Anhinga (S) are of Mexican origin and Gerardo V-2-466 is an Italian derivative from a conventional breeding program involving a Mexican dwarf durum.

The varieties Wells and Leeds from the United States, which have good quality and performed well in North Dakota where they were bred, have a narrow range of adaptation.

The two dwarf durum mutants, GAB 123 and Castel del Monte, have a very narrow range of adaptation. Overall, they rank twelfth and fifteenth among 16 varieties.

During the past three years, selections of the line Crane (Cross 23055) did exceptionally well in the yield trials in Mexico. The top-yielding variety of the FIDYN is a selection from this cross. Another cross with exceptional yield potential is Cisne (Cross 27617), the top yielder of the 1969-70 crop at Sonora, Mexico. During 1970-71, Cisne was used as a check variety and it again proved its superiority. Table W5 shows the average yields of different selections of Crane and Cisne compared with check varieties. In addition to these two crosses, four new ones now in early generation seem to have good yield potential. These are:

1. Jori x 61 130-Leeds/Grulla "S"-Flamingo (Cross 27582);
2. Jori 67 x Crane "S" (Cross 27591);
3. Crane "S" (*Triticum polonicum,* 185309 x *Triticum polonicume*-Tehuacan^2/Grulla "T"), Cross 31725; and
4. Anhinga "S" (Capelli$_E^3$-Ghiza x Tehuacan^3/Barrigon Yaqui$_E$-Tehuacan), Cross 31733.

When the durum breeding program was intensified three years ago, the main objective was to obtain lines with high yield potential combined with yield stability. The results of the last two cycles of yield tests and the FIDYN indicate that some of the CIMMYT dwarf durums have good yield levels and reasonably good yield stability. So, now the emphasis in the breeding program is: (1) to maintain and improve the yields; (2) to widen the genetic base for the different rusts; (3) to breed for quality; and (4) to incorporate mildew and *Septoria* resistance.

Dr. George Varughese (right) of CIMMYT discusses the durum wheat improvement program.

An attempt has been made to identify new genes for dwarfness to increase variability for this character. Recently, some new dwarf genes have been found and there are now five recessive dwarfing genes available. Attempts

TABLE W5. Average yields of different selections of the durum wheat lines Crane and Cisne grown at CIANO, 1970-71.

Line	Pedigree	Yield kg/ha	Check	
			Variety	Yield kg/ha
Crane "S"	D-23055-33M-1R-3M-0Y-67Y-0M	9950	7 Cerros	8860
Crane "S"	D-23055-56M-5Y-1M-0Y	9470	7 Cerros	9170
Crane "S"	D-23055-33M-1R-3M-0Y	9300	7 Cerros	9170
Crane "S"	D-23055-56M-5Y-3M-0Y	9055	7 Cerros	8800
Crane "S"	D-23055-56M-5Y-1M-0Y	9000	7 Cerros	8800
Crane "S"	D-23055-56M-5Y-2M-0Y	8810	7 Cerros	8800
Cisne "S"	D-27617-18M-6Y-0M	9650	Cajeme 71	9149
Cisne "S"	D-27617-18M-3Y-0M	9600	7 Cerros	9154
Cisne "S"	D-27617-18M-6Y-2M-0Y	9120	Cajeme 71	9190
Cisne "S"	D-27617-18M-5Y-2M	8900	7 Cerros	8460
Cisne "S"	D-27617-17M-6Y-1M-4Y-0M	8810	Cajeme 71	8700
Cisne "S"	D-27617-18M-6Y-1M	8700	7 Cerros	8460

are being made to combine these different sources. A combination of one recessive gene from Norin 10 with a recessive gene from a Chilean variety behaves in a semidominant way. This combination is present in the line Stw 63-GII "s"/C1-8133.2h-Cfn x Cpt 8, (Cross 31613).

When many of these dwarfing genes are combined into a single line, crosses with tall varieties will hopefully give a higher proportion of dwarf segregates than has been obtained using a single recessive gene.

PATHOLOGY RESEARCH

The Rusts

The stem, leaf and stripe rusts are the most important diseases of wheat. One or more of these rusts can be found wherever wheat is grown and all are a continuous threat to high wheat productivity.

The continuing success of any wheat breeding program depends upon the incorporation of a wide range of sources of resistance genes, followed by proper selection and wise utilization of the resultant recombinations. In most instances, rust resistance — especially resistance to stem rust — of CIMMYT wheat cultivars and lines has been based on a relatively broad spectrum, which in part permitted the successful transplant of Mexican wheats to many countries of the world. Nevertheless, there is a continuing need to broaden the spectrum and to increase in depth the genes for resistance to rusts in the CIMMYT gene pool. Research is conducted in fields and greenhouses to locate other sources of resistance in the seedling and adult plant stages, for both bread and durum wheats.

During the past year, much information has been gathered regarding the distribution of the races of *Puccinia graminis tritici.* Table W6 shows percent distribution of the standard races of stem rust in Sonora (Yaqui and Mayo Valleys) and Los Mochis, Sinaloa (1969-70). About 200 collections of infected wheat varieties from commercial and experimental fields were analyzed on the 12 standard set differentials. It appears that Race 15, present in the previous crop season, has essentially disappeared; Race 113 was the most predominant. Race 151 was less prevalent in the Sonora 1969-70 season than in Toluca (1969).

The 200 stem rust collections were also tested in the seedling stage in the greenhouse

TABLE W6. Percentage distribution of standard races of Puccinia graminis f. sp. tritici in Sonora (Yaqui and Mayo Valleys) and Los Mochis, Sinaloa, México, 1969-70 (approximately 200 collections).

Standard race	Percent
11	9.0
12	26.0
13	6.0
39	13.0
56	2.0
113	41.0
151	3.0

Dr. Ralph M. Caldwell of Purdue University explains a point about rust development to a CIMMYT trainee.

on 18 selected wheat genotypes and these genotypes were grown to the adult stage at CIANO (1969-70). Their field and seedling reactions against *P. graminis tritici* are listed in Table W7.

It appears that no single gene, except Sr-13 and Sr-17, provide very effective protection. It also indicates that the varieties *Tobari 66, Inia 66, Lerma Rojo 64A almost certainly carry genes for adult plant resistance* since a high percentage of isolates are able to attack them in the seedling stage, but they are resistant under field conditions. The resistance genes present in Norteño 67, Noroeste 66, Renown, Line S, Selkirk, Mendos and Yuma are highly effective, both in the seedling and the adult plant in the field.

During the fall of 1970, Elite Yield Trials #1 and #2 were prepared for shipment to collaborators in several countries. These yield tests included the most important commercial Mexican varieties and the most promising experimental lines in the CIMMYT breeding program. The seedling and adult plant stem rust reactions of these lines and varieties to races 12-1, 2, 3, 5, 6 and 151-1, 2, 3, 6, are listed in Tables W8 and W9.

TABLE W7. Distribution of virulence of Puccinia graminis f. sp. tritici from 200 samples collected in Sonora, México (1969-70) in relation to different tester genes, Mexican cultivars and other resistant genotypes.

Genotypes	Percentage of isolates showing virulence (on seedlings)	Field reaction 1969-70
Inia 66	13.2	5MR
Lerma Rojo 64A	81.6	5MR
Siete Cerros	15.4	20S
Tobari 66	5.9	5MR
Norteño 67	2.9	5R
Noroeste 66	0.7	TrR
Penjamo 62	91.9	40S
Pitic 62	92.6	80S
Sonora 64	5.1	20MS
W 3282 Line K (Sr 6)	93.4	60S
W 1373 Yalta (Sr 11)	42.6	50S
W 2550 Gamenya (Sr 9b)	94.1	50S
W 3125 Renown (Sr 17)	10.3	TrR
Mentana (Sr 8)	91.9	80S
Line S (Sr 13)	2.9	TrMR
Mendos (Sr 11 + Sr T t + Sr 17)	0.0	0
Selkirk (Sr 6 + Sr 17)	6.6	TrR
Yuma	0.0	0

TABLE W8. Seedling and adult plant reaction in greenhouse conditions to races 12-1, 2, 3, 5, 6 and 151-1, 2, 3, 6 of Puccinia graminis tritici for all entries of the 1970-1971 Elite Yield Selection Trial #1 (EYST #1).

Variety number	Variety or line* and pedigree	Race 12-1, 2, 3, 5, 6		Race 151-1, 2, 3, 6	
		Seedling	Adult	Seedling	Adult
13	NP876-Pj62 x Cno-Pj62 27983-21Y-1M-0Y	3	TrMR**	3 +	NA
15	Tobari 66	X	10MS	3	NA
12	Norteño 67 x Cno-Son64 27868-28Y-1M-0Y	3	TrMR	1	10MR
14	Bluebird-Norteño 67 27100-278M-1Y-6M-0Y	1	TrR	3	NA
11	Bluebird-Ciano 67 26592-1T-16M-1Y-300M-0Y	3	5MR	3	TrMR
4	Yecora "S" 23584-26Y-2M-1Y-0M-1Y-0M	3	TrMR	3	TrMR
3	Ciano "S"-Noroeste 66 25111-17M-3T-6M-1Y-0M	3	TrMRX	3 —	5MR
2	Bluebird # 4A (B) 23584-26Y-2M-3Y-1M-0Y	3	0	3	0
5	Inia 66	3	5MS	3	TrMR
1	Pi 62	3	80S	3+	NA
19	Bluebird-Inia 26591-1T-7M-0Y-301M-0Y	1	TrMR	3	10MR
16	Bluebird-Ciano 67 26592-1T-17M-0Y	3	0	3	NA
20	Yecora 70 23584-26Y-2M-1Y-0M	3	0	3+	10MS
18	Inia-Bluebird 26478-32Y-7M-1Y-1M-0Y	3 —	5MR	2+	0
17	Inia "S"-Siete Cerros 27175-1M-1Y-1M-0Y	1+	10MS	3	10MS
24	Ciano "S"-Gallo 27829-19Y-2M-0Y	NA***	20MS	3	20MS
22	Bluebird 4A (R) 23584-26Y-2M-3Y-1M-0Y	3 —	TrMR	3	0
21	Yecora "S" (B) 23584-26Y-2M-1Y-0M-86Y-0M	NA	0	3+	NA
23	Chris-Bluebird 26448-1Y-1M-2Y-1M-0Y	1	5MR	2	0
25	LR64^2-Son64 19865-58M-100Y-100M-101Y-100M	3+	10S	4	5MS
8	Saric "S"	NA	0	2+	0
7	Inia "S"-Napo 63 22398-39M-1R-0Y-101M-0Y	3	5MR	3	TrMR
6	Yecora "S" 23584-26Y-2M-1Y-0M-11Y-0M	3	5MR	3	0
9	Ciano "S"-Siete Cerros 25322-6M-1R-205M-300Y-101M	3	5MR	3	0
10	Siete Cerros	4	60S	4	80S

* All originated in México.
** Notes in standard rust scales.
*** NA: No data available.

TABLE W9. Seedling and adult plant reaction in greenhouse conditions to races 12-1, 2, 3, 5, 6 and 151-1, 2 3, 6 of Puccinia graminis tritici for all entries of the 1970-1971 Elite Yield Selection Trial #2 (EYST #2).

Variety number	Variety or line* and pedigree	Race 12-1, 2, 3, 5, 6		Race 151-1, 2, 3, 6	
		Seedling	Adult	Seedling	Adult
13	LR64-Son64² x Tob66 27180-26M-4Y-3M-0Y	3	NA	3**	5MR
15	Cpo-Cno(Son64 x Tzpp-Y54/Cno) 25820-16Y-1M-1Y-1M-0Y	3—	NA	1	0
12	Bluebird-Inia 26591-1T-7M-0Y	NA***	NA	3	5MR
14	Saric 70	1+	NA	NA	0
11	Yecora "S" (R) 23584-26Y-2M-1Y-0M-(6-10Y)	3	10MS**	3	0
4	Kalyan-Bluebird 26902-30M-1Y-1M-0Y	3	NA	3	TrMR
3	Bluebird 4A (R) 23584-26Y-2M-3Y-1M-0Y	X	TrMR	3	0
2	Ciano "S"-Inia 66 25717-11Y-3M-1Y-0M	3	20S	3	20MR
5	Ciano² x Son64-Kl. Rend. 26529-3T-7M-4Y-4M-0Y	1	0	1+	0
1	Yecora "S" 23584-26Y-2M-1Y-0M-89Y	3+	5MR	3	TrMR
19	Jar "S"-Napo x Sharbati 28048-20Y-2M-0Y	3	NA	NA	20MS
16	Inia-Bluebird 26478-32Y-9M-1Y-5M-0Y	3	TrMR	3	TrMR
20	Jar² x Men-8156 26787-300Y-300M-302Y-201M-0Y	0	0	NA	TrMR
18	Yecora "S" (R) 23584-26Y-2M-1Y-0M-302M	3	5MR	3	0
17	Penjamo 62	3+	60S	3+	50S
24	Bluebird # 4 (R) Resel 23584-26Y-2M-3Y-2M-0Y-300M	1	TrMR	1+	0
22	(Son64Y50E x Gto/Inia)(Cno"S"-Son64) 28084-1Y-4M-0Y	3	0	3+	0/20S
21	Tobari	3	10MS	3	10MS
23	Cal/Cno "S" x LR64²-Son64 27169-48M-1Y-1M-0Y	4	TrMR	3+	5S
25	Siete Cerros	4	60S	4	60S
8	Bluebird-Ciano 67 26592-1T-16M-1Y-1M-0Y	1+	0	3	0
7	Bluebird (R) 23584-102M-103Y-100M-0Y	3—	TrMR	1	TrMR
6	Inia 66	1±	10MR	3	10MR
9	Ciano "S"-Son64 23582-50Y-3M-0Y	3	5MR	3	0
10	Inia 67-Cal (Inia "S"/Son64-Y50E x Gto)	3	10MS	3	10MR

* All originated in México.
** Notes in standard rust scales.
*** NA: No data available.

CIMMYT wheat germ plasm displays great variability in its genes for leaf rust resistance. However, an attempt must be made to sort these out as clearly as possible so that a more scientific approach can be applied in breeding wheat varieties which will differ in leaf rust resistance. The present analysis of the rust population in regard to its virulence spectrum will permit the identification of both types of specific and general resistance.

For this purpose, 204 collections of leaf rust were made from several different genotypes in the Yaqui and Mayo Valleys, Sonora, and Los Mochis, Sinaloa (1969-70). These were analized in the rust laboratory at Chapingo for virulence frequency. Fifteen wheat varieties bred at CIMMYT or in other countries and representing more than eight genes for resistance were used to test the total population virulence of *Puccinia recondita* in relation to individual host genes.

There are two types of population of the pathogen in relation to a particular host genotype — virulent or avirulent — irrespective of their reaction to any other host genotype. So, an estimate of the potential usefulness of a specific host genotype in a breeding program can be obtained from the proportion of the whole collection of isolates of a geographical area which are virulent on it. In Table W10 the effectiveness of a gene or a combination of genes can be determined based on the percentage of the total isolates virulent on the respective genotype.

TABLE W10. Distribution of virulence of isolates of Puccinia recondita from 204 samples collected in Sonora, México (1969-70) in relation to different genotypes of wheat.

Genotype	Percent of isolates virulent on seedlings	Field reaction
Inia 66	96.9	80S
Lerma Rojo 64A	100.0	50S
Siete Cerros	78.1	20S
Tobari 66	10.4	TrR
Norteño 67	25.0	5S
Noroeste 66	7.3	5MS
Pénjamo 62	100.0	10MS
Pitic 62	100.0	50S
Sonora 64	26.0	10MS
Lee	16.7	—
Waban	3.1	TrR
Exchange	0.0	0
Democrat	100.0	80S
Agatha	0.0	0
Preska	0.0	0

The commercial varieties Inia 66, Lerma Rojo 64A and Pitic 62 were highly susceptible in the Yaqui Valley. They were also susceptible to many of the rust collections in the seedling stage. Of the total isolates, 78.1 percent attacked Siete Cerros while Sonora 64 was attacked by only 26.0 percent. This agrees with the field observation for the reaction (1969-70) on Sonora 64 which showed "10MS" compared to "20S" on Siete Cerros. Both of these varieties were attacked late in the season whereas Inia 66, Lerma Rojo 64A and Pitic 62 had considerable rust early in the season.

Although Tobari 66 was attacked by 10.4 percent of the isolates in the seedling stage, the variety showed little infection in the field. Tobari 66 maintained resistance until quite late in the season and it probably carries resistance which is operating at the adult plant stage. Norteño 67 and Noroeste 66 showed "5S" and "'5MS," respectively, in the field. This is lower than expected for Norteño 57 because 25.0 percent of the isolates were able to attack it in the seedling stage. However, the reaction was as expected for Noroeste 66 because only 7.3 percent showed virulence at this stage.

The genes for resistance in the varieties Exchange, Agatha (Lr 20) and Preska are universally effective in the Mexican wheat belt and are being incorporated into CIMMYT's dwarf varieties.

No attempt has yet been made to classify the population of *Puccinia striiformis* present in the Toluca Valley and at El Batán, State of México. However, the field reaction to *P. striiformis* indicated a parallel reaction for the two centers of research (MV-70) in regard to susceptibility and resistance on a set of Mexican released cultivars and varieties from other countries (Table W11).

The reaction to *P. striiformis* by several Mexican varieties and lines on a worldwide basis can be assessed in Table W12, compiled

TABLE W11. Reaction of wheat varieties to Puccinia striiformis in the regions of Toluca and El Batán, State of México, México. 1970-1971.

Variety	Field reaction			
	Toluca		El Batán	
	1970	1971	1970	1971
Sonora 64	20MS	60S	60S	60S
Ciano 67	TMR	20MR	TMR	10MR
Azteca 67	TMR	10MR	TMR	10MR
Bonanza	TMR	10MR	10MR	10MR
Noroeste 66	TMR	60S	30MS	10MR
Tobari 66	TMR	TMR	TMR	TMR
Red River	TMR	10MR	TMR	5MR
Yaqui 50	40S	20S	50S	30MS
Nadadores 63	30MS	30MS	30MS	5MS
LR 64A	TMR	80S	20MS	5MR
Siete Cerros	50S	60S	50S	40S
Kalyansona	50S	40S	50S	—
Zambezi	5MR	10MR	5MR	10MR
Yecora 70	TMR	10MR	5MR	10MR
Saric 70	TMR	20MR	TMR	20MR
Cajeme 71	TMR	5MR	5MR	5MR

TABLE W12. Reaction (leaf infection) to Puccinia striiformis by Mexican varieties and lines compiled from the Fifth International Spring Wheat Yield Nursery.

	Pullman, Washington	Elvas, Portugal	Gatersleben, Germany	Ankara, Turkey	Tel-Amara,* Lebanon	Mivhor Farm, Israel	Gorgan, Iran	Lyallpur, West Pakistan	Molo,* Kenya	S. Catalina,* Ecuador	Tibaitata, Colombia
Siete Cerros	35MR	0	30S	5MR	50S	10S	0	MR	60MS	70S	70S
Tobari 66	TMR	0	TR	2MR	50S	0	0	0	10MS	10MS	10MR
Ciano 67	TR	—	0	2MR	50S	0	0	0	40S	20MS	70S
Tzpp-Son64/LR64A-Tzpp x AnE (A) 22429-11M-1Y-1M-0Y	10MR	0	0	5MS	60S	0	0	0	50S	20S	60MS
Tzpp-Son64/LR64A-Tzpp x AnE (B) 22429-16M-1Y-1M-0Y	TR	0	TR	5MS	30MS	0	0	0	80S	20S	40MS
Sonora 64	40MR	—	30S	15MS	100S	0	10MS	0	90S	60S	100S
Pénjamo 62	90MR	0	10MS	5MS	100S	0	0	0	40S	—	40MR
Noroeste 66	TR	—	10MS	5MS	100S	0	5MR	0	40MS	30S	70MS
Son64-Kl.Rend.(Argentina)	TMR	0	0	2MS	100S	0	0	0	60MS	50MS	40MS
LR64A	70MR	0	5MR	5MS	100S	0	0	R	70MS	70S	40MS
Inia 66	35MR	—	2R	5MS	30MS	0	0	0	70S	70S	90S
Nor 67	TR	0	TMR	25S	100S	TR	50MS	0	30MS	30MS	20MS
Bonza 55(Col-Ecuador)	40MR	0	—	30S	100S	0	0	0	30MS	15MS	TR
Pi 62	5MR	0	TMR	1MR	50S	0	0	0	30MS	10MS	80S

* All the genotypes ineffective.

from the Fifth International Spring Wheat Yield Nursery. The most severe epidemics of this rust were observed in Ecuador, Colombia, Kenya and Lebanon.

Septoria Leaf Blotch

This problem is endemic and is one of the factors limiting wheat production in some years in Brazil, Argentina, Morocco, Algeria, Tunisia, the coastal areas of Turkey, and the highlands of Kenya, Ethiopia, Colombia, Ecuador and Guatemala. Planting of rather susceptible materials with improved cultural practices — heavy fertilization in areas with favorable conditions for disease development (frequent rains or high humidity from flowering to early maturity of grain) — have combined to make *Septoria* leaf blotch an increasingly important problem in some areas.

CIMMYT research now makes a special effort to identify resistance in both bread wheats and durum wheats. The International Nursery for Septoria (ISEPTON) was assembled at the end of winter at Ciudad Obregón, Sonora and distributed to cooperators around the world wherever the disease is prevalent. The nursery comprises advanced lines and varieties reported to have resistance to *Septoria.*

Entries include Gaboto, Tezanos Pinto Precoz, Buck Manantial, Toropi, Iassul and Nariño from South America; Tobari, Pitic, Pénjamo, Calidad and Pato from CIMMYT; Agatha, Chris, Crim and Selkirk from the United States; and Mara, Opal and Kolibri from Europe.

TABLE W13. Reaction of wheat genotypes to Septoria tritici under field conditions in several areas of the world (1970-71).

Genotypes	Israel	Morocco	Tunisia	Turkey		México (Pátzcuaro)		
	Kiryat-Gat	Merchouch	Manouba	Izmir	Tarsus	CB*	SN**	ISEPTON II
Tob 66-B Man x Bb II-25998-5B-3J-101J-1Y-0M	20MS***					2	1	1
Tob 66-CC x Pato II-27369-1T-4M-0Y	40VS		3				4	2
Tob 66-Calidad II-26492-39M-1Y-3M-0Y				3	4			2
Tob 66-8156 (Several Lines)	20S		2				3+	
Inia "S"-Napo x Tob 66 28078-8M-1Y-1M-0Y			3				3+	
Inia-Cno x Cal (Several Lines)				3			3+	
Inia-Napo x Cal² (Several Lines)			3				3	
TzPP²-An³E (Several Lines)	15S							2
Corre Caminos II-19792-2M-7T-1C-3T-100M-0Y	30S					4		3
Calidad II-22429-16M-1Y-1M-0Y	30S		1			3	4	3
Pato Rojo (Several Lines)	TRSM	3	2			5		
Pato Blanco (Several Lines)	10MS		3	4	3		3	1
Pato-Ciano II-28258-300Y-301M	5S		1					
Fletcher			3			3		
Era			3			3	2	
Chris		4	3	3		3		
Samaca	20S		3				3	
Crespo			2	4	4	3	2+	3
Sugamuxi			2			3	4	
Toropi	5S	3	3			1	1	1
Iassul	30S	2	1			1	1	1
Nova Prata	5MS		1			3		
Carazinho		3	3			2	1	
Weibulk Ring			1			2	1	
Opal			2			3		
Mara		3		3	3			1+
Ariana 66				4	3		2	
Victor I	10S			3				
Mexicano 1481	10S		2			4		2

* Bread Wheats Crossing Block, Summer 1971.
** Bread Wheats Screening Nursery, Summer 1971.
*** Disease reaction in percentage. All other reactions measured on a 0-9 scale.

One set of ISEPTON will be planted in central México near Pátzcuaro, State of Michoacan, at 2,200 meters elevation. Although wheat is not an important crop in the area, *Septoria tritici* develops well in the almost complete absence of any other disease of wheat, a consideration of great importance in screening materials for resistance.

The South American and CIMMYT materials mentioned have been included in different international nurseries and tested in North Africa and the coastal areas of Turkey. Their reaction, along with the reaction obtained in Pátzcuaro in the summer of 1971, can be seen in Table W13. The promising CIMMYT lines resistant to *Septoria* include crosses with Tobari 66, Pato, Corre Caminos and Calidad.

TRITICALES

Specific Adaptation

The highly fertile Armadillo strains generally display sensitivity to adverse environments, especially at high latitudes. A broader genetic base is essential to increase the general adaptation to environments outside of México.

Dr. F. F. Pinto, reporting on the performance of the triticale screening nursery in Ethiopia, observed that triticales appeared to be as promising in yield as the best bread wheats and were superior to all of the durum wheats in the trials. These and other encouraging results have led to research on the utilization of triticales as human food. Favorable reports of grain yields were also received from cooperators in India, Spain, Argentina and some other Asian countries.

Specific adaptation of triticales was observed in tests conducted at two high-elevation locations in México. Duplicate yield tests of 39 triticale strains and 4 wheat checks were grown at El Batán and Toluca during the summer of 1970. Rainfall at El Batán was adequate to maintain growth throughout the season. Over-abundant rainfall at Toluca during July and August created a high water table and drainage problems. Infestations of leaf rust, stripe rust, scab and leaf firing, at least partially caused by barley yellow dwarf virus, were evident on susceptible strains during the latter part of the season. Some triticale strains lodged late in the season, but this had only a minor influence on yield. The average yield of the triticale strains at Toluca (3,934 kg/ha) was above the yield of the top wheat variety (3,716 kg/ha). The yield of the top triticale strains (4,853 kg/ha) exceeded wheat yields by more than one ton. A similar yield pattern developed at El Batán. The average yields of both triticales and wheat were higher than at Toluca — 4,578 kg/ha for the triticales and 3,016 kg/ha for the wheat.

Another yield test at the Toluca nursery contained 21 bread wheats, 7 durums and 8 triticales. A high nitrogen application rate (120 kg/ha) was used in this test. Damage

Dr. Frank Zillinsky of CIMMYT explains development of dwarfness in his triticale program to members of the CIMMYT Board and visitors.

from herbicide application and from lodging was evident during the latter part of the season. Averaged yield of the bread wheats was 4,508 kg/ha. Pitic 62 was the top wheat variety with a yield of 5,349 kg/ha. The seven durums average 2,609 kg/ha with a top yield of 3,553 kg/ha. The eight triticales averaged 4,384 kg/ha with an Armadillo strain providing the highest yield (5,620 kg/ha) of all entries in the test. The durum wheats and some of the bread wheats suffered damage from head blight before harvest.

Apparently the environmental conditions and disease infestations at these higher elevations in México were more suitable for the production of triticales than for wheat. The opposite seems to be true for the irrigated winter season on the coastal plain of Sonora.

As the genetic variability in the triticale program increases, the appearance of strains having specific adaptation in locations with widely different environments is expected to occur more frequently. An objective that remains is to combine high grain yield with yield stability under a wide range of environments and dates of plantings.

Yield Results

The triticale yield trials were grown at Navojoa during the 1970-71 winter season. Two bread wheats (Inia 66 and Siete Cerros) and two durum varieties (Crane and Jori) were used as checks. Fertilizer applications (60-50-00) were applied before seeding. Irrigation water was applied on November 18, 1970. Freezing temperatures were recorded January 6-8, causing damage to early-sown crops, but no visible damage to any strains in the yield tests was observed. Above average crop development was maintained throughout the season. Most triticale strains started lodging about two weeks after flowering and lodging increased during the last two irrigations. No lodging occurred among any of the bread wheat and durum checks. A buildup of aphids early in February was effectively controlled by insecticide application by airplane. A leaf rust infestation occurred late in the season, but crop damage was negligible. Crop yields were even higher than in the previous winter season. Among the checks, the yields of the two durum strains (Jori and Crane) and the bread wheat variety Siete Cerros were essentially equal at about 6.6 tons per hectare. Inia averaged just under 6 tons per hectare.

Table W14 compares average grain yields for the 1969-70 and 1970-71 seasons.

Although the average yield of all triticales in the test increased in Navojoa (1970-71) as did the yields of the wheat varieties, the yield of the top triticale variety was reduced from the previous season. This is the first season that the yields of triticale strains under test failed to increase relative to the wheat checks. It appears that this year's results are comparable to those grown under a higher level of nitrogen fertilizer last year at CIANO. The greater resistance to lodging of the wheat checks permitted the expression of fertilizer response. The triticales lodged earlier in the season as a result of the more luxuriant growth from additional nitrogen.

An unusual yield pattern developed among triticale strains in yield trials at Navojoa. Figure 2 illustrates the yield range for the two wheat checks (Inia and Siete Cerros) compared with the top and bottom triticale strains in each of the eight tests.

Although each test consisted of 25 varieties, many triticale strains were discarded during the season due to disease susceptibility, weak straw and other agronomic characteristics. Fifteen strains were used in each test. The most unusual phenomenon is the narrow range of yield differences between the top and bottom triticale varieties. Inia and Siete Cerros are high-yielding, relatively stable wheat varieties with broad environmental adaptation. Still, the average range of yield differences between these two varieties was greater than the range among the triticales, most of which had not been yield tested before.

These data indicate a lack of genetic variability among the genotypes under test. This might be expected since the Armadillo genotype predominated throughout. There are, how-

TABLE W14. Summary of grain yield in triticale tests at Navojoa, Sonora, México, during the 1969-1970 and 1970-1971 crop seasons.

Season	Triticales			Wheat Checks	
	Number of strains	Average yield	Check triticale	Lowest variety (average)	Top variety (average)
Navojoa 1969-70	18	5066	6282	5321	6491
Navojoa 1970-71	90	5250	5600	5950	6600

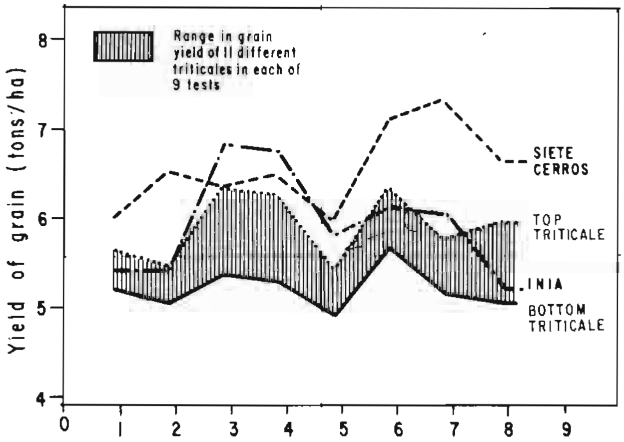


FIGURE W2. Yields of triticales compared with selected wheat varieties in 9 different yield tests grown at Navojoa, Sonora, México, 1970-71.

ever, at least 18 different crosses or segregating populations from which these strains were selected. Probably the lack of variability in resistance to lodging is the predominant factor in reducing the expression of yield potential among the different genotypes. The results of triticale trials at Toluca in 1970 contrasted sharply with those at Navojoa in 1970-71. Although some strains of triticales at Toluca lodged, it occurred late in the season and did not significantly influence yields. Yield differences at Toluca between the check varieties (Inia and Siete Cerros) were very small (200 kg/ha) in the two tests. Among the triticale strains, however, the top strains outyielded the bottom strain and the best wheat check by more than one ton per hectare in each of the two trials.

Breeding Triticales for Resistance to Lodging

Susceptibility to lodging is the major factor masking differences in fertilizer response among strains of triticales. Since lodging is the limiting factor in improving triticales' yielding ability at nitrogen application of 60 kg/ha, while recommended applications for wheat are 120-150 kg/ha of nitrogen, the need for increased resistance to lodging in the triticale breeding program is obvious.

Three different genetic sources are being used to decrease lodging in triticales. A normal height selection with thick stems and stiff straw is one source. The original selection was a heterozygous plant from a bulk outcrossing population. The progeny of this plant were named Beaver. Selections from the segregating progeny were used in crosses to Armadillo strains. No difficulty was experienced in recovering strong-strawed plants with good fertility in the F_2. The F_3 lines indicate that the degree of improvement in lodging resistance could not be expected to increase yield by more than one ton per hectare. None of the F_3 lines, however, appeared to have straw equal in thickness and strength to the original selection. The first strains from the Beaver x Armadillo cross will be included in yield tests in Sonora during 1971-72. Introduction of dwarfing genes from bread wheats provides another source to decrease lodging. Hybrids between fertile hexaploid triticales and double (E_2) and triple (E_3) dwarf wheats were allowed to outcross to hexaploid triticales to provide a viable pollen source and to maintain the rye genome. The proportion of dwarf (E_2) segregates in the F_2 and F_3* populations from these crosses is very much lower than is expected from the same generation in wheat x wheat crosses of similar plant heights.

Among the possible reasons for this are: (1) the influence of the rye genes for height might

The search continues for dwarfing genes to decrease lodging in triticales.

be greater than those in wheat; (2) one or more of the dwarfing genes in bread wheat may be located on the D genome which is not maintained in hexaploid triticales; and (3) the need for backcrossing or outcrossing to hexaploid triticales reintroduces the original height genes from triticales.

Outcrossing in the F_2* is often necessary to reproduce seed. Promising dwarf (E_2) triticales were recovered from the early generations and are being grown in progeny rows. Dwarfing genes from bread wheats are also being introduced via octaploid triticales. Although the seed set from crosses between these two forms is greater than from crosses between hexaploid triticales and wheat, the extra effort required to produce the octaploid reduces the usefulness of this approach. The most serious drawback to the utilization of dwarfing genes from bread wheat is the low proportion of dwarf plants recovered from the segregating populations.

Interfering with the full expression of dwarfing genes from wheat were genes for tallness in the rye genome. A dwarf rye plant was found in the rye nursery in October 1969. It was named Snoopy. The plant was very late and very susceptible to bacterial stripe. These problems are being overcome by intentional outcrossing to earlier maturing disease resistant plants. F_1 hybrids between triticales and the dwarf rye were extremely vigorous, but were so late in flowering that very little pollen from alternating border rows was available for outcrossing. Therefore, many of the hybrids failed to set seed. Judging from the appearance of the F_1 hybrid plants, the dwarfing genes from the rye were dominant or partially dominant. Hybrids from E_2 triticales and Snoopy were not more than 12 to 15 inches tall. Unfortunately, they develop too late and failed to produce any seed. Fertile dwarf triticales from crosses involving Snoopy eliminate the detrimental influence of tall genes now present in all hexaploid and octaploid triticales. Tallness could be reintroduced into triticales if necessary through the wheat genomes.

As the new lodging-resistant strains advance to the replicate yield trials, it is not expected that the yields will increase in direct proportion to their increase in resistance to lodging. Observations on the performance of double (E_2) and triple (E_3) dwarf wheats indicate that the gain in lodging resistance from dwarfing

Many crosses are made in the effort to combine high grain yield with yield stability.

is attained much more rapidly than response to high fertility levels. However, resistance to lodging must be developed before the responses to high fertilizer levels can be utilized.

Physiology Related to Quality

Grain shriveling continues to be one of the main obstacles delaying the development of acceptable commercial triticale varieties. Although considerable progress has been made during the past two years by selecting strongly for better grain type, much more improvement is needed.

To further increase triticale grain density (test weight), a procedure was devised to select for dense grains in early generation bulk populations by using sucrose or K_2CO_3 solutions. The dense grains and controls from seven segregating populations (Toluca, 1969-70) were grown in Navojoa and reanalyzed for test weight. In 5 of the 7 lines, test weight improved. This selection procedure will be continued for several generations to evaluate the feasibility of this approach.

Nutritional Quality in Triticales

The possibilities of producing triticales having good nutritional quality were demonstrated by research on chemical composition of the grain. Dr. Evangelina Villegas of CIMMYT found

* F_2 and F_3 symbols are used here to designate the second and third generation after the original cross. Outcrossing to the hexaploid triticales occurs in the F_1 and subsequent generation.

a wide range in protein content and in percent lysine among triticale strains. The average protein content of triticale was about two percent higher than for bread wheat grown in Sonora. Dr. Fred Elliott of Michigan State University used meadow voles for bioassays of triticale protein quality. He found that triticales ranged in qualty from very poor to nearly the quality of egg protein.

His techniques indicated toxic or antimetabolic substances in the grain of some strains. In some strains, antimetabolic or toxic substances are apparently in the bran layer. By removing this layer from the ground grain, Dr. Elliott was able to improve nutritional quality of the protein. Researchers in Holland isolated alkyl resorcinols from rye grain. These had a growth depressing effect. Dr. Villegas has analyzed many triticale lines for alkyl resorcinol content. Some of the lines with low nutritional values in bioassays are also low in resorcinols, indicating that either other growth depressing metabolites are present or that the protein digestibility and availability of amino acids differ from line to line. More research is needed to clarify the cause of differences in nutritive value.

Of 191 triticale lines studied, 21 were selected for good protein quality on the basis of Dr. Elliott's research with meadow voles. Some of these lines were used in feeding trials on chicks and laying hens. Experiments are now underway at Washington State University and Ciudad Obregón by Dr. James Mc Ginnis and Dr. E. Rivera, respectively. Other nutrition experiments with chicks are being done at Chapingo by Dr. M. Cuca.

The results of the experiments are very encouraging. It appears that strains of triticales with superior nutritional quality for chicks and laying hens can be screened by using meadow voles. Meadow voles are very sensitive to the presence of antimetabolic or toxic substances in their diet. Such substances must not be present if triticales are to be used as food.

WHEAT PHYSIOLOGY AND AGRONOMY

Climate

The interpretation of crop yield responses to genetic and agronomic factors, and to season is inextricably related to climate. For the entire wheat growing season at CIANO, extensive climatic data was collected daily. Measurements included solar radiation, screen temperature and relative humidity, pan evaporation, wind velocity and soil temperature. Table W15 and Figure W3 present summaries for the 1970-71 season.

FIGURE W3. Climatic data (weekly means) for November 2 to May 16 at CIANO, Cd. Obregón, Sonora, México.

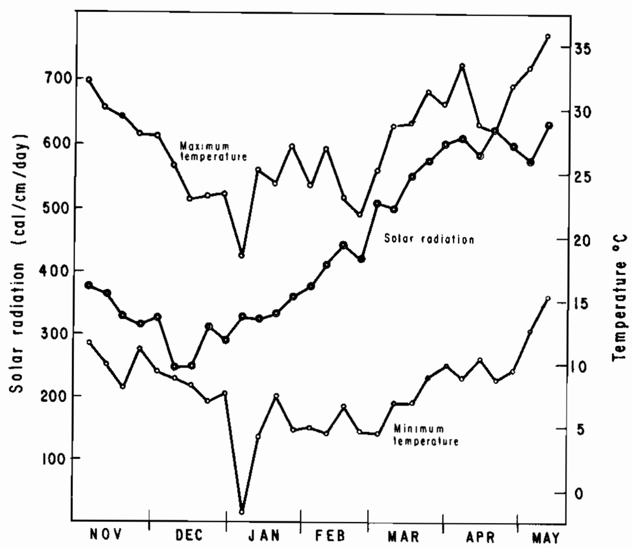


TABLE W15. Climatic conditions for the 1970-1971 crop season at CIANO, Ciudad Obregón, Sonora, México (27° 20′ N, 109° 54′ W, 40 meters above sea level).

Month	Solar radiation cal/cm²/day	Air temperature (°C) mean	maximum	minimum	Evaporation (USWB Class A) mm/day	Total rainfall mm
November	346	20.2	33.7	4.4	4.1	0
December	269	16.5	29.3	3.2	2.6	6.2
January	331	13.7	23.7	—4.2	3.5	0
February	409	14.6	28.5	1.0	3.6	0
March	535	18.0	32.7	1.3	5.5	0
April	602	19.7	35.1	5.8	6.6	0
May*	596	24.0	36.7	8.5	9.0	0

*May 1 to May 16 only.

The winter was drier than average while January and February were colder than average. Exceptionally heavy frosts occurred during January 5-11 with three successive days of minimum air temperatures around —3°C. Especially high evaporative demand occurred in late March and early April.

Wheat Physiology

The 1970-71 season initiated crop physiology studies. The purpose is to determine the important physiological and morphological characteristics leading to high grain yield. This should permit more effective selection of parents and progeny in the breeding program. Considerations are presently restricted to wheat grown under conditions where water supply is adequate, nitrogen fertilization is high (200 kg/ha N) and disease is minimized. Initially, emphasis is on studying the crop situation (solid stand in the field), whether in the field or in an artificial environment.

Two approaches are being used. With one, development, growth and yield information is being collected on a large and diverse set of genotypes. After several seasons, it is hoped that this information, supplemented by response curves determined in controlled environments, can be used to construct a dynamic crop growth model. Within the genetic and climate framework, this should provide a sound basis for predictions about desirable traits for higher yield.

FIGURE W4. Some measurements made on genotypes within the set chosen for intensive study, illustrated by a comparison between Sonora 64 and Yecora 70 sown on November 26 at CIANO, Cd. Obregon, Sonora, México (see Table W16, also).

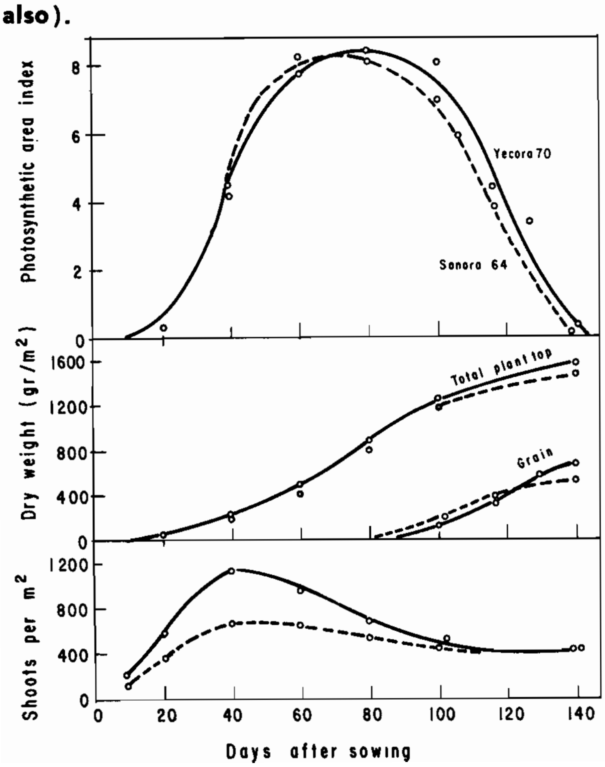


Figure W4 illustrates some of the measurements being made on each genotype in this study with a comparison between an older variety, Sonora 64, and the new variety, Yecora 70, which outyielded Sonora 64 by 27 percent in the trial shown. The parameters in this and subsequent figures and tables were determined from replicated quadrat cuts taken within adequately buffered areas of the crop. Table W16 summarized key parameters for most of the set of genotypes studied. Not all genotypes were in the same trial so direct comparisons between all is not possible. However, examining the relationships between parameters over the whole group is useful, for example, grain yield versus grain number.

Some of the genotypes listed in Table W16 were chosen for measurements of the depth and quantity of roots. This work was done cooperatively with Drs. L. H. Stolzy and R. Luxmoore of the Department of Soils and Plant Nutrition, University of California, Riverside. Table W17 shows that reduced plant height, contrary to earlier conjecture, was not associated with reduced roots, at least in terms of dry weight of roots. For the set of genotypes studied, the reverse tended to be true.

In the second approach to the physiology of yield improvement, one of the best-yielding new varieties (Yecora 70) was used in an attempt to determine what factors were limiting grain yield with ample water and nitrogen. In one study, crop photosynthesis was altered at various stages of development by shading and by CO_2 fertilization treatments (Table W18). There was reasonable agreement between the two sets of results and good evidence for the importance of photosynthesis for grain yield, not only in the grain-filling stage, but also during much of the vegetative phase when sink size (grains/m²) was being determined.

In another trial, light competition between shoots during the post-ear emergence period was altered at ear emergence by thinning or by aggregating plants grown in spaced pots. The effect of variation in sink size on grain yield under given light conditions was determined (Figure W5). Some points from Table W18 treatments are also included in this figure. As sink size increased, grain yield also increased up to the maximum sink size (33,600 grains/m²) which produced a grain yield of just over 1,000 g/m² (11.2 tons/ha at 12% moisture) Thus, the light environment is sufficient for grain yields of at least 11 tons/ha, but to achieve this efficiency of light utilization, sink size must be substantially increased

TABLE W16. Grain yield and related parameters for some of the genotypes studied intensively in crop physiology trials. All seeded at 100 kg/ha, 20 cm rows with 200 kg/ha N and 60-100 kg/ha P_2O_5; seeded November 26-27 at CIANO, Ciudad Obregón, Sonora, México, 1970-71.

Genotype	Mature plant height cm	Grain yield (dry weight) g/m²	Date of 50% anthesis	Total dry weight at anthesis g/m²	Photosynthetic area index at anthesis	Grain number x 10²/m²	Dry weight per grain mg
Yecora 70	88	664	Feb 26	1,080	8.6	162	41.2
LR x $N_{10}B$) An_E^3	100	665	Mar 7	1,125		194	33.7
Sieve Cerros	105	651	Mar 7	1,240		189	34.4
Bluebird #4 (Cajeme 71)	90	639	Mar 11	1,135		145	43.3
Potam 70	98	637	Feb 17	845	7.3	171	36.7
Turpin	78	620	Mar 7	1,040		171	38.1
Olesen	53	610	Feb 21	700		204	29.9
Chenab 70	125	605	Mar 5	1,175		155	39.1
Durum, Jori	103	596	Feb 25	940		112	53.5
Nuri 70	110	580	Feb 26	975		163	35.6
Saric 70	90	576	Mar 9	1,120		138	41.5
Zambezi	108	575	Feb 26	970		178	32.4
Pitic 62	123	570	Mar 6	1,025		164	34.6
Inia 66	113	567	Feb 20	780		140	40.6
Pénjamo 62	110	556	Feb 27	1,090		152	36.5
Tobari. 66	113	535	Feb 24	895		153	35.1
Victor I	95	532	Mar 19	760		153	34.8
Sonora 64	100	521	Feb 18	900	8.1	141	36.9
Kloka	115	518	Mar 9	1,225		174	29.8
Ciano 67	105	501	Feb 15	830		136	37.0
Triticale, Beaver	133	494	Mar 10	860		166	29.7
Nainari 60	140	488	Mar 8	1,135		128	38.3
Triple Dirk	155	465	Mar 6	1,070		109	42.3
Gabo	140	400	Mar 1	1,035		123	34.6
Napo 63	140	374	Feb 21	895		112	33.5

TABLE W17. Dry weight of roots for six genotypes of differing plant height. Roots washed from soil cores from a depth interval of 0-50 cm (Jan. 8) or 0-75 cm (March 3 and maturity) at CIANO, Ciudad Obregón, Sonora, México 1970-71.

Genotype	Mature plant height cm	Root Dry Weight (g/m²)			Mean of relative values of root dry weight, % of Olesen
		Jan 8 0-50 cm	March 3 0-75 cm	Maturity 0-75 cm	
Olesen	53	36.9	66.2	82.0	100
Turpin	78	34.6	70.5	77.5	98
Cajeme 71	90	30.8	63.6	103.6	102
Ciano 67	105	27.1	35.6	65.8	70
Pitic 62	123	32.5	59.7	53.2	81
Nainari 60	140	26.2	42.0	49.5	65

TABLE W18. Response of grain yield to alteration of crop photosynthesis at various stages of development: Yecora 70, sown December 8, 350 kg/ha N and 100 kg/ha P_2O_5 at CIANO, Ciudad Obregón, Sonora, México, 1970-71.

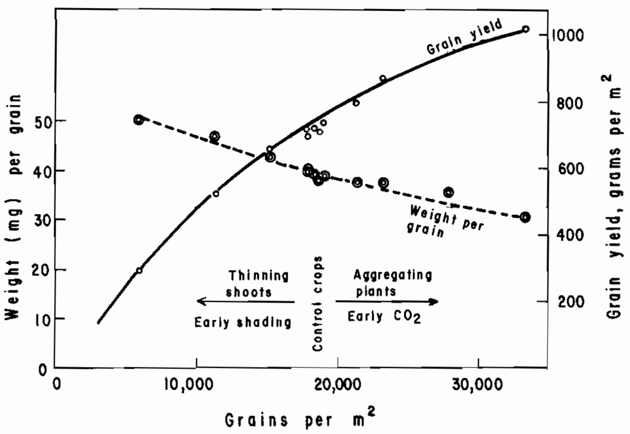
Treatment Period	% Grain yield relative to control	
	Shading**	CO_2 fertilization***
Early vegetative (12-45)*	100	112
Mid vegetative (46-73)	89	123
Late veg., anthesis (74-98)	83	107
Grain filling (99-129)	82	111

* Days after sowing in parentheses; floral initiation, ear emergence, anthesis and maturity at 30, 90, 91 and 130 days, respectively.
** 50% shade over plots at all times.
*** Crop supplied with about 750 ppm CO_2 during daylight hours for about 70% of days.

over that of control crops. Intergrain competition also increases and final grain size is reduced.

Reduction of the sink size (grain removal) and source size (removal of photosynthetic area) of individual shoots within control crops confirmed the results of Table W18 and Figure W5. A tentative conclusion is that for the variety Yecora, grain yield is limited both by sink size (grain number/m², controlled largely by pre-anthesis photosynthesis and light) and by source size (controlled by post-anthesis photosynthesis, leaf area and light). Increases in either of these factors for this and like genotypes should result in increased grain yield.

FIGURE W5. Response of weight per grain and grain yield to changes in sink size (grains/m²) achieved with various treatments (see text). Variety Yecora 70 was seeded December 8-9 with 350 kg/ha N and 100 kg/ha P_2O_5; 50% anthesis occurred March 9-15 for all treatments.



The overall average yield for control crops of Yecora in these trials was 9.0 tons/ha (12% moisture) with all border effects removed. This is probably a record yield for wheat at CIANO and indicates what can be achieved with optimal cultural conditions. Yields of six-row plots two meters long, listed in Tables W2 and W4, are apparently greater. However, measurements suggest that because of border effects, these yield figures must be reduced 25 percent to indicate potential farm yields.

Wheat Agronomy

The agronomic studies at CIANO last season continue earlier CIMMYT soils and plant nutrition work. The aim is to determine optimum cultural practices for the new wheats being developed in the CIMMYT program. Seeding date, density of seeding and row spacing, nitrogen fertilization, depth of cultivation and flooding were the main factors examined. Studies concentrated on the new bread wheat, Yecora 70, under optimal irrigation practices. Some trials included new durum and triticale lines. These agronomic studies complement more extensive cultural trials conducted by the CIANO staff.

The date-of-sowing trial (Table W19) shows the major effect climate can have on grain yield.

Maximum yields were obtained with the recommended sowing date (mid-November to

TABLE W19. Effect of the date of seeding on development and yield of five Mexican varieties (seed rate, 100 kg/ha; N at 200 kg/ha and P_2O_5 at 60 kg/ha, CIANO, Ciudad Obregón, Sonora, México, 1970-1971).

Date of seeding	Variety	Grain yield tons/ha (12% moisture)	Date of 50% ear emergence	Comments
November 5	Sonora 64	2.7	Jan 18	frost damage
	Potam 70	5.4	Jan 19	" "
	Yecora 70	5.5	Jan 29	" "
	Saric 70	7.0	Feb 12	
	Cajeme 71	6.9	Feb 13	
November 26	Sonora 64	5.8	Feb 14	
	Potam 70	7.1	Feb 13	
	Yecora 70	7.4	Feb 24	
	Saric 70	6.5	Mar 8	
	Cajeme 71	7.0	Mar 9	
December 17	Sonora 64	5.7	Mar 7	
	Potam 70	5.9	Mar 10	
	Yecora 70	6.8	Mar 14	
	Saric 70	6.5	Mar 21	
	Cajeme 71	6.6	Mar 21	
January 7	Sonora 64	5.2	Mar 22	
	Potam 70	5.3	Mar 22	
	Yecora 70	5.3	Mar 28	high temperature
	Saric 70	5.5	April 5	" "
	Cajeme 71	5.5	April 5	" "

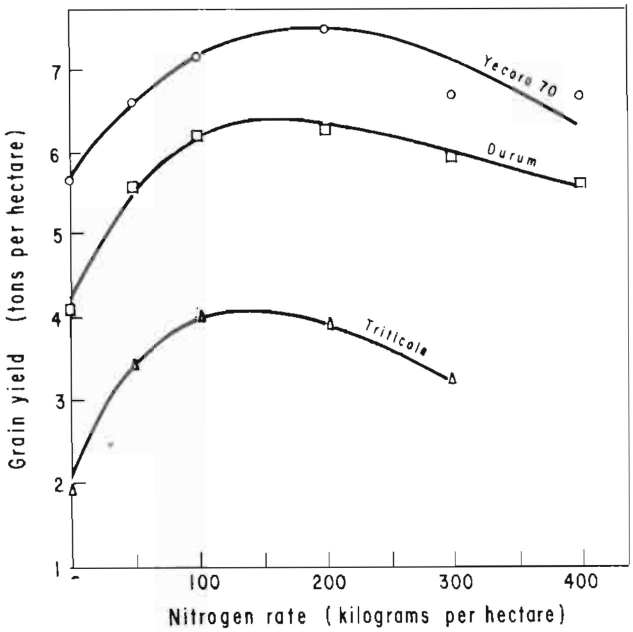


FIGURE W6. Response of grain yield to nitrogen fertilization in 3 wheats (Durum: Flamingo "S", 27582-8M-6Y-3M-0Y; Triticale: Armadillo "S" X-308-27Y-2M-1Y-302B-0N-101B). Seeded December 2 with 100 kg/ha P_2O_5; N supplied as urea.

mid-December). However, with more experimentation, possibly somewhat earlier sowing (early to mid-November) will prove desirable with later varieties (Saric 70 and Cajeme 71). The reduced sensitivity to frost at ear emergence of the variety Potam 70 compared to Sonora 64 is significant. Also, the relatively good performance of the late varieties at the latest sowing date probably reflects the unusual pattern of declining temperatures from late March through mid-April (Figure W6).

Results of the nitrogen fertilization trial are shown in Figure W6. The soil nitrogen levels at this site were considerably higher than for the experiment reported last year when Yecora 70 yielded only 0.7 tons/ha with no nitrogen. Still, the ability of the shorter genotypes (Yecora 70 and durum) to respond to more nitrogen is again evident. They did not lodge in any treatments. Contrarily, soon after ear emergence, the taller triticale lodged moderately at 100 kg/ha nitrogen and severely at higher levels of nitrogen. A treatment where lodging was prevented at 300 kg/ha nitrogen indicated that the severe lodging reduced yields about 25 percent or one ton per hectare. The yield decline at very high nitrogen levels for Yecora and durum was clearly associated with smaller individual grain weights. This may indicate that very high tissue nitrogen predisposes the plant to stress at high temperature or under high evaporative demand, an effect possibly exaggerated by delayed ear emergence (5 days delay with 400 kg/ha nitrogen compared to no nitrogen).

The rate-of-seeding and spacing trial with the variety Yecora (200 kg/ha N, 80 kg/ha P_2O_5, seeded November 26) shows no significant interaction between rates (50, 100, 200 and 300 kg/ha) and row spacings (10, 20, 30 and 40 cm). Main effects were also significant, although there was a slight tendency for yields to decrease with narrower spacings and with higher seeding rates. Forty centimeter spacing with 50 kg/ha seed gave 8.1 tons/ha while 10 centimeter spacing and 300 kg/ha seed gave 7.4 tons/ha. Other treatment combinations gave intermediate yields.

Repeating last season's flooding trial (a cooperative effort with the University of California at Riverside) with emphasis this year on post-anthesis flooding failed to reconfirm the yield advantage found last year. The variety Yecora tolerated 12 days continuous flooding without yield reduction and 22 days flooding caused only a 14 percent reduction.

A trial to study the effect of deep cultivation (ripping to 40 cm) with high fertilization (200 kg/ha N, 80 kg/ha P_2O_5) and frequent irrigation showed a significant increase in grain yield (8.4 versus 7.5 tons/ha) over conventional cultivation (discing to approximately 20 cm) for the variety Yecora. This response is probably related to hardpan formation with repeated cultivation, but it is difficult to determine the importance of deeper rooting under the above conditions which avoided plant water stress.

Plastic-lined plots allow study of wheat subjected to controlled post-anthesis flooding. Control plot is at left.

INTERNATIONAL WHEAT NURSERIES

The International Wheat Nurseries Program, started in 1960 as an inter-American yield trial, has expanded to include 11 nurseries.

These nurseries are playing an extremely valuable role in wheat and triticale improvement by supplying participants with. (1) basic information about adaptability of varieties and yield potential, and about disease and pest resistance; (2) parental materials for accelerated breeding programs; (3) indications of which varieties might serve as immediate introductions into potentially high production areas; and (4) a means of evaluating promising breeding materials on a worldwide basis while fostering international cooperation.

This interchange in 62 countries throughout the major spring wheat regions of the world has generated a meaningful international network. Plant breeders and plant pathologists from developing and developed countries benefit from the association by contributing to the worldwide upgrading of spring bread wheats, durum wheats and triticales.

There has been a growing number of requests for each of these nurseries as their value has become apparent to scientists around the world. These nurseries are available upon request to scientists working in spring wheat producing areas throughout the world, within the limits of the availability of seed supply and budget for shipment. We have been able to respond to virtually all requests.

The geographic distribution of the 1970 experiments is indicated in Table W20. It has become evident from the large amount of experimental seed being shipped and the increasing requests, that CIMMYT is performing a valuable role in the distribution of wheat and triticale germ plasm, and as a clearing house for data obtained from growing these experiments in different parts of the world.

The aims of the various nurseries differ. A description of the major types may be helpful

TABLE W20. The distribution of CIMMYT Wheat Program experiments during 1970 by crop and geographic region of the world.

Type of crop	Name of experiment	GEOGRAPHIC REGION OF THE WORLD									
		Europe (18 countries)	Middle East (9 countries)	Africa (14 countries)	Asia (9 countries)	North America (2 countries)	Meso America (2 countries)	South America (6 countries)	Oceania (2 countries)	Subtotals by experiment	Totals by crop
Bread wheats	7th International Spring Wheat Yield Nursery	10	13	19	13	13	6	12	3	89	
	Elite Selection Yield Trials 1&2	2	4	7	6	5	6	9	0	39	
	4th International A&B Bread Wheat Screening Nurseries	9	9	11	13	10	13	19	2	86	
	F_2 Bulk Populations	2	10	13	12	10	1	25	0	73	
	1st International Septoria Nursery	1	2	3	0	1	5	2	0	14	
	Bread Wheat Subtotals	24	38	53	44	39	31	67	5		301
Durum wheats	2nd International Durum Yield Nursery	6	15	11	4	6	4	3	0	49	
	2nd International Durum Screening Nursery	3	7	4	3	7	5	4	0	33	
	Durum Wheat Subtotals	9	22	15	7	13	9	7	0		82
Triticale	2nd International Triticale Yield Nursery	3	5	4	6	4	2	5	0	29	
	1st International Triticale Screening Nursery	2	1	4	0	6	3	5	2	23	
	Triticale Subtotals	5	6	8	6	10	5	10	2		52
	Totals by Geographic Area	38	66	76	57	62	45	84	7		
	Percent of the Grand Total	9%	15%	17%	13%	14%	10%	19%	2%	Grand Total 435	

in assessing the vital role these experiments play in increasing wheat production throughout the world.

Yield Nurseries

A cornerstone of the success of the wheat project has been the International Spring Wheat Yield Nursery. As a direct result of the success of this nursery, other yield nurseries were recently initiated for the durum and triticale programs to supplement their efforts throughout the world.

The volume of advanced lines soon became too great to test through the international yield nurseries. Therefore, elite selection yield trials were offered to rapidly test and evaluate new advanced-generation materials of outstanding promise under a wide range of climatic and disease conditions. This additional channel of interchange has greatly increased the flow of potentially valuable, yet largely untested material, from all cooperating breeding programs.

Screening Nurseries

In 1967 the First International Screening Nursery was offered to interested scientists to identify outstanding advanced lines with a solid base of disease resistance. One year's testing at many locations throughout the world in areas with a high expectation of disease incidence is a substitute for several years' testing at one or a few locations. An added benefit is a more immediate exchange of germ plasm within a network of active breeding programs. The success of this approach in testing advanced lines (F_3-F_7) led to similar nurseries for durums and triticales. Two bread wheat screening nurseries, one following each season's harvest at Ciudad Obregón and Toluca, were needed to handle the entries, to better coordinate shipping and planting dates, and to reduce time necessary to report results.

Additional nurseries were instituted during 1970 to supplement our activities and round out the program. The International Septoria Nursery (ISEPTON) was established to identify new sources of resistance to *Septoria* leaf blotch and provide a convenient channel for intercountry exchange of germ plasm. Other specific disease nurseries are planned for 1971-72 to deal with problems such as powdery mildew, *Fusarium* and *Alternaria* diseases.

Communications

The communications network needed to coordinate and facilitate the exchange of results has demanded a significant commitment to this project. Large quantities of seed are received and shipped each year. All nurseries are packaged and sent with complete instructions for the management of the nurseries and field books for recording data. Reports on the reactions of nursery entries tested in our greenhouses to specific races of stem and leaf rusts are forwarded as the information becomes available.

As data are returned, the results are condensed and summarized, first into preliminary reports and later, a final report for general distribution. During 1970 we concentrated on the development of new and better computerized methods for preparation of these reports and to reduce the data processing and publication time.

The International Wheat Testing Program has become a vital part of the CIMMYT Wheat Project. Only through the speedy exchange of germ plasm and information can this program continue to provide the materials and information requested by our cooperators.

WHEAT TRAINING PROGRAMS

CIMMYT's Philosophy

CIMMYT provides training and learning experiences in several areas, depending on the background of the trainee and the needs of the country programs. Training or research experience is provided to postdoctoral appointees, in-service training for research scientists and production agronomists, and guidance on thesis projects for graduate students working toward the Ph.D. Also, facilities are provided for visiting scientists.

Postdoctoral trainees include those who have positions to accept in their national programs or who will benefit from a one or two year association with CIMMYT and may later accept a position with CIMMYT or another international agency.

In-service trainees at the research scientist level are the major emphasis of CIMMYT training. These include young scientists from developing countries who have considerable variation in background and education. The aim is to provide a cadre of trained scientists to staff the national programs with which CIMMYT is involved. Hopefully, some of them will train other young men in their country along similar applied lines. In selecting young scientists for training, CIMMYT encourages sponsoring agencies to ensure that young men chosen have good health, are well motivated, are intelligent, are energetic and have the ability to work well with other people.

The training at CIMMYT is applied. Trainees learn how to attack problems. They learn techniques. They learn to live together and work together as a team. At all stages, they are an integral part of the CIMMYT resident program and work with and under the supervision of the CIMMYT staff. Trainees receive instruction and experience in all aspects of research, including all disciplines, so that their understanding of these different fields is broad. In certain instances, groups of the trainees may receive specialized training in one of the disciplines, but this is more a change in emphasis and the trainees still learn the techniques of the other fields. CIMMYT's philosophy is "learn while doing" and all trainees are expected to spend much time in the field observing, taking notes and fully engaged in the manual as well as mental effort expected of the senior CIMMYT staff.

Production agronomists are in very short supply on a worldwide basis and they are an important group. New varieties must be exploited for economic and social improvement. The production agronomist combines the plant, soil and climate. He produces the package of practices designed to extract the maximum yield and economic return from inputs under different conditions. He knows the cost of inputs, the price of the product and the means of protecting crops from diseases, insects, weeds and other pests. He should know how to harvest and store the product, and be able to advise his government on policies which will encourage sound practices. Generally, he must ensure that the farmer receives the greatest benefit possible from the new technology.

For both research scientists and production agronomists, direct instruction is given during nonpeak field periods. This instruction is often necessary to provide a background for research experience. Scientists from many countries visit CIMMYT throughout the year. Whenever possible, these scientists are requested to present seminars to the trainees and CIMMYT staff members. This provides not only a means of disseminating the latest advances and theories, but provides an opportunity for the young scientists to meet with international authorities.

CIMMYT staff members assist and advise thesis projects in joint arrangements with the graduate schools. CIMMYT's approach orients these students in an applied direction.

Training activities encompass all aspects of the research program. Emphasis is on "learning while doing."

Accomplishments in 1970-71

Forty-one trainees from 20 countries participated in the CIMMYT program. This is the largest group in one year. Also, this was the first year of the production training program. Trainees received practical instruction in breeding, plant pathology, agronomy, cereal technology and experimental design, a basic knowledge of cultural practices, and an understanding of the factors responsible for agricultural development and methods of extending new techniques and varieties to farmers. The first group of seven trainees completed the eight-month course. Trainees came from Korea, Morocco and Tunisia. In 1971-72, trainees will be able to conduct applied research trials with farmers in northwestern México.

The objectives of the training program have been defined so that trainees are aware of what they will learn and what they will be expected to know at the completion of their training period. They are required to demonstrate how to carry out the various research activities and how to grow a wheat crop, assuming they must operate similar programs in their own countries. Training continues to be modified, considering trainees' comments.

Two in-service training manuals, one on breeding and one on production, have been developed in the past year. These manuals are available to past trainees and cooperating agencies. The manuals describe the methods of breeding and growing wheat step-by-step. Training aids to accompany the manuals are being developed. These materials should be useful in national training programs.

A trainee self-evaluation system helps vary instruction to meet the trainees' needs.

Hugo Alvarez, a staff member, joined the training program to assist with administration, organization and supervision.

During the past year, there were five scientists-in-residence under the postdoctoral program. Two were transferred to CIMMYT staff positions, one has taken a position in the United States and two have not yet completed their tenure.

One graduate student completed his thesis project and has taken a position with the International Rice Research Institute.

CIMMYT staff members consider the training program one of the greatest contributions of this center. Graduate trainees now form an international team with common aims reaching across national boundaries. Their ties of friendship have greatly increased the flow of materials and information among countries. Through the aegis of supporting agencies, periodic meetings are held at which many of the former trainees have an opportunity to exchange views, renew friendships and update each other on the progress of their respective national programs. CIMMYT staff members visit the country programs as often as possible. They, together with sponsoring agencies, help overcome problems blocking utilization of their skills so that they can become functional and effective workers in their countries' progress. CIMMYT circulates new materials and seeds to them to keep them current with new developments and so they remain interested and active participants in the Green Revolution.

Selection of grain in early generations is demonstrated to CIMMYT trainees.

COUNTRY PROGRAMS

The following sections give a brief summary of the progress of wheat research and production in the country (national) programs with which CIMMYT collaborates. The greatest responsibility and the major contributions and resulting progress in these programs rests with the scientists and officials of the countries involved. CIMMYT is, however, pleased to be associated with the progress reported.

INDIA

Production of wheat continued its upward climb to a record 23.25 million tons compared to 20.1 million tons in 1970. Estimated acreage was 17.8 million hectares, an increase of 1.2 million hectares over the previous year. Yield advanced from 1,211 to 1,299 kg/ha (Figure W7). Generally, the monsoon of the previous season was favorable, but winter rains were delayed until late January in the main production areas, resulting in substantial damage to rainfed areas. For the second year in a row, the start of monsoonal type rains at harvest was abnormally early, beginning in early May. This caused some losses to grain which was cut, but still lying unthreshed in the field. (Possibly the large increase in area under irrigation is modifying weather patterns.) The need for increased mechanization of threshing has been highlighted by grain losses.

This year significant agricultural benefits spread to Rajasthan, Bihar, West Bengal and Eastern Uttar Pradesh. Previously, these areas, except for Bengal, were very slow in adopting new practices and varieties. Acreage sown to Kalyansona increased rapidly in Rajasthan. In Bihar a significant increase in seed supply coupled with rice losses in the previous summer expanded wheat production to land which normally lay fallow during the winter. Similarly, cyclonic storms which damaged rice crops

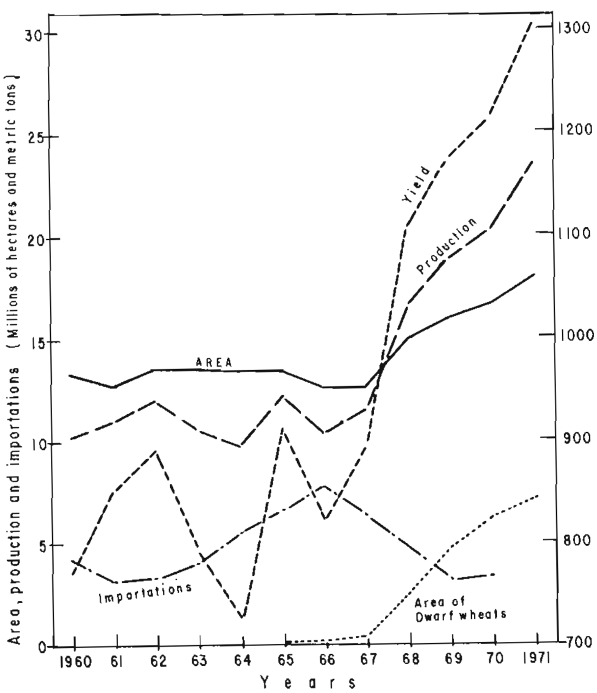


FIGURE W7. Total area, production, yield, dwarf acreage and importations of wheat in India, 1960-1971. Source: official government figures.

Shri A.S. Minhas, wheat breeder at Gurdaspur, Punjab, shows the exceptional head development at his northern station.

Wheat breeders and pathologists meet at Junagadt, Gujarat, with Dr. Y. M. Upadhyaya (center) zonal coordinator for the Central Zone. Each year zonal meetings are held in the five zones to review progress and consider new approaches. "Wheat under the palms" is becoming increasingly common throughout the world.

encouraged agricultural authorities of West Bengal to increase wheat production.

Indian wheat research is conducted under the All-India Coordinated Wheat Improvement Program in which central and state institutions cooperate. Assistance is provided by the Rockefeller and Ford Foundations.

In the past two years, the variety Kalyansona has been susceptible to a new race of stripe rust. Since Kalyansona predominates in the areas affected by this disease, a potential hazard exists if conditions are favorable for its development. Fortunately, most of the other commercial varieties are resistant to this biotype and can be rapidly introduced. Despite repeated warnings, it is unlikely that the farmers will change from growing Kalyansona until some damage is experienced.

Breeding Research

Indian breeding programs have been expanding rapidly. The quality of material being developed has improved, also. This has led to increasing demands for testing facilities so that the number of yield tests, particularly in the northwestern plains area where research centers are heavily concentrated, have been doubled to incorporate this large mass of material. A total of 390 breeding trials ranging in size from 16 to 36 varieties were grown in the coordinated system of trials. This does not include breeders' trials conducted at the breeding stations before entry into these cooperative series.

The variety Hira, formerly know as HD1941, was released for production in the irrigated zones of the Northwest. This and two other similar selections are characterized by very early heading and a prolonged fill period. These characteristics appear related to yield.

For the drylands of central India, Narbada-4 (a medium-tall bread wheat) and A-9-30-1 (a durum variety) were developed. They are recommended for Madhya Pradesh because of high yield. Both varieties were released in the current year.

Several Bluebird lines (Cross II-23584), differing from those released by INIA in México, have been selected at several Indian stations. Some of these appear promising in yield tests.

Many Indian-Mexican crosses have entered advanced yield tests. Several are widely adapted and possess high-yield potential. A steady flow of these materials should come from the program, resulting in greater diversification of commercial varieties.

Agronomic Research

India conducts a very active agronomic research program. Presently, research seeks the best methods to obtain maximum yield from 3-gene dwarfs emerging from the breeding programs. Varieties of this type have a very high degree of lodging resistance. Some of the varieties respond to closer spacing. Among the taller varieties, such as Sonalika (an early, large-seeded, low-tillering variety), there is response to higher seeding rates and closer spacing to provide more plants per unit area. Rates of 115-120 kg/ha nitrogen have given high economic returns. The aggressive agronomic program is keeping abreast of the changing varietal picture.

Pathology

The wheat disease survey was continued with the participation and cooperation of the Ford and Rockefeller Foundations. The trap nursery, designed to monitor disease changes, was grown at 70 locations. Bimonthly newsletters, reporting disease development throughout the wheat areas, are being used. These letters present data from the disease surveys and scientists' travels, and reports from collaborating institutions.

The past season was essentially disease- and insect-free. In the first half of the season, rainfall was low, resulting in a very slow buildup of inoculum. When the rains finally arrived in late January, inoculum levels were so low that only light local epidemics were produced.

In the summer of 1970, a new race of *Puccinia striiformis* was found on summer plantings of widely grown Kalyansona (Cross 8156) at high elevations in northern India. Careful surveillance was maintained, but inoculum remained at a low level and no significant damage was sustained. Fortunately, this race appears to be avirulent, or nearly so, on the other principal dwarf varieties as shown in Table W21.

Leaf rust, which originates from both a northern and southern oversummering population, was observed on commercial crops in December in both regions. Dry conditions precluded its multiplication and spread.

TABLE W21. Preliminary observations on the virulence spectrum of yellow rust (Puccinia striiformis) at three locations in northwestern India on the most important commercial varieties.

Variety	Pantnagar	Delhi	Gurdaspur
Kalyansona	30S	20S	0
Sonalika	0	TS	0
Hira (HD 1941)	5MR/TS	0	TS
Safed Lerma	0	0	0
Chhoti Lerma	0	0	0
UP 301	0	0	0
Kiran	0	20S	0

Stem rust appeared very late in the South. It spread slowly and erratically. No serious attacks occurred, even on susceptible varieties.

Alternaria triticina and other foliar diseases were retarded and unimportant, also.

A new screening nursery for diseases was sown for the first time this year. The breeding programs contributed their advanced lines and potential varieties. These materials were grown in the summer at high elevations in southern India and in the winter at 10 locations where disease usually appears in epidemic form. A good screen was obtained for *Helminthosporium sativum, Alternaria triticina,* the three rusts and *Erisyphe graminis.* The data were summarized and distributed to cooperators. This provides a method of identifying sources of disease resistance and screening the advanced material for potential resistance.

No serious insect outbreaks were observed. Nematode surveys were done with rust surveys and collections are being identified.

Quality

The quality laboratory of the Indian Agricultural Research Institute continued to improve its service to the breeding programs of that center, and as far as possible, provide testing services at the level of the coordinated wheat program on advanced lines. Two other institutions, the agricultural universities of Uttar Pradesh and Punjab, have set up quality laboratories to provide backstop facilities for their breeding programs. One of these institutions sent a young scientist for training to the CIMMYT Protein Quality Laboratory in México.

There continues a need to establish smaller laboratories for simple, definite tests at the other major centers. Hopefully, the larger units at the centers mentioned above will cooperatively assist sister institutions with the more complex tests at the advanced stages of varietal development. Most varieties are low in bread-making quality. However, *chapati* is still the most important use for wheat in India.

Is the Small Farmer Participating in Agricultural Change?

In the third and fourth year of increased wheat production, many critics continue to assert that the principal effect has been to make the rich richer and the poor poorer.

A "large" farm in India has more than 10 hectares. There are many reasons why the large farmer will be first to change. There are other reasons why certain areas in a country change more rapidly than others. Both have happened in India. It is also true, however, that the new approach to agriculture has moved rapidly from large to small farmers and from progressive areas to less progressive areas.

A 1968 study in Northern Uttar Pradesh by the U. P. Agricultural University and the Rockefeller Foundation found that in this progressive area, large farmers and small farmers had already adopted new technology. A USAID study reported in 1970 that about half of the farms (25 million farmers) were using new technology. The technology is not easily applied in low rainfall areas, but the spread of technology has continued. Among these 25 million farmers, 6 percent were classified as large farmers, 32 percent, medium, and 62 percent, small. These figures indicate the spread of technology from a few large farms to many small farms. In February 1971, a Ford Foundation economist reported that in samplings of the area where farmers first adopted the new practices, 98 percent of all farmers—large and small—use new varieties, fertilizer and other inputs. Within irrigated areas, all sizes of farms have benefited.

One of the less quoted reasons for the small farmers' betterment was the government policy of market stabilization through price support. The well-to-do farmers have been able to withhold their products at harvest time, marketing them when prices rise in the next preharvest period. The small farmer, because of his need for cash, cannot do this. By stabilizing prices at harvest time, the small farmer is protected. Sales from stocks have stabilized the market more than at anytime in the past.

It is unrealistic to expect that changes in wheat prices alone will eliminate all income differences between large and small farmers. These inequities have existed and will probably always exist to some extent under any system. The wheat price policies adopted have allowed wheat farmers to increase their incomes. Large farmers are able to spend more money on consumer goods, stimulating other sectors of the economy. Many small farmers have been able to eat better and now often have something to sell for cash for the first time. This cash income allows purchase of the inputs that provide his better standard and leave something to make his life better. Agricultural change has solved only a small part of the problem, but most farmers are now participating in the cash economy more than in the past.

PAKISTAN*

Wheat production, for the first time in recent years, is expected to fall below the previous official high of 7.28 million tons for 1970. Production in 1971 was an estimated 6.5 million tons (Figure W8). The principal reasons for this decline are: (1) less and untimely use of improper fertilizer; (2) a shortage of irrigation water in the canals; (3) political change combined with participation by many large farmers in the national elections which coincided with sowing time, resulting in a decreased level of farm management.

According to sales figures available, it appears that there was less fertilizer applied (31,000 tons of nitrogen and 3,300 tons of P_2O_5) in the present year than in 1970-71. The high-

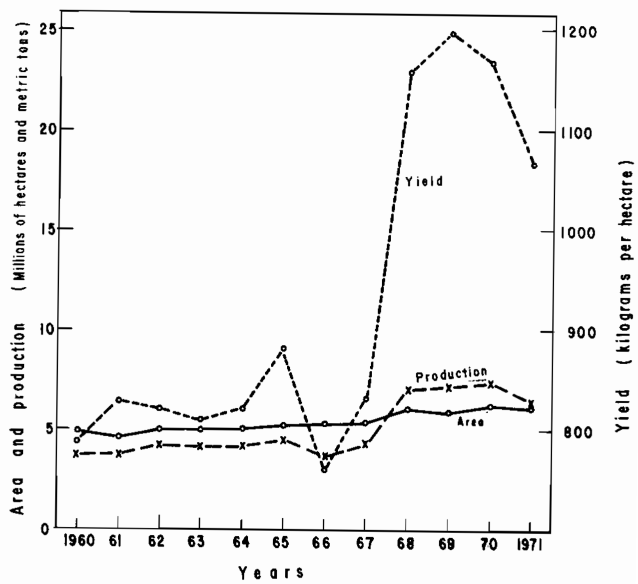


FIGURE W8. Total area, production and yield of wheat in Pakistan during 1960-1971. Source: official government figures and estimate for 1971.

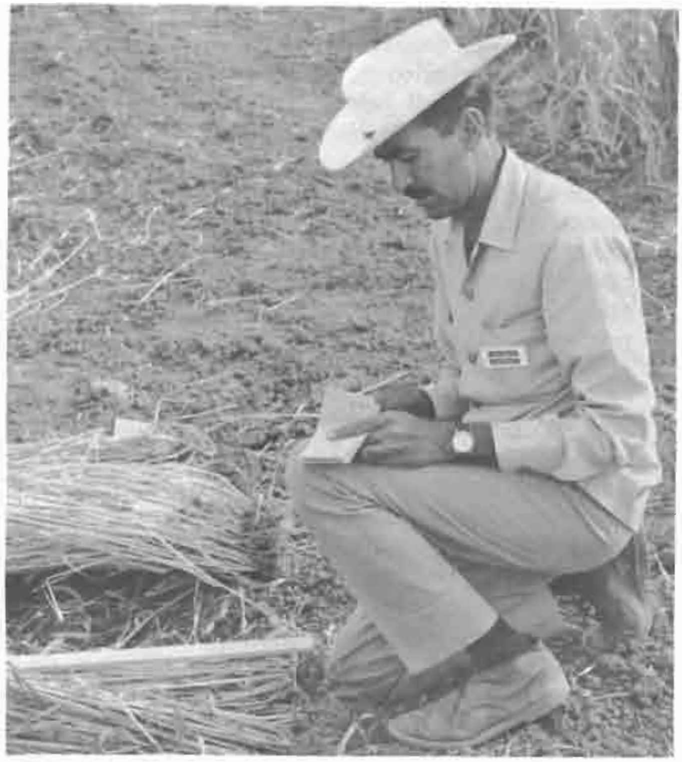
* Pakistan wheat research is done through the Accelerated Wheat Improvement Program with assistance provided by the Ford Foundation.

est 1970-71 sales were made during September to November. Probably, in addition to using less fertilizer, the applications were made too late to maximize results. It is not clear whether this resulted from a supply shortage at the critical time or whether this was related to farmers involvement in the elections. Two other factors may have indirectly affected fertilizer use. In the 1970 summer season, considerable areas of the rice crop were badly damaged by insects, leading to a near failure of the crop in some districts. This lowered the income of the farmers and they may have been unable or unwilling to invest in fertilizer for the following wheat crop. Also, the cost of fertilizer was increased by three rupees per bag and this, coupled with increasing costs for spare machinery parts, diesel oil, electricity, etc., may have discouraged some of the farmers from investing in fertilizer.

Undoubtedly, the most severe problem limiting wheat production is unbalanced fertilizer formulas—the low ratio of P_2O_5 to nitrogen. The desirable nitrogen-P_2O_5 ratio for most areas is 2:1. In previous years, the ratio was rarely closer than 6:1 and this year the spread increased to 7:1. In the early years of the Accelerated Wheat Production Program, there had been an accumulation of available phosphorous from weathering of soil minerals since extreme nitrogen deficiency limited both plant growth and grain yield—indirectly reducing phosphate extraction. Yield increases in the first two or three years of fertilization largely resulted from nitrogen application. Many farmers concluded that phosphate fertilization was unnecessary. With increased grain yields from nitrogen fertilization, the accumulated available phosphates were rapidly depleted. The shortage of phosphorus has become increasingly critical during the past two years and the full beneficial effect of the nitrogen applied has not been realized. This has been reflected in lower yields from year to year. The most important step needed to increase wheat yields is to expand the use of phosphate fertilizer.

Also, there may be a zinc shortage in some more sandy wheat production areas. This can seriously limit the efficiency of the major elements. More research is needed to clarify the magnitude of this problem.

Rainfall and snowfall in the headwater of the Indus River were very low during the summer season of 1970. This resulted in low availability of canal water on which West Pakistan is so dependent, reducing yields.



A young scientists from Pakistan prepares envelopes for thrashing of single plants.

In the rainfed area, rains were nearly absent until late February, which reduced yields. Although this is a substantial area (about a third of the wheat area), its contribution to total production is less.

Total area sown to wheat was marginally lower—15.04 million acres compared with 15.39 million acres for the preceeding year. This slight reduction is probably accounted for in the rainfed area where the moisture shortage prevented sowing.

Breeding Research

There are four principal centers of wheat research corresponding to the four provinces into which West Pakistan was divided—Sind, Punjab, Northwest Frontier and Baluchistan. The centers are at Tandojam, Lyallpur, Peshawar and Quetta. Vigorous and progressive programs are conducted at these research centers. The cooperation among the research scientists of these institutions is notable.

Although Mexipak (Cross 8156) remained the dominant variety, occupying 60 percent of the wheat acreage, the new variety Chenab 70 (derived from Cross C271 x Willet dwarf-Sonora 64) appears superior in grain yield and could take over a large area. Unfortunately, much of the seed from 10,000 acres was marketed as grain last year due to malfunctioning of seed procurement. Its yield superiority and broad adaptation is likely to make Chenab 70 the leading variety in the near future.

Barani 70 (Pitic 62-Gabo x C 271) was released last year for rainfed production. This variety has given excellent yields under these conditions. Even under restricted irrigation and limited fertility, it has shown superior performance to Mexipak, which has spread rather widely into rainfed areas. Blue Silver (Sonalika) and an early-maturing, unnamed line from Cross C 271^2 x Lerma Rojo-Sonora 64 have performed well for late planting and can be used to follow a late harvest of the preceeding crop. Both are about the same as Inia 66 and Norteño in maturity and perform better. About 150 to 190 tons of seed are available for each of these two varieties.

One of the Bluebird lines (II-23584-17Y-1a-0a) has shown good disease resistance and good grain characteristics. About 3,000 plant selections made in Pakistan of the same Mexican cross (II-23584) that initiated the Bluebird series were tested at Lyallpur for yield performance and several appear superior to the aforementioned selection. They will be reevaluated during the 1971-72 crop season.

Nayab 70 (Penjamo 62-Gabo 55 x Gabo 56) x (Tezanos Pinto Precoz-Nainari 60) and PAK 70 (Willet dwarf-Sonora 64 x C 271) are two new varieties being increased for use in the Sind.

In summary, the highly productive Pakistani breeding program is now developing many promising strains which should diversify Pakistani production and give needed disease protection. Agronomic and soils research need further expansion to provide the information necessary to increase and stabilize yield.

Plans for a summer nursery at Kaghan have been advanced and, hopefully, a summer crop comprising materials from the different breeding centers will be produced. This can substantially speed development of new varieties.

Pathology

Because of dry conditions during the season, this was largely a disease-free year. The new yellow rust race which entered the subcontinent in the late season two years ago caused no appreciable damage to Mexipak, although it is susceptible. In two fields a locally severe epidemic developed.

In a field which received heavy manure applications, a heavy fertilizer application and five or six irrigations, there was a rapid buildup leading to a 70 percent yield loss while adjacent fields of lower fertility showed only trace amounts of rust.

At Tandojam, where an artificial epidemic was used, the named Mexican Bluebird varieties (II-23584) showed from 5 percent to 30 percent stem rust of a susceptible type, whereas other selections from the same cross selected in Pakistan were resistant. At the same station, Pitic 62, which is susceptible to stem rust in most locations, showed resistance. Later, identification at Murree revealed that biotypes of races 15 and 40 were present in collections from the Bluebird lines.

Screening is being done in Islamabad for several diseases. This is done on materials received as introductions, and from the provincial breeding programs and from other countries. This is one of the few places in the subcontinent where screening can be done for flag smut, which occupies localized areas of the North.

Pakistan also assists in race identification of rusts.

Quality

With the increased production, which has made Pakistan self-sufficient in wheat, the program has now turned to improving quality. Two laboratories, one at Tandojam, Sind and one at Lyallpur, Punjab, are servicing the breeding programs of those centers. Three cereal technologists who received training at CIMMYT in the past three years are employed in this work.

AFGHANISTAN

The drought, which affected an area from Kashmir through Syria, was particularly severe in Afghanistan. It caused a nearly complete failure of much of the dryland wheat production, which accounts for nearly one million hectares of the total 2.5 million hectares. This has forced Afghanistan to import substantial quantities of wheat. Seed stocks for 1971-72 sowings were acutely limited in many areas.

Crop prospects were good for irrigated tracts and there has been an increasing use of the new dwarf varieties. In several areas, production was 2 tons/ha while the research stations produced 5 tons/ha. This indicates the possibilities for increasing production through use of improved agronomy. Farmers are now using considerable fertilizer, but in some areas the application is restricted to diammonium phosphate without using urea as a complement. This results in inadequate levels of nitrogen and maximum yields are not realized. Diammonium phosphate is an excellent starter fertilizer for wheat, but top-dressing with additional nitrogen is needed.

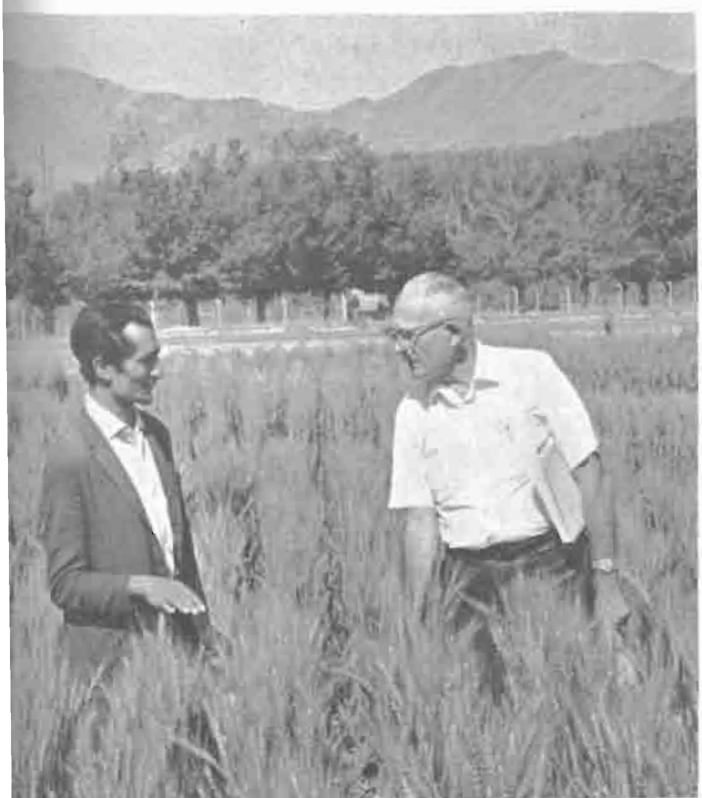
In the Helmand Valley (site of a major irrigation project), the spread of dwarf wheats has been quite rapid. The principal variety is Mexipak (Cross 8156), covering about 85 percent of the wheat area. Yields averaged 3.3 tons/ha. The best areas averaged 4.2 tons/ha. This substantial yield has given the farmers a profit four or five times the level previously achieved. There are about 18,000 hectares of improved varieties sown with new technology in this project.

Several research stations are performing well in assessing the value of introduced lines and varieties. The better varieties are being tested nationally and production of seeds is moving forward. Wheat is grown under varied ecological conditions, ranging from those similar to Pakistan and India to areas of winter wheat production at the higher elevations. Research and extension is done in collaboration with the USAID group. In the past year, plans moved ahead for Indian participation in research support. Three Indian scientists will work with the research organization and USAID.

At higher elevations, wheat gave a favorable economic response to nitrogen levels up to 133 kg/ha and P_2O_5 levels of 80 kg/ha. There appeared to be a P_2O_5 carryover in the following year and sometimes for two years. It appears that early availability is impaired. In southwestern Afghanistan, agronomic tests showed that plantings made earlier than October 15 were substantially damaged by frost. Probably October 15 is most suitable for sowings in this area.

More and better research is needed to increase agricultural production. Agricultural research station budgets must be increased so that the necessary inputs are available when needed. Salaries for agricultural scientists must be increased to attract and keep some of the best young men.

Dr. E. V. Staker (right) of USAID listens to Ghulam Hassan discuss a variety in the wheat nursery at the Darul Aman Station near Kabul, Afghanistan.



IRAN

The research and production program in Iran is conducted by the Ministry of Agricultuer with technical assistance from FAO scientists. Weather conditions in Iran were similar to those in Afghanistan and Syria. The shortage of rainfall in some areas reduced yields markedly. Inia 66, which has spread successfully to much of the higher rainfall and irrigated areas, caused some concern because of increasing loose smut—a disease to which it is susceptible. New seed stocks were purchased, but the loose smut rate in these was also fairly high. Chemical control of this dis-

A combine fleet harvests a seed crop of Inia 66 in the Caspian region of Iran.

ease is now economically possible, particularly for seed used in production of commercial seed. This will reduce infection to a fully acceptable level.

Iran has a dynamic wheat breeding program and much material is being bred and selected. Several new promising selections and varieties are in preliminary increase. These include: P4160-Nariño 59 x Sonora 64; Cajeme 54-II.36896 x Gabo 56²/Sonora 64; ADL 16; PV 18; Chenab 70; P4160²-Nariño 59 x Lerma Rojo 64A; Crespo; Huelquen; and Sonora 64-Klein Rendidor. Among these, P4160²-Nariño 59 x Lerma Rojo 64A (a 2-gene dwarf) appeared especially promising.

In the Caspian region, the widely grown variety Akova is susceptible to stem rust while Inia 66 is not. This year, early-sown Okova was not heavily attacked, but late seedings showed heavy infestation and losses in some fields could be very high. Inia 66 remained free of stem rust. All of the named Bluebird varieties (Nuri 70, Yecora 70 and Cajeme 71) were susceptible to yellow rust. Potam 70 was also susceptible. The varieties Tobari 66, UP 301, México 120, Calidad, Ciano 67, Jaral and Azteca were rust-free, but several of these were attacked by mildew *(Erisyphe graminis).*

Durum varieties and lines grown at Karaj Station near Teheran showed a heavy attack of what appeared to be a virus. The material was late sown. Since there was no evidence of a similar attack at other locations with the same material, the infection was local and perhaps of limited importance.

The Ministry of Agriculture is reorganizing its research centers to provide greater integration of the various disciplines related to crop research and production. This is a very welcome step. In countries where all research disciplines have worked on the production problems of the crop with a team approach, yields and production have soared. Where fragmented research prevails, production lags. The very competent Iranian wheat scientists should move production forward aggressively once an integrated, interdisciplinary, nationwide research program is launched.

TURKEY

Wheat is the principal crop of Turkey, occupying about 8.5 million hectares. Most of this area lies on the relatively dry Anatolian Plateau. About 1.5 million hectares of wheat are in the more moist, warmer areas of the coastal plains in the North, West and South. Fall-sown spring wheats are grown in the coastal region while fall-sown winter wheats occupy most of the Plateau.

Research is conducted by the Ministry of Agriculture with technical assistance provided by the Rockefeller Foundation, Oregon State University, USAID and CIMMYT. The newly reorganized Wheat Project, now in its first year of operation, is centered in the Wheat Research and Training Center at Ankara.

Weather conditions were very favorable for wheat production in the current year. Production has been estimated at a record 13 million tons from 8.6 million hectares. Production was 10 million tons last season when much of the winter wheat area suffered from lack of moisture.

Varietal Improvement

There has been a very rapid buildup of materials being screened in Turkey, both in the winter and spring wheat areas. In the winter wheat areas, besides vigorous hybridization programs underway in Turkey, much material is now being processed from the winter-spring crosses made by Dr. Rupert in California and the extensive breeding program of Oregon State University. Vigorous winter wheat breeding programs are being pursued at Eskisehir and Ankara. Many new crosses have been made between outstanding USSR varieties (Bezostaya, Kaukaz and Aurora) and the best local and introduced spring and winter varieties. In the spring wheat areas, large populations of various generations have been introduced from CIMMYT and from many programs of other countries. This is providing a sound base for widening the germ plasm pool in all programs.

At present, Pénjamo 62 dominates the varietal distribution in the spring wheat region. This variety, although classed susceptible to *Septoria tritici*—a major disease of the coastal areas, has shown sufficient tolerance to provide fairly high yields. Lerma Rojo 64 and Super X (Cross 8156) are grown on limited areas. They, too, are susceptible to *Septoria* and yields are greatly reduced under heavy attack. Several other Mexican and Italian varieties are being tested.

In the winter wheat area, principal varieties are the Turkish varieties 220/39, 111/33, 1593/51 and 4/11. The use of recently introduced varieties Bezostaya from the U.S.S.R. and Wanser from the United States is increasing on commercial acreage. Newer varieties under test include Turkish varieties 406, Bolal and 093/44. These are promising and may replace older varieties. Important durum varieties are Akbasak, 073/44, Berkmen and Karakilcik 133.

The bread wheat variety 220/39 is tall with weak straw, but good bread-making quality; 111/33 is very susceptible to yellow rust and *Septoria*. 1593/51 is susceptible to yellow rust and has weak straw, but yields more than 220/39; and 4/11 is resistant to most diseases, but is subject to shattering. Bezostaya has resistance to yellow rust, but is susceptible to stem rust. Wanser is moderately resistant to yellow rust, but has only fair bread-making quality.

Turkey's 1971 record wheat production overtaxed storage facilities.

Of the new varieties, 406 (Yaktay) is a selection of San Marino. It has good resistance to *Septoria,* but is susceptible to brown rust and moderately susceptible to yellow rust. No. 093/44 is moderately susceptible to leaf and yellow rust, but yields better than the older varieties 220/39 and 1593/51. Bolal (No. 2973) appears quite promising.

Among the Italian varieties under small increase, Libellula appeared to have about the best *Septoria* resistance. Splendeur, a French winter wheat, appeared very promising at Eskisehir. The new Russian variety Kaukaz appeared very promising, also. It has good stem and leaf rust resistance plus good resistance to *Septoria.*

Arising from the new, widely expanded germ plasm base, varieties with resistance to the major diseases will soon be selected. In the spring wheat region, varieties with a somewhat longer duration would be desirable to avoid the early spring frosts which sometime sterilize the heads.

Pathology

Diseases of the winter wheat area include rust, bunt and loose smut. Of the rusts, stripe rust is most important and in favorable years can cause heavy losses. In the spring wheat region, stripe rust and *Septoria tritici* are most important. Both can cause heavy losses to susceptible varieties. Leaf rust and stem rust can also cause severe losses in some years. In the high rainfall areas around the Sea of Marmora, *Erisyphe graminis* sometimes becomes serious.

In the past year, a trap nursery and disease survey was organized with help from Drs. Eugene Saari and J.M. Prescott. They visited Turkey in December to advise Turkish scientists on methods of operation. Several newsletters were issued, detailing disease development throughout the region. This program, in two or three more years, should clarify the development and importance of the various diseases throughout the country.

Large screening nurseries were analyzed at several locations for *Septoria* resistance and other diseases. This has provided much useful information to other programs with similar diseases problems. The research base in pathology is rapidly expanding.

Soil Management

Most winter wheat in Turkey is grown under dryland conditions (300-400 mm rainfall per year). Farmers use a wheat-fallow rotation. The cultural practices are adapted to a livestock economy which depends on the stubble and weeds from the fallow as a main feed source. Since most of the moisture of the fallow year is lost to the weeds, wheat germination the following autumn must wait for the first rains. If they are delayed, the wheat is unable to strongly establish itself before winter. The result is winterkill and lowered yields. Agronomic research on tillage practices and soil management systems is continuing. Soil problems in the Anatolian Plateau are aggravated by the very high clay content of the soil which prevents practices used where soils are lighter textured. It will be necessary, through adaptive research, to modify existing techniques or devise new ones to determine which methods will give the best results with minimum power. Timing and method of operation will be important to conserve moisture during the fallow year. Weed control remains a major problem.

Training

Turkey has several very good agricultural scientists, but they are too few. Consequently, training ranks high in plans for expanded wheat research and production. Eight young scientists are now studying abroad. Four additional wheat scientists are training at CIMMYT. This program will continue. The infusion of this new talent into the Turkish program will strengthen staffing patterns at the research stations where present staff can not meet the demands of the expanding research program.

ALGERIA

Algerian wheat production advances rapidly.

Algeria, along with Tunisia and Morocco, was once called the granary of Rome. Later, it was the source of wheat for Europe during the French Colonial period. As population increased in recent years, Algeria had to import significant quantities of wheat. This was principally bread wheats.

Cereals are the most important agricultural crop of Algeria, occupying about 3.2 million hectares of the 6 million hectares cultivated. About 90% of the acreage seeded to annual crops is cereals. Durum wheat occupies about 1.5 million hectares and bread wheat uses 740,000 hectares (1969-70). Production of total cereals during the past 10 years has varied from 700,000 tons to 2.34 million tons. In 1969-70 wheat production was 1.4 million tons —900,000 tons of durum wheat and 500,000 tons of bread wheat. Imports to meet present needs are about 320,000 tons. This is 40% of the total requirement.

The increasing deficit explains the government's interest in increasing wheat yields to avoid use of scarce foreign exchange for large importations. The first trials with Mexican wheat were conducted by the National Institute for Agronomic Research in a cooperative program with FAO during the 1967-68 season. Based on these results and the successful production program in Tunisia, about 5,000 hectares were grown in 1969-70, using varieties purchased from Tunisia.

This was a success and the government, under its 1970-73 four-year plan, undertook an accelerated production program using improved varieties and techniques. The objective was to achieve national self-sufficiency as quickly as possible. Talks with the Ford Foundation began in August 1969 to explore the possibilities of CIMMYT assistance in building research and production programs. In June 1970 representatives of the Ford Foundation and CIMMYT visited Algeria and concluded that possibilities of increasing production were excellent. The government was considering sowing about 200,000 hectares of improved wheats in the 1970-71 season. The group believed that the shortage of trained personnel, both at the scientific and production level, would be one of the most limiting factors. CIMMYT agreed to train several young scientists sent to México under the auspices of the Ford Foundation.

In September 1970, the Ministry of Agriculture and Land Reform (MARA) in cooperation with the Ford Foundation convened a four-day international conference in Algeria to discuss possibilities for wheat improvement in the three countries of the Maghreb. Recommendations were prepared at the request of the Secretary General of MARA for the upcoming production program by CIMMYT participants. Subsequently, the government established a wheat project and a wheat committee to provide policy guidance.

About 17,000 tons of seed were imported, but because some of it arrived late, the area sown was about 138,000 hectares of Inia 66, Siete Cerros and Tobari, and 2,000 hectares of Italian varieties. The government organized special courses for nearly 1,000 *chefs de cul-*

ture to acquaint them with the technology for the new wheats. The season was favorable and a good crop was forecast. Estimates for the new wheats ranged from 1.5-2.0 tons/ha. Final figures are not available.

One *ingeniero* and three technicians received training at CIMMYT during 1970. Also, three technicians left for training in seed production in India. There is a broad educational program underway in Algeria which will produce many *ingenieros* and technical personnel for the agricultural programs.

The Algerian production program is dynamic and fully backed by the government. Research and extension capabilities should move forward rapidly and imports will be progressively reduced as the area covered by new varieties and technology expands.

TUNISIA

The dwarf varieties and improved technology have continued their steady advance and this year occupied an estimated 103,000 hectares, about one-tenth of the wheat acreage. Farm yields of 2.5-3.5 tons/ha are now common. In demonstration plots, a yield of 6.9 tons/ha has been achieved. Although final production estimates are not available, 700,000 to 800,000 tons were predicted. The spread of dwarf wheats has exceeded the goal and production is much greater than expected. The growing numbers of farmers attending field days at demonstration sites indicates their increasing interest.

Fertilizer usage increased from 28,000 tons in 1969-70 to 43,000 tons in 1970-71. Where nitrogen is applied, P_2O_5 is applied. An estimated 80 percent of the farmers growing dwarf wheat use fertilizers at or near the recommended rate. The government has acted to make inputs available. Credit for seed and fertilizer is available.

Plans during the current year were made to transfer the Accelerated Cereal Production Project (ACPP) to the Cereal Board in order to integrate research, extension and marketing.

Training of new research scientists is being continued, both through the CIMMYT program and at the graduate level.

There are 16 *ingenieros* and 25 technicians in the wheat program. There is still a need to train a man for seed production. This could best be done outside Tunisia. Then this man could train others when he returned.

Plans have been made for research on wheat-legume rotations to replace the wheat-fallow-wheat rotations. This should increase sheep production, too. More weed control research is needed. As bread wheat production increases, research on durum wheat and other crops must be intensified in order to diversify the agricultural base. Increased economic research to monitor the changes taking place in the agricultural sector is also needed. There is a growing need for training cereal technologists, plant pathologists and entomologists. The importance of barley in the drier areas makes it important that this area of research be intensified.

Weather Conditions

The 1970-71 season began with no rains until mid-December and soils were very dry. This was followed by frequent rains, cold weather and high winds through mid-March. Then rains were limited until harvest, but the weather remained cool with high humidity.

The late start of the rains prevented pre-sowing mechanical weed control. This resulted in weed problems, particularly with wild oats. The late emergence after mid-December rains resulted in low tillering and the continuous rains led to loss of nitrogen through leaching and denitrification.

Diseases and Pests

Septoria tritici, a major wheat disease in Tunisia, was favored by the prolonged wet season. However, it reached epidemic proportions only in the Mateur area. Losses were low since Tobari and Pénjamo, which are tolerant to this disease, are grown in the area. There was also some yield reduction in the Beja-Bou Salem region. In the low rainfall belt, extending from Le Kef to Pont de Fahs, there was no appreciable damage.

Rusts were present, but posed no problem. In scattered fields, infestations of the oat cyst nematode *(Heterodera avenae)* caused very reduced stands. In the dry areas, *Fusarium* root rot was noted, but it was not serious. *Ophiobolus* was of minor importance, also. *Erisyphe graminis* was commonly observed, but it failed to develop to levels which reduced yield.

Among the insects, the Hessian fly *(Phytophaga destructor)* was present in low incidence. The North African sawfly *(Cephus tabidus)* was common, but damage was light. The new durum variety INRAT 69 appeared somewhat more susceptible than other improved durums. Low-level local infestations of stinkbug, stem maggot and cereal leaf beetle were observed.

The new commercial bread wheat varieties appeared to be performing well under different climatic conditions. Inia 66 continued to produce the highest yields. Production area continues to exceed goals and production is greater than expected.

Varietal Improvement

This (1970-71) was the fourth year of the ACPP—a government project with technical assistance from USAID, the Ford Foundation and CIMMYT. CIMMYT's direct involvement dates from late 1968.

Considerable advances have been made in increasing the amount of genetic material under selection and test. Breeding materials for the bread and durum wheats were sown at the INRAT stations of Ariana and Beja, and the new station of Manouba. Winter x spring wheat crosses supplied by Dr. Rupert were sown at Le Krib, the coldest part of Tunisia. Selection for low rainfall adaptation is done at Bou R'bia for bread wheat and barley.

Varietal improvement is done with bread wheat and durum wheats. Barleys and triticales are also under test. In the past season, 1,015 wheat varieties were sown in the crossing block for observation and hybridization. Also, 210 F_1's, 3,371 F_2 populations, 5,465 F_3 lines, 1,702 F_4 lines and 228 F_5-F_9 lines were sown for selection. In addition, 11,185 varieties and advanced lines were tested in observation nurseries, and 153 yield tests and 97 preliminary multiplication plots were grown.

Seed introductions were received from 18 countries. Tunisian materials were sent to 14. This increasing interchange of materials is broadening the base of the breeding program throughout much of the world.

Although Tobari and Pénjamo provide fair tolerance to *Septoria* and performed well on the higher rainfall areas, breeding and selection for higher resistance is one of the major thrusts of the program. Many varieties and lines have been screened (Table W22). From these, three lines with superior resistance have been identified and are being multiplied. These have been named:

1. Zaafrane = BT2292 = Sonora 64-Klein Rendidor 19975-68Y-1J-1Y-1J-5Y-1T.
2. Soltane = BT2296 = Sonora 64-Klein Rendidor 19975-68Y-1J-6Y-1J-3Y.
3. Utique = BT2348 = Calidad "S" 22429-16M-1Y-4M-0Y (Mex 1603).

Zaafrane and Soltane have consistently yielded higher than Inia 66 during the past four years in microtrials and during two years on farmer demonstrations at widely scattered locations. They show good tolerance under heavy attacks of *Septoria* and have produced well where powdery mildew was also heavy. They possess good resistance to the three rusts.

Utique also expresses good tolerance to *Septoria*. Under *Septoria*-free conditions, yields were equal to Inia 66. Under heavy infection, Utique provides yields one ton per hectare greater than Inia 66. Utique has resistance to stem rust, moderate resistance to leaf rust, but is susceptible to stripe rust. Its breadmaking qualities are good.

About 4,000 kilograms of each of these varieties are expected from demonstrations and multiplications.

TABLE W22. Yields of commercial varieties and promising experimental lines grown on small replicated demonstration plots on Tunisian farms, 1970-71.

	Locations		
	Zaouche tons/ha	Naffat tons/ha	Chaouat tons/ha
Inia 66	2.95	2.38	2.26
Florence Aurore	2.87	1.32	2.58
Ariana 66	4.19	3.63	—
Tobari	3.39	2.58	2.13
Pénjamo	4.21	2.52	—
Utique (Mex 1603)	4.16	2.91	2.17
Zaafrane (2292)	3.89	2.94	2.52
Soltane (2296)	4.15	2.40	2.44
Siete Cerros	—	1.63	—
Indus 66	3.56	—	2.54
Mexipak 65	—	1.72	2.40
Mexipak 69	3.62	—	—
BT 2279	4.07	2.11	—
BT 2355	—	2.10	—
BT 2281	—	2.22	—
BT 2286	—	2.57	—
BT 2426	—	1.49	1.49
BT 2224	2.93	—	—
BT 2363	—	—	2.37
BT 2368	4.36	—	—
BT 2354	—	—	2.10
Centrifen	3.83	—	—
Sonalika	2.61	1.97	—
Chhoti Lerma	3.19	1.69	2.51
D 5825	4.25	2.74	2.52
D 56-3A	3.16	—	2.72
Jori 69	2.84	2.26	2.42

Ariana 66 continues to perform well, but it is very late in maturity.

Durum wheat research continues with much the same aims as bread wheat. A new variety (named INRAT 69) developed by the INRAT program has been selected, multiplied and released. This variety was formerly known as D 5825. It is somewhat tall with moderate susceptibility to the rusts. It is quite tolerant to *Septoria* and has yielded well in widespread tests. It is much superior to the old durum varieties it is displacing. About 400 tons of seed should be produced on the 230 hectares planted in 1970-71. The Mexican durum variety Jori 69 and lines of the new Mexican durum Cocorit have been tested. Their yields are good, but because of susceptibility to *Septoria*, they cannot be recommended for areas of high rainfall. A late variety (Roussia), grown in Tunisia as a local, has good *Septoria* resistance.

In addition to these more advanced materials, many bread and durum selections have been made which show good *Septoria* resistance. As these are processed further, new, high-yielding varieties will replace those being used as a stopgap measure.

Varietal Evaluation

Results of the variety demonstrations are presented in Table W23. Ten additional varieties were included in various trials, but are not listed in the table because they were not tested at enough locations to permit an adequate evaluation. Barley varieties were included at the six sites with lowest average rainfall. The demonstrations consisted of duplicated 5-meter by 50-meter plots with 2.5-meter by 50-meter plots used when seed supply was limited. Seventeen locations representing the better soil and management of the dryland wheat areas of Tunisia were seeded. One was not harvested because saturated soil over a prolonged period resulted in complete crop failure.

TABLE W23. Yield, graint test weight and plant height from several farm demonstrations throughout northern Tunisia in 1970-71.

Variety	Number of locations	Yield tons/ha	Yield % of Inia 66	Test weight kg/hl	Test weight % of Inia 66	Plant height cm
Inia 66	16	3.04	100.0	80.1	100.0	88.5
Florence Aurore	16	2.73	89.7	80.1	100.0	120.5
Ariana 66	10	3.32	107.7	79.4	99.1	105.9
Tobari	16	2.87	94.5	79.9	99.8	87.6
Pénjamo 62	12	3.55	111.2	78.4	97.8	93.9
Utique-Mex 1603 TzPP x Son64 LR64 x TzPP-An$_E$ 22429-16M-1Y-4M-0Y-0TU	16	3.19	104.8	81.1	101.3	88.1
Zaafrane BT2292-Son66 x Kl. Rend. 19975-68Y-1J-1Y-1J-5Y-0TU	16	3.12	102.6	78.3	97.8	88.9
Soltane-BT2296-Son64 x Kl. Rend. 19975-68Y-1J-6Y-1J-3Y-0TU	16	3.10	101.9	79.0	98.7	89.4
Siete Cerros	6	2.99	95.5	76.6	94.8	91.7
Indus 66	8	3.21	104.9	78.2	96.6	87.5
Mexipak 65	7	2.82	102.5	77.1	96.5	89.9
Mexipak 69	8	3.28	101.8	77.1	95.9	76.7
BT2279-LR64-Son64 x Napo 63 II-22390-20M-8R	9	3.23	103.2	77.9	96.9	87.1
BT2281-TzPP-Son64 x LR64-Son/Son64A x SK^6-An 21428-1M-1R-6C-3R	8	2.84	99.2	79.7	99.1	79.8
BT2286-LR64-Son64 x Napo63 22395-100M-100R	8	3.14	100.5	75.7	94.7	87.5
BT2426-LR-$P4160_E^3$	7	2.43*	73.5	78.2	97.8	77.1
Centrifen	6					
Sonalika	14	3.01	94.9	78.1	97.4	87.2
Chhoti Lerma	14	2.88	94.8	77.2	96.5	88.7
Inrat 69 (D5825, durum)	16	3.08	102.2	79.4	99.4	89.4
Bedri 69 (D56-3A, durum)	13	2.90	95.5	79.2	98.9	108.5
Jori 69 (durum)	16	2.95	96.3	82.0	102.6	92.8
* Very low seed germination reduced yield.		2.92	96.0	79.6	99.4	77.8

Saturated soil, *Septoria,* wild oats, oat cyst nematode and low spring rainfall limited yields and influenced relative performance of the varieties in various trials. Inia 66 appeared to lack adaptation to the prolonged period of saturated soil and accompanying nitrogen deficiency. This may have limited the yield of Inia 66 more than other varieties.

Severe *Septoria* infestation in two trials and moderate infestation in several others was an advantage for the three new varieties with improved resistance to *Septoria*—Utique, Zaafrane and Soltane. Varieties with late maturity may also have benefited by delay of the most susceptible stage of plant development until conditions were less favorable for *Septoria* infection. Varieties heavily infested were Jori, Bedri 69, BT2279, BT2286, Centrifen, Florence Aurore, Siete Cerros, Mexipak 65, Mexipak 69 and Indus 66. Bushel weight was influenced as well as yield.

Wild oat infestation appeared to harm the high-yielding varieties more than the traditional varieties. Oat cyst nematode infestation severely reduced yield in two trials and contributed to high variability. The three trials most heavily infested with oat cyst nematode were the ones in which statistically significant differences were not obtained. The low yield of BT2426 is primarily the result of very low seed germination rather than lack of adaptation. In the three trials in the Le Kef area, the yield of barley was 9.2, 6.2 and 12.0 quintals per hectare higher than the yield of wheat. This is an increase of 31, 27 and 50 percent, respectively.

These trials should be continued because they serve both as demonstrations and a measure of varietal adaptability over a wide range of Tunisian conditions. Barley should be included in the drier areas. Except for special needs, the full set of wheat varieties tested in any one year should be grown at each site in order to obtain an adequate evaluation of each variety under the climate and conditions of the season.

Cultural Practice Studies

Trials with rate and date of seeding of Inia 66 at different nitrogen levels were continued as well as trials with varieties at different seeding dates. For the first date of seeding in the Le Kef area, there was no decrease in yield at the lowest seeding rate (50 kg/ha). However, for the second and third dates of seeding, yields were about 500 kg/ha lower at the 50 kg/ha seeding rate compared with higher rates. Low winter temperatures in this area delayed plant growth and development.

Varieties used in the date-of-seeding trials were Inia 66, Soltane (BT2296), Florence Aurore, Siete Cerros and Inrat 69 (D5825) at three dates of seeding. At Mateur under severe *Septoria* attack, yields of the December 7 planting were superior to yields from November 11 and January 30 plantings of Inia 66, Soltane and Inrat 69. Yields of Siete Cerros and Florence Aurore were drastically reduced for the first planting date, but yields from the second planting date did not differ from the third. Under the high level of *Septoria* infection in the first and second seeding, the yield of Soltane exceeded Inia 66 by 5.8 and 5.5 kilograms, respectively. At Medjez El Bab without *Septoria,* the yield of Inia 66 was best for the first seeding date. Yields of the other varieties did not differ between the first and second seedings. Yields of all varieties were lowest for the third seeding. The three seeding dates were December 15 (germinated by rain following seeding on November 11), December 29 and January 14.

Tunisia needs *Septoria* resistance in both bread and durum wheats with a wide range in rate of maturity in both types to provide a long period of favorable seeding dates. This would give growers more time for seedbed preparation and provide increased flexibility in farming operations. Date-of-seeding trials with varieties of different maturity rates will be needed for many years because of the great difference in growing conditions each season. As long as susceptible varieties are grown, *Septoria* infestation will influence the results of date-of-seeding trials. The slow maturity rate of traditional varieties tends to minimize losses from *Septoria* because the plants often do not reach the stage of maximum susceptibility to *Septoria* until after the most favorable weather for *Septoria* infection has passed.

Saturated soil occurs often in the flat coastal areas and in the valleys of the Mateur region due to a high water table and slow internal drainage of the heavy clay soils. Because of the generally poor internal drainage of Tunisian soils, saturated soil may occur over most of the wheat area in growing seasons of high rainfall, such as 1970-71. Therefore, practices to minimize losses from saturated soil need to be developed. The opportunity is greatest in areas of highest rainfall because of the greatest probability of a good crop each year. Possible approaches are soil corrugations to provide ridges of aerated soil with seed and fertilizer placed in these ridges, resistant varieties such as Pato, or change of variety maturity and/or seeding date to minimize or avoid the problem. Practices which reduce the saturated soil problem may reduce *Septoria* infection.

Fertilizer Studies

The Accelerated Cereals Production Program (ACPP) has now completed three seasons of fertilizer experimentation in northern Tunisia. Experimental efforts have been concentrated in more favorable rainfall areas (300-700 mm annual precipitation) of the country. Experiments have been kept relatively simple in design with an emphasis on making them useful for farmer demonstration purposes in addition to applied research. All fertilizer trials have been conducted on farmers' fields with their assistance and cooperation in land preparation, field days and harvesting.

Nitrogen response has been very pronounced in most of the trials. For example, during the 1969-1970 crop season, yield increases from nitrogen application ranged from zero to 2.34 tons/ha (0-308%), depending on the base fertility level, preceeding crop and rainfall. A 710 kg/ha average yield increase (39.2%) over the check was obtained from nitrogen use on 21 experiments at the recommended rate.

The fertilizer program for 1970-71 has been increased, both the types of experiments and the number of trials. This season 37 experiments and several practical fertilizer test strips of the following types were done: rate and date of nitrogen application; comparison of three sources of nitrogen (ammonium nitrate, ammonium sulfate and urea) at different rates; N, P_2O_5 and K_2O at different rates; P_2O_5 rate experiments and simple phosphate demonstration strips comparing two P_2O_5 rates adjacent to nitrogen experiments; comparison of six bread wheat varieties at different nitrogen rates; comparison of four durum wheat varieties at different nitrogen rates; and simple demonstrations strips involving ammonium orthophosphate with and without five microelements added.

A few of the experiments were either not harvested or were not acceptable statistically because of a high coefficient of variation caused by nonuniform damage from oat cyst nematodes, hail, flooding, competition from wild oats, farmer errors and seeding mistakes. Of the trials planted, 76 percent were carried through to completion and met the necessary statistical standards.

Yield data from all nitrogen trials are given in Table W24. The average yield for all experiments was 30.7 q/ha.* The averages for the maximum yield and check treatments were 37.9 and 27.6 q/ha, respectively. This is a net increase of 10.3 q/ha, or a 49.3 percent increase from nitrogen usage.

All of the fertilizer trials involving nitrogen rates showed definite positive responses this year. For most trials, these responses were statistically significant. The date of nitrogen application was less important. Overall, the best date for applying nitrogen in all rainfall regions was a split (½ at seeding and ½ at tillering) or all at seeding in the lower rainfall areas. It appears that the optimum nitrogen rate for the high rainfall areas (more than 500 mm) is 90 kg/ha and is 67 kg/ha for areas receiving less. These recommendations will vary with soil type, preceeding crop, soil moisture reserves, rainfall, varieties, etc., each year. Farmers should evaluate the fertility status of their farm based on the cropping history.

Since the ACPP started in 1968, Tunisian farmers have rapidly become aware of the benefits of nitrogen. Nitrogen consumption increased from 17,000 tons in 1968-69 to 40,000 tons during the 1969-70 season. Preliminary estimates for 1970-71 are approximately 60,000 tons. Although these figures represent total nitrogen usage on all crops in Tunisia, the large increases in introgen consumption largely result from farmers applying more fertilizer to wheat.

Early phosphate responses were noted at several locations during the early part of the growing season. This was probably due to slow root growth and development resulting from saturated soil conditions. Yield data indicated positive phosphate responses at only two locations. However, these differences were not statistically significant. Soil tests for available phosphate revealed sufficient quantities for the wheat crop at most locations. Apparently there has been an accumulation of available phosphate due to the relatively low grain yield during past years. Also, many of the better farmers have been applying phosphate annually.

Adding K_2O provided no benefit this season. At two locations it had a slight yield depressing effect.

The practical demonstration using ammonium orthophasphate with and without microelements added gave no yield differences. Apparently the microelements (zinc, boron, copper, manganese and molybdenum) are not limiting production factors.

* One quintal = 100 kilograms.

TABLE W24. Summary of 1970-71 wheat yields in Tunisia from all experiments involving rates of nitrogen. Yields in quintals per hectare (1 quintal = 100 kilograms).

Type of experiment	Experimental mean q/ha	Maximum yield treatment for each experiment		Mean of check treatment q/ha	Difference between maximum yield treatment and check q/ha	Yield increase %
		N kg/ha	Yield q/ha			
		More than 500 mm of average annual rainfall				
RDN	30.4	133	39.7	28.7	11.0	38.3
RDN	42.1	133	49.2	33.0	16.2	49.0
RDN	34.6	90	41.0	35.7	5.3	14.8
RDN	34.9	90	41.5	31.1	10.4	33.4
Forms of N (A)	25.9	120	35.0	14.7	20.3	138.0
Forms of N (B)	26.0	160	33.9	14.7	19.2	130.6
Bread Wheat x N (A)	21.5	200	38.5	23.0	15.5	67.3
Bread Wheat x N (B)	23.5	133	34.2	26.6	7.6	28.5
Durum Wheat x N	30.2	166	38.6	24.7	13.9	56.2
		Less than 500 mm average annual rainfall				
RDN	37.3	22	41.4	39.2	2.2	5.6
RDN	25.5	90	30.0	23.6	6.4	27.1
RDN	31.1	90	38.7	26.4	12.3	46.5
RDN	26.4	22	29.4	23.2	6.2	26.7
RDN	21.2	133	25.9	20.4	5.5	26.9
RDN	18.4	90	22.2	18.2	4.0	21.9
RDN	28.1	67	34.3	24.8	9.5	38.3
RDN	39.4	90	46.6	33.4	13.2	39.5
RDN	15.1	67	21.5	9.2	12.3	133.6
RDN	45.5	90	51.1	41.1	10.0	24.3
RDN	48.2	90	53.7	49.7	4.0	8.0
RDN	46.8	45	52.7	46.7	6.0	12.8
RDN (A)	8.9	90	13.6	6.6	7.0	106.0
RDN (B)	12.6	67	17.3	8.3	9.0	108.4
Forms of N	42.7	120	50.5	32.6	17.9	54.9
Forms of N	26.0	120	35.1	28.3	6.8	24.0
Bread Wheat x N	46.2	67	53.1	47.7	5.4	11.3
Durum Wheat x N	28.5	123	37.6	30.2	7.4	24.5
NPK	42.8	100	54.0	29.8	24.2	81.2
Totals	859.8	2,774	1,060.3	771.6	288.1	1,377.6
Averages	30.7	99	37.9	27.6	10.3	49.2

RDN: Date of application and rate of nitrogen.
Forms of N: Comparison of three different forms of nitrogen at various levels.
Bread Wheat x N: Comparison of several varieties of bread wheat at various levels of nitrogen.
Durum Wheat x N: Comparison of several varieties of durum wheat at various levels of nitrogen.
NPK: Nitrogen, phosphorus and potassium at different levels.

A yield increase and cost-benefit ratio of 3:1 is normally necessary for farmers to readily adapt a new fertilizer practice. Considering the cost of ammonium nitrate in Tunisia and the price that farmers receive for their wheat, a cost-benefit has been calculated for the 28 experiments reported in Table W24 as follows:

$$\text{Cost-Benefit Ratio} = \frac{\text{value of yield increase (dinars/hectare)}}{\text{cost of nitrogen fertilizer (dinars/hectare)}}$$

$$= \frac{10.3 \text{ q/ha} \times 4.5 \text{ dinars/quintal}}{3.8 \text{ dinars/quintal } NH_4NO_3 \times 3}$$

$$= 4.1:1$$

Even though these data are from experiments and do not completely represent large-scale production fields, a cost-benefit ratio of 4.1:1 is very good, especially considering the wide range of environments under which these experiments were grown. These results should encourage Tunisian technical personnel and farmers to utilize more nitrogen to increase production.

WEED CONTROL

Reduced wheat yield resulting from weed competition probably exceeds two million quintals per year in Tunisia. This conservative estimate is based on an average loss of 3 q/ha on 700,000 hectares. Because of this high loss, a weed control program was initiated in 1970-71.

Wild Oats Control

Wild oats presents the most serious weed problem. Economically, control by cultural practices is best. However, chemical control may be practical in certain rotations and for combating severe infestations. Also, an effective chemical control method is needed in the ACPP program to protect breeding nurseries, multiplication blocks, experiments and demonstrations.

Dicuron (80% W.P. of 2224-CIBA) was the most promising of four herbicides evaluated for wild oats control. At 3 kg/ha of commercial product, it controlled wild oats, ryegrass and several important broadleaf weeds. There is flexibility in time of application which is necessary to avoid the difficulties of a rigid spraying schedule during the wet season. Satisfactory control was obtained by applications made from pre-emergence to the 4-leaf stage of wheat development. However, the 3-leaf stage appeared to be optimum. This timing is early enough to prevent damaging wild oat competition and late enough to assess the infestation before investing in the application. Phytotoxicity may be a problem, especially if the application is followed with 2,4-D. New high-yielding varieties tended to be less sensitive to Dicuron than other varieties.

WL-17731 (20% emulsion-Shell) at 7.5 liters of commercial product per hectare gave excellent control when it was applied at the late-tillering stage of the wild oats. This material may be most useful for control of light-to-moderate infestations or for preventing reseeding of wild oats. In heavily infested fields, early competition may seriously reduce wheat yields. Critical timing may be a problem.

Avidex (46% emulsion of triallate) did not appear promising because of phytotoxicity, inconsistent control and the need for soil incorporation before planting. Soil incorporation presents more problems in Tunisia than in countries with more equipment and more advanced technical skills.

Carbine (11.8% emulsion of Barbon) did not appear promising because of the precise tim-

Wild oats present a continual threat to Tunisian wheat producers.

ing required. Without air application, this is a serious handicap. Also, there was phytotoxicity.

Broadleaf Weed Control with 2,4-D

There is a need for early broadleaf weed control without risking damage of wheat. Information on phytotoxicity of 2,4-D is especially needed because of the potential value of this widely used material. It controls most broadleaf weeds, the practice is established and the cost is low.

Experimentation consisted of time-of-application trials with 2,4-D, MCPA and Buctril, strip application of 2,4-D and MCPA across the ends of varietal trial plots, and observations of phytotoxicity in all varietal trials treated with 2,4-D for weed control. Wet, cold weather may have influenced the sensitivity of the wheat plants to the 2,4-D applications.

Of 14 varietal trials treated with 2,4,-D, head distortion resulted in all but three experiments. Spray application dates ranged from January 23 to March 26 and the stage of wheat development varied from 3¾ leaves to mid-jointing. Varieties in most of these trials can be arranged in five categories of sensitivity to 2,4-D as expressed by severity and frequency of head distortion. Within groups, varieties are arranged in decreasing order of sensitivity (Table W25).

There could be a relationship between damage and maturity stage of the varieties.

A sequence of characteristic symptoms was associated with 2,4-D applications at successively later stages of plant development: before and at the start of tillering, fused leaf margins (onion leaf); at early tillering, shortened rachis, often with whorls of spikelets at the same node, nodes with no spikelet or with an aborted spikelet; and at late tillering through tillering, fused glumes and some spikelets with few florets. The most extreme head distortion occurred in the trials where tillering appeared most vigorous at the time of spray. Compared with 2,4-D, MCPA application had less, but a similar influence on vegetative development and resulted in very little head distortion, even on sensitive varieties. Abnormal development of heads may not result in yield reduction. Information relating yield to 2,4-D symptoms, treatments, and conditions at application is needed to improve recommendations for the new high-yielding wheats.

Herbicides Not Used Commercially

Nine promising herbicides not commonly used in Tunisia were evaluated because there are limitations to the use of 2,4-D. An early herbicide application is often needed, but the 2,4-D cannot be applied until after the full tillering stage without risk of damage to the wheat. Later application may involve plant damage by application equipment, phytotoxicity or risk of harmful drift to other crops such as legumes, vegetables or grapes. Another advantage of a relatively early herbicide application is the reduced probability that saturated soil will interfere with the operation.

The herbicides evaluated were Karmex (diuron), Lorox (linuron), Ingran (terbutryn), Actril (ioxynil), Buctril (Bromoxynil), MCPA, Bronate (Bromoxynil and MCPA) and Bonval (dicamba). The 2,4-D was always included as a standard. Ingran was promising because a broad spectrum of weeds were controlled, including excellent control of canary grass *(Phalaris* sp). Under Tunisian conditions, the dosage must be reduced to approximately one kilogram of active ingredient per hectare to avoid phytotoxicity problems. Buctril at 1.76 liters per hectare, MCPA at 1.17 liters and Bronate at 1.76 liters were promising because a broad spectrum of broadleaf weeds were controlled and there were no phytotoxicity problems.

Karmex was evaluated for control of *Oxalis.* Only mediocre control was achieved and there was a phytotoxicity problem. However, further research may prove Karmex useful for this purpose.

TABLE W25. Sensitivity of various varieties to 2,4-D.

Very Sensitive	Sensitive	Intermediate	Insensitive	Very Insensitive
Soltane (BT2296)	BT2286	Penjamo	Florence Aurore	Inrat 66
Zaafrane (BT2292)	BT2279	Centrifen	Ariana 66	(B5825)
Sonalika	Tobari	Inia 66	Chhoti Lerma	Jori 69
Utique (Mex1603)	BT2281		Bedri69 (D56-3A)	

MOROCCO

The Cereal Improvement Project operates as a program of the Moroccan Ministry of Agriculture with the technical assistance of USAID, CIMMYT and the Near East Foundation. This (1970) is the second year of CIMMYT participation. Three CIMMYT scientists work on varietal improvement, agronomic research and demonstration. USAID and the Near East Foundation, under contract with USAID, provide three additional extension agronomists in major wheat areas at Fez, Marrakech and Rabat. Administrative support is provided by USAID. The project is implemented through a committee of the Ministry.

Barley ranks first among cereals in area sown, occupying about 52 percent of the acreage. Durum wheat follows with 20 percent of the area and bread wheat with 12 percent. Durum is particularly important because of its use as *couscous*, a staple of the Moroccan diet. Yields of wheat have been traditionally low. From 1938 to 1962, wheat yields averaged 605 kg/ha. Considering the good soils and favorable rainfall, there was much room for improvement. During the last five years, yields per hectare have nearly doubled (an average of 1,012 kg/ha).

The yield increase is reflected in increased production. The average annual production for the past 10 years is 585,000 tons of durum and 365,000 tons of bread wheat. Averages for the past five years are 1.36 million tons and 5.10 million tons for durum and bread wheats, respectively.

Since wheat production is very dependent on rainfall, there is considerable annual variation. During the 1970-71 crop year, rains were delayed until late December, resulting in very late emergence of the crop throughout most of Morocco. The durum crop occupied an estimated 1.3 million hectares, about 80,000 hectares less than the previous year. The current crop estimate is 1.6 million tons, an increase of about 200,000 tons from the previous year. The estimated bread wheat acreage is 500,000 hectares, about the same as the previous year. Production should be more than 600,000 tons, slightly less than for 1969-70.

Five varieties cover most of the durum acreage. They are BD2777, BD3225, BD2909, BD 1658, and BD272. BD2777 is an introduction from Cyprus, known there as Kyperounda. It occupies more than 50 percent of the area. The other varieties are native Moroccan types. Much of the bread wheat acreage is sown to BT908, BT3597 (Mara) and BT2309. BT908 and BT3597 (Mara) are quite resistant to *Septoria* although they are susceptible to leaf and stem rust and can be adversely affected when sown late. The dwarf varieties have not yet taken over a major area, but they are used increasingly as their superior yield characteristics are demonstrated. Tobari 62, with fair tolerance to *Septoria*, is spreading. Pénjamo 62, with some tolerance, is also grown. In the South, where *Septoria* is rarely severe, Siete Cerros (Cross 8156), and to a lesser extent, Inia 66, are rapidly gaining acceptance. In demonstration plots in this area, more than 6 tons/ha were produced with irrigation near Marrakech.

The research program has expanded rapidly and many new breeding lines and selections with superior resistance to *Septoria* and to other diseases have been identified. New varieties should be available as selection and testing advances.

Unfortunately, the new dwarf varieties of durum presently available are not resistant to *Septoria*. Despite this, they yield equal to the traditional varieties. Morocco needs new durum varieties of the dwarf type with good *Septoria* resistance. Because of the large durum area, the development of such a variety would rapidly increase yields and simultaneously facilitate the spread of new technology. A major effort to produce such a variety is now underway.

A great need continues for training more young Moroccan scientists in research and extension. In the past three years, 14 technicians have received training at CIMMYT. These men are prepared for technical positions but unfortunately, because of the overall shortage of trained scientists, most of them have been assigned to other Ministry programs. If a continuing efficient research and extension program is to be developed, more young scientists at the *ingeniero* level are needed. Then, by working within the project, a team could be gradually built which would take over the program as a fully integrated project of the Moroccan Ministry.

Seed production has been improving. Excellent quality, weed-free seed was being grown on some farms last year. On others, severe weed problems probably limited seed quality. Careful selection of seed production farms will help prevent loss of valuable new varieties.

Many excellent demonstrations were grown throughout Morocco during the past year. Combined with government economic policies to stimulate use of inputs such as fertilizers while assuring a fair price for grain, these demonstrations should rapidly increase yield and production.

Fertilizer Experimental Program

The fertilizer research program, initiated during the 1968-69 crop season, is an integral part of the Cereal Project. It is carried out in collaboration with the fertilizer and management research section of the Moroccan National Agricultural Research Institute. The program was designed to complement and intensify wheat fertilization work being conducted by personnel of the Institute. Principally, this was accomplished by a series of experiments on farmer's fields, complementing the Institute's work at research stations. The program, which concentrates solely on wheat fertilization, has greatly expanded the range of variables studied.

Moroccan government officials discuss new durum varieties with members of the CIMMYT research team at the Merchouche Nursery.

This cooperative effort has been mutually beneficial. The rapid development of recommendations for use in the extension program has been aided by the Institute's experience, facilities and personnel. Also, strengthening this aspect of the wheat research has enabled Institute personnel to use limited resources for other work without neglecting problems of immediate concern to the farmers. The research stations are concentrated in the irrigated zones so that relatively less research was previously possible under dryland farming conditions. The CIMMYT-assisted program has concentrated on dryland farming.

During 1970-71, experiments were placed at 16 locations. Fourteen gave useful information. These experiments included: nitrogen rate and timing of application trials in both the high (more than 450 mm) and intermediate (350-450 mm) rainfall zones; nitrogen rate experiments on Mexican, Italian and Moroccan varieties; P_2O_5 and K_2O studies; two types of nitrogen experiments under a dryland cropping regime; and a nitrogen response study on eight varieties of bread and durum wheats.

The 16 locations were located so that they provided a sampling of the principal wheat growing regions of the high and intermediate rainfall zones, and the northern and central zones of Morocco. Within the zones, the experiments were located to represent the principal soil types and rotations.

Despite a long delay in the onset of fall rains (1970), unusually high precipitation in April and May (1971) created good conditions for yield and fertilizer response. Although *Septoria* attacks were significant at some locations, the dry winter prevented early buildup of inoculum so the attack was late and losses were generally light. Yields of Mexican varieties were reduced at several sites by low seed set in third and fourth florets which failed to fill.

Leaf rust was widespread on susceptible varieties, particularly in the intermediate rainfall zone. Cool spring temperatures delayed the buildup of stem rust and it was not a factor in any tests. A prolonged stripe rust attack moved into the heads of the local variety BT 2306 in two locations of the central zone, reducing yield.

Experimental Results

Table W26 summarizes results of nitrogen trials by rainfall zone, rotation and variety. The *average yield increase* at optimum nitrogen was 11.7 q/ha, compared with the nonfertilized check at 20.3 q/ha. This is a return of 17.5 kilograms of wheat for each kilogram of nitrogen applied, or an economic return of 7.5:1.

For the high rainfall zone, the average optimum nitrogen rate in this year's experiments closely paralleled that recommended commercially (64-68 units/ha). Recommendations for the zone are based on adequate available moisture for 35-50 q/ha yields. Moisture is limiting on yields so infrequently in this area that recommendations are made for maximum yield, considering soil type, rotations and variety. Moisture was not limiting and results were as expected.

In the intermediate rainfall zone (Table W26), the recommended rates were too low to produce maximum yields where varieties were on rotations such as wheat following legume or wheat following clean fallow—conditions favorable to wheat growth. The recommendations are based on a shortage of moisture sometime during the growing season, often in the latter part. Since rainfall, particularly in the spring, was abnormally high this season, the optimum response level was considerably above recommended rates.

The rotations favorable to wheat are followed mainly in areas of deep, better-watered soils in this zone. Where soils are shallow, the wheat-legume rotation rapidly becomes marginal and is replaced with wheat-pasture-fallow or continuous cereals. Therefore, the recommended rates in these favorable rotations of wheat-legume are usually too low in a year of high moisture for continuous wheat or for wheat-pasture rotations in the less favored areas of the zone.

Although the recommended rates in the less favored areas produced good results, they might have been too high if spring moisture had been limiting. The recommendations, however, are kept somewhat above the optimum level to take advantage of fortuitous rains. These areas are capable of producing 15-25 q/ha yields with proper varieties and full use of available moisture. They contribute substantially to the commercial production.

There was no response to K_2O and only low response to P_2O_5. Phosphate produced a response only once in two years and then not at levels above the 40-60 kg/ha rate recommend. However, many of the experiments were conducted on modern farms where P_2O_5 levels were probably maintained through regular applications.

In the dryland experiments, row spacing of 35 centimeters with a seed rate of 44 kg/ha was compared with row spacing of 17.5 centimeters and 100 kg/ha. Different nitrogen levels were used. At one location, results were inconclusive. At the other, wider spacing and lower rates were inferior to normal seeding. The good rainfall favored the denser plant stand.

The recommended nitrogen rates for Mexican and Italian varieties in the rainfed regions are shown in Table W27. These recommendations were prepared from data obtained by the Moroccan Agricultural Research Institute and the wheat program fertilizer studies.

Two rates of nitrogen are given for each area, based on the preceeding crop. There is

TABLE W26. Summary of nitrogen fertilizer experiments conducted on farmers' fields during the 1970-71 crop cycle in Morocco.

Treatment	Check plot Yield q/ha	Recommended nitrogen rate kg/ha	Response level nitrogen rate kg/ha	Yield at Response level q/ha	Yield increase q/ha	Return kg grain/kg N
			High rainfall zone (450-800 mm)			
Rotation I*	26.1	68	64	38.0	11.9	18.6
			Intermediate rainfall zone (300-450 mm)			
Rotation I	20.3	48	65	30.7	10.4	16.0
Rotation II	11.6	63	63	23.3	11.7	18.6
Average of all trials	20.3	60	67	32.0	11.7	17.5

* Rotation I: Wheat following sugarbeets, legume (edible or forage) or clean fallow.
Rotation II: Wheat following cereal (grain or forrage, oilseed or weed fallow.

TABLE W27. Recommended nitrogen rates for the Mexican and Italian varieties in the principal nonirrigated areas of Morocco.

	Rainfall mm	Soil depth cm	Recommended rate		Method of application
			Rotation I*	Rotation II**	
Gharb Plain	450-600	100 +	60	80	All at seeding or Split application
Preriffen Hills (McKnes, Fes and Taza Provinces)	400-800	50-150	60-80	80-120	Split application
Sais Plain	500-600	50-100	80-100	120 +	Split application
Romani Plateau	450	75-100	60	80-100	Split application
Chaonia	350-400	50-100	60	80	All at seeding
Upper Chaonia	300-400	50	40	60	All at seeding
Doukkala	300-350	50-100	60	80	All at seeding
Phosphate Plateau	300-400	50	40	60	All at seeding

* Rotation I: Wheat following sugarbeets, legume (pulse or forrage) and clean fallow.

** Rotation II: Wheat following oilseed, cereal (grain for forrage) and weed fallow.

some overlapping, particularly for wheat after fallow. Since many farmers begin their fallow late, it is difficult to differentiate between clean fallow and a weed fallow. The advantage of the clean fallow appears related to organic matter breakdown or native fertility of the soil. Legumes produced a positive effect on following crops.

Maximum wheat yields generally require an increase of about 40 kg/ha N or 60 kg/ha N after safflower or a heavy cereal crop. Much research experience has been done with wheat in a wheat-legume rotation and less information is available for wheat-after-wheat or wheat-after-oilseed.

Varietal Improvement

Much breeding material was evaluated during 1970-71. This included 4,766 advanced lines and varieties, and 4,085 segregating populations of *Triticum vulgare*. Also, 490 advanced lines and varieties and 485 segregating populations of *Triticum durum* were evaluated. In addition, 169 lines of triticale and 422 varieties and collections of barley were grown. These experimental materials were grown at experiment stations in Merchouch, Sidi Kacem, Cotonniere, Marrakech and Fez.

Weather conditions at Sidi Kacem and Merchouch were very favorable for *Septoria* epidemics. This permitted a very satisfactory screening of material for *Septoria* resistance. Many individual plants were found in segregating *T. vulgare* populations which combined tolerance to *Septoria* with a high level of resistance to the rusts.

Yields of advanced lines and varieties in replicated trials are presented in Table W28. The yield data presented for Sidi Kacem were obtained under a heavy attack of *Septoria*. Nevertheless, several lines significantly outyielded the best commercial variety (BT908).

The new high-yielding varieties attract increasing numbers of Moroccan farmers with their production potential.

TABLE W28. Best yielding lines and varieties in Morocco during 1970-71 (replicated experimental plots in yield trials).*

Name of variety or cross and pedigree	Sidi Kacem			Fez		Marrakech		Merchouch	
	Septoria attack %	Yield		Yield		Yield		Yield	
		kg/ha	% check	kg/ha	% check	kg/ha	% check	kg/ha	% check
Son64-Kl. Rend/Bb"S" (26804-6Y-1M-0Y)	60	4542	117	3838	105				
Son64-LR64 (HD-1799)	50	4504	116	5525	151				
Bb"S"-Cno (26572-61Y-3M-0Y)**	60	4454	114	4529	124				
Son64-Y50$_E$ x Gto/Inia"S" (23528-7M-1T-1M-8Y-0M)	80	4454	114	4479	122				
Son64-Y50$_E$ x Gto/Inia"S" (23528-7M-1T-1Y-0M)	80	4446	114	4567	125				
No"S"-Cno"S" (24941-13M-3Y-1M-2Y-1M)**	40	4384	112	4250	116				
Inia"S"/Son64A x TzPP-Y54 (LR64^2-Son64 x Jus) (23817-4T-1M-1Y-1M-0Y)	50	4296	110	2792	76				
Tacuari-Pj62 (Mj-119-100M-100Y)	40	4284	110	4896	134			2854	88
Jar66-Cno"S" (25067-32M-2Y-1M-1Y-0M)**	30	4041	104	3742	102				
Son64-Y50$_E$ x Gto/Cno-Son64 (30426-2M-0Mch)				4009	109				
Son64-Y50$_E$ x Gto/Cno-Son64 (30426-6M-0Mch)				3979	108				
LR64A (TzPP-Y54) (HD-1622)	40	3967	102	5404	147				
Potam 70	70	3928/28***	101	4413/32	120	6075	184	3369/44	104
LR64"S" x Hua-R. (HD-1675)	20	3917	100	5279	149				
Nuri F-70	50	3879/28	100	4355/32	119	6162	186	3160/36	97
Bb"S"-Inia66 (26591-1T-7M-0Y)	90	3870	99	5384	147	5900	178		
Pénjamo 62	70	3827/28	98	4223/32	118	5117	155	2599/48	80
Cajeme 71 (Bb #4)	40	3821/20	98	4743/12	129	6442	195	3257/44	100
Cno"S"-Inia"S" (23959-52T-1M-3Y-0M)	90	3820	98	6584	179	6542	198		
Bt-908 (The best commercial variety) (Check)	30	3894/28	100	3666/32	100	3304	100	3245/36	100
Siete Cerros	100	3772/36	97	3950/32	108	5571	169	2798/88	86
Yecora F-70	90	3568/28	92	3986/32	109	5779	175	3125/44	96
Tobari 66	70	3337/28	86	3954/32	108	5050	153	2885/60	89
Inia 66	70	3287/36	84	4052/32	110	5846	177	2839/88	87
MID-7	30	3179	82	3258	88			2300	71
MID-324	30	2764	71	3113	85			2667	82
BT-2306						2653	80		

* These lines were the highest yielding ones from various yield trials.
** These lines were also among the best yielders during the 69-70 season.
*** The number indicates replications considered for the average yield used in the table at each location.

There were no diseases of importance in the Fez nursery where many lines and varieties significantly outyielded BT908. The yield data from Sidi Kacem and Fez are reliable. Both nurseries had uniform stands of plants and low experimental error.

The yield data from Merchouch are not reliable because of severe competition from wild

TABLE W29. Best lines or varieties in the yield trials at Merchouch, Morocco in 1970-71.*

Exp. & Var. No. 70-71	Name of variety or cross and pedigree	Septoria reaction**	Yield kg/ha	% of check
	The International Spring Wheat Yield Nursery			
ISWYN 12	Pato Argentino (21974-4R-4M-2Y-0Y-0P-0Y)	3	3984	164
" 34	Cajeme 71 (Bb # 4) (23584-26Y-2M-3Y-2M-0Y)	7	3746	154
" 22	(LR64 x N10B) An$_E^3$	2	3454	141
" 13	Son 64 x TzPP-Nai60 (B) (18889-6T-4T-2T-1T-2B	5	3392	139
" 31	Potam 70	5	3359	138
" 14	Siete Cerros	6	2621	108
" 50	BT-908	2	2433	100
	The Regional Spring Wheat Yield Nursery			
RSWYN 11	Calidad "S" (22429-16M-1Y-1M-0Y)	3	3883	180
" 10	Pato Argentino	3	3875	179
" 13	Ariana 66	3	3759	174
" 8	Potam 70	6	3596	167
" 14	BT-2297 (19975-68Y-1J-4Y-1J-4Y)	5	3592	166
" 18	Siete Cerros	6	2538	118
" 12	Inia 66	6	2521	117
" 25	Florence Aurore	5	2500	116
" 6	D5825	2	2383	110
" 20	Pénjamo 62	5	2175	101
" 5	BT-908	2	2158	100

* Yields were greatly affected by a heavy infestation of wild oats and mechanical damage, as well as by Septoria and leaf rust.
** Septoria reaction taken from 0 (immune plant) to 9 (all foliage and glumes covered with lesion-bearing pycindia).

oats in much of the nursery. The data from the irrigated nursery in Marrakech show clearly the outstanding performance of the Mexican varieties and advanced lines under these conditions. They were far superior to BT908.

Several promising high-yielding lines and varieties with considerable tolerance to *Septoria* were identified in the International Spring Wheat Yield Nursery and in the Regional Spring Wheat Yield Nursery. These data are in Table W29.

After three cycles of the varietal improvement program, several advanced lines and varieties show promise for use as commercial varieties in Morocco if the results are confirmed in the 1971-72 crop cycle. A small seed multiplication program is being initiated for several of the most promising lines.

Undoubtedly, however, the best material will be in F_3, F_4 and F_5 lines that have been selected under Moroccan conditions. Some of the lines will enter preliminary yield tests during 1971-72.

BRAZIL

For the past four years, Brazil has been developing an aggressive program to increase wheat production. The government program has the immediate objective of increasing production now and the long-term objective of increasing yields and stabilizing production through research.

The immediate objective has emphasized using materials and information now available, attempting to induce their use with a sound economic policy. The government established a stimulating minimum guaranteed price for wheat. Through the official Bank of Brazil, arrangements are made to purchase all wheat grain at the established price. Credit is advanced to farmers. Seed, fertilizer and pesticides are available at seven percent interest while interest on other inputs is 15 percent for small farmers and 18 percent for large farmers. To provide this credit, banks are required to set aside a certain proportion of their credits for agricultural loans.

The government has also stimulated the private sector to participate in this production effort. It has provided credits and other encouragements to the Federation of Wheat Cooperatives (FECOTRIGO) for promoting wheat production (and also for the promotion of soybeans, which are grown as a summer crop in the same areas and generally by the same farmers who grow wheat as a winter crop). With credit and other assistance from government, FECOTRIGO has embarked on a vast program of warehouse construction capable of coping with the rapidly increasing demand for more storage capacity for both wheat and soybeans. FECOTRIGO has also encouraged its members to use lime and fertilizer — especially phosphates. The government is also stimulating the private sector to develop the fertilizer, pesticide and machinery industries. Under this stimulus, mechanization has advanced rapidly and modern machinery is used on about three-fourths of the area sown to wheat.

During the past four years, the area sown to wheat, yield per hectare and total production have increased spectacularily (Figure W9). Production rose from less than 400,000 metric tons in 1967 to 1.8 million tons in 1970. The estimated production for 1971 is more than two million tons, despite severe losses in some areas from late frosts and aphid infestations. The striking increase in production has already reduced imports considerably with a concurrent large saving in foreign exchange. Similarly, spectacular increases in soybean production yielded a 1970 crop of about two million tons. The production breakthrough for wheat and soybeans in southern Brazil has resulted in great enthusiasm among producers, agribusiness and government officials.

Brazil has large tracts of flat or rolling land in areas with adequate winter rainfall for wheat production. If ways can be found to alleviate the soils problem and to provide increased protection from diseases and insects, Brazil may become self-sufficient in wheat production within the next five years. Whether this target is achieved will depend primarily on the effectiveness of the research program.

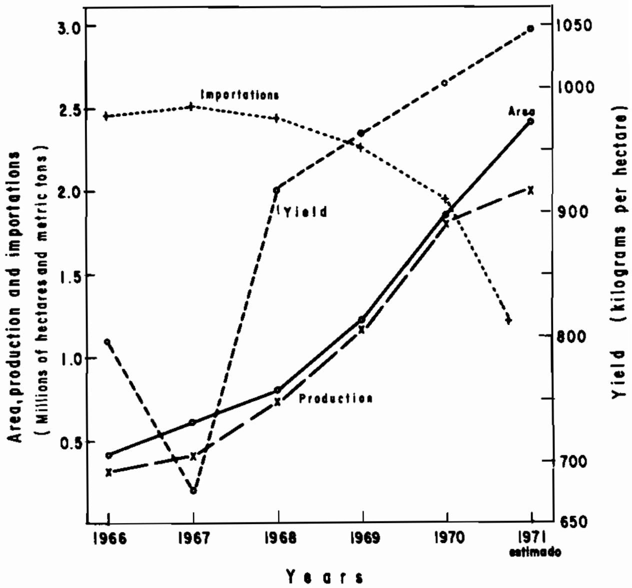


FIGURE W9. Importations, yield, area and production of wheat in Brazil, 1966-1971.

Soil Problems

The soil problems in southern Brazil are complex and difficult to solve. Generally, the soils are laterites with low pH, high levels of soluble aluminum and strong phosphate fixation. The high level of soluble aluminum is toxic to many crops and restricts yields of others, including wheat.

Experimental work in recent years has established that wheat yields can be increased greatly with heavy applications of lime, proper phosphorous and nitrogen fertilization plus use of aluminum-tolerant varieties. During the past two years, many farmers have begun to apply lime to reduce aluminum toxicity. During this period, an estimated 320,000 hectares have been limed at the rate of 3.7 tons per hectare. More favorable responses to phosphate and nitrogen fertilization are obtained following liming.

There is a need for varieties which respond better to fertilization, with shorter, stronger straw combined with a broader spectrum of disease resistance. These will allow farmers to more fully capitalize on the progress being made through the adoption of the improved cultural practices.

Considering the magnitude, complexities and importance of the soils problem, the research effort is still grossly inadequate.

Disease and Insect Problems

There are many diseases. Leaf and stem rust can be destructive. *Giberella* spp. (scab) causes severe damage in susceptible varieties in some years, but there is considerable tolerance in the commercial types. *Septoria nodorum,* which flourishes under the same conditions favorable to scab, is important. The variety Lagoa Vermelha appears quite tolerant. *Erisyphe graminis* (powdery mildew) causes losses in some years. Yellow dwarf virus is fairly common. Reportedly, a soil-borne mosaic virus could be a hazard as soil pH is raised to counter aluminum toxicity. Two varieties have good resistance.

Although losses from insects have not been of great importance, they must be given more attention in the research program as wheat culture is intensified and expanded.

During the 1971 crop, aphids caused considerable-to-severe losses in some areas. Although reports indicated the damage was caused by the English grain aphid *(Macrosiphum granarium), Macrosiphum urticae* was probably also involved in the infestation. It caused moderate-to-severe damage in the 1971 crop in some adjacent areas of Argentina. Aphids must also be considered in future research programming since they are important as vectors for viruses, especially the barley yellow dwarf virus which is present in Brazil.

Wheat Breeding

Development of improved wheat varieties is fostered under the government's Accelerated Wheat Improvement Program. Three organizations participate—the National Ministry of Agriculture through the *Instituto de Pesquisas a Experimentacao Agricola do Sul* in the states of Rio Grande do Sul and Santa Catalina, IPEAS and IMPEAME in the states of Parana and Sao Paulo, secretaries of agriculture for the states of Rio Grande do Sul, Santa Catarina, Parana and Sao Paulo, and FECOTRIGO. Supplementary foreign technical assistance is provided by FAO under a United Nations Development Program grant and the Massey Ferguson Company.

The breeding program aims at developing high-yielding, fertilizer-responsive, semidwarf varieties with improved industrial quality and a broad spectrum of disease resistance, combined with tolerance to aluminum toxicity and the adaptation of the Brazilian varieties. A vast program of crossing and selecting is making rapid advances toward achieving this objective. CIMMYT is collaborating by providing many segregating populations and advanced lines for evaluation.

Although collaboration exists in the breeding effort, no provisions have been made for uniform yield testing of advanced lines and varieties under a wide range of conditions. The full potential benefits of the broad breeding effort will not be obtained until more extensive cooperative testing is done. Such cooperative uniform testing would help to rapidly identify broadly adapted varieties with an unusually broad spectrum of disease resistance.

Staff Development

During the past three years, Brazil has emphasized training young scientists for its wheat improvement program. CIMMYT has participated in this training program. During 1971, five Brazilians scientists trained at CIMMYT. A total of 11 have received CIMMYT training in México since 1969. Five of these scientists were supported during their study in México by scholarships from the Inter-American Development Bank.

ARGENTINA

The area sown to wheat and total production continue to decline. This trend has been in progress for several years. In part, this has resulted from stagnant, or nearly stagnant, wheat yields while yields of maize and sorghum have continued to increase. As a result, production of these two crops has increased at the expense of wheat areas.

Of even greater importance has been the lack of economic incentive to the farmer. Wheat prices to farmers are among the lowest in the world. This is compounded by high prices for inputs, particularly fertilizer and pesticides. The unfavorable weather of the past

Scientists from many national programs meet with CIMMYT scientists in México to study CIMMYT's methods and learn the latest developments.

Dr. Armando Campos (above photo, left) explains CIMMYT's bread wheat program to a visiting scientist from Poland.

In the photo at the right, Dr. Marco Quiñones (left) of CIMMYT discusses durum wheat kernel type with scientists and producers from various parts of the world.

three years has further discouraged farmers from growing wheat. Unless this downtrend in wheat production is arrested by remedial measures, Argentina will cease to be a wheat exporter in the near future.

Research progress will tend to increase yields and productivity. However, it is doubtfull whether this alone, without changes in economic policy, will be able to reverse the production trend.

Varietal Improvement

Within the current year, the first semidwarf bread wheat varieties have been approved for release from the INTA breeding program. The varieties Precoz Parana INTA, from the cross Sonora 64-Knott #2* (II-18893-12P-3B-3P-1B-1T), and Marcos Juarez INTA, from the cross Sonora-Klein Rendidor (II-19975-68Y-1J-6Y-4Y-1J-0B), were released.

These two varieties have outyielded the most popular commercial varieties by 300-500 kg/ha during the past three years. In years of favorable rainfall when improved cultural practices are used, including proper fertilization, or when wheat follows alfalfa, these varieties have given yields of one ton per hectare above conventional types. The INTA breeding program has reached a stage where the flow of new varieties with greater yield potential will be on a continuing basis.

A dynamic seed multiplication program is now needed in order to provide large volumes of seed of the new varieties. In this way, farmers will have early access to the new seed.

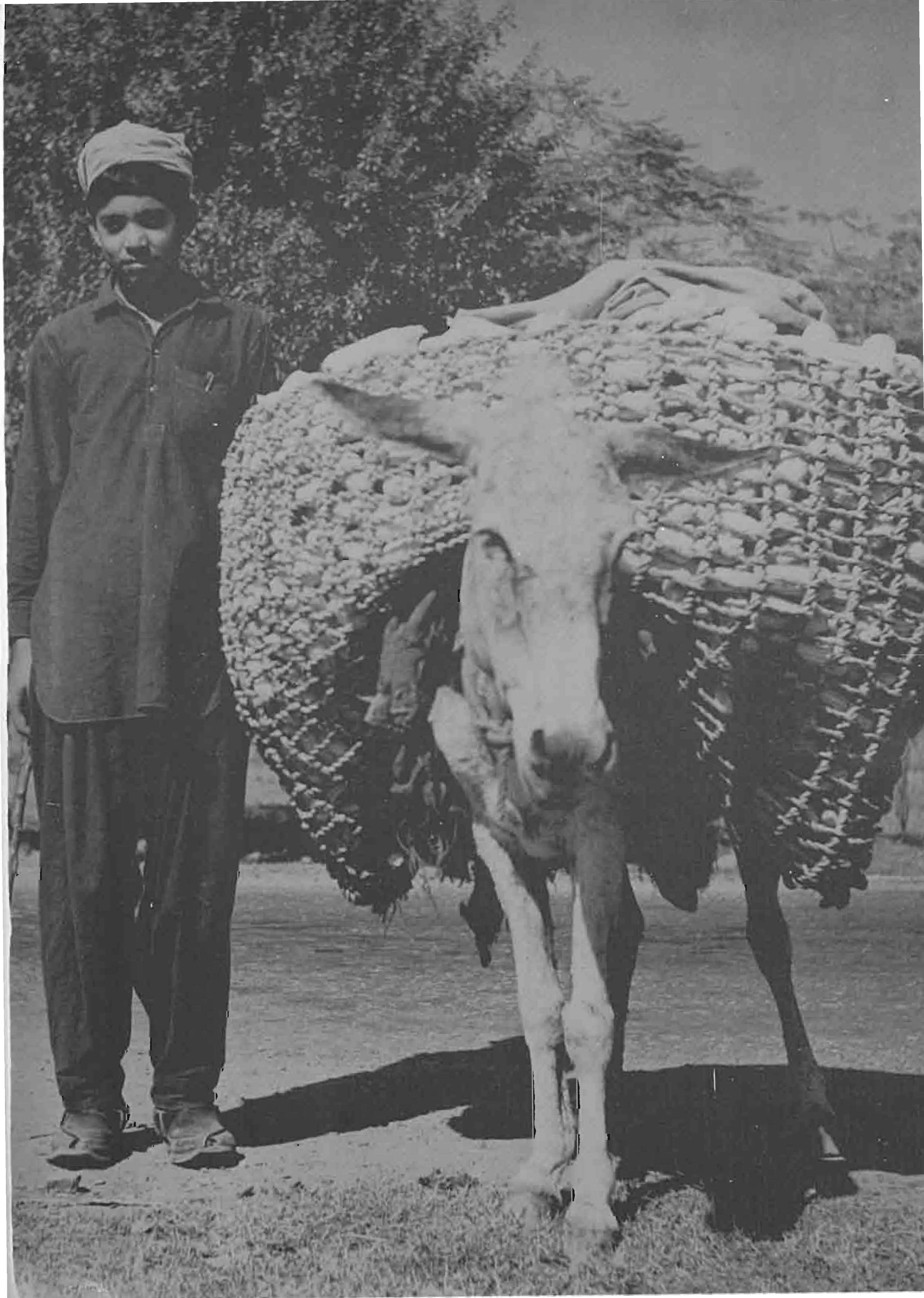
Progress is also being made in the improvement of durum wheats. The prospects for developing high-yielding durum varieties is even more favorable than for bread wheat. Many very promising semidwarf durum wheat lines, arising from crosses of tall Argentine varieties with Mexican dwarf types, are in final testing stages. Several of these have outyielded the present commercial varieties by 20 to 30 percent during the past three years. The favorable results have led to a rapid expansion of durum breeding, particularly at the Balcarce station.

Use of Chemical Fertilizers

Although much research has explored the feasibility of using chemical fertilizers to increase wheat yields during the past ten years, little fertilizer is used in commercial production. Consumption has increased, but very slowly. In areas where rainfall is favorable and one could expect substantive gains from fertilizer usage, the area receiving fertilizers is very small. The sole exception is in southern Buenos Aires Province where use of phosphatic fertilizers, and to a lesser extent nitrogenous fertilizers, has expanded rapidly during the past three years.

The greatest obstacle to the increased or continued use of chemical fertilizers is the very unfavorable cost-benefit ratio. With the high cost of nitrogenous fertilizers and low price for wheat and maize, it takes 7 kilograms of wheat or 11 kilograms of maize to buy 1 kilogram of nitrogen. Unless it is possible to change this ratio, there will be no appreciable increase in fertilizer use.

* Knott # 2 was an unnamed line developed from a convergent backcross made by D. R. Knott of the University of Saskatchewan, Canada.



MAIZE

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INTRODUCTION

Despite a 12 million ton reduction in the 1970 United States crop directly attributable to leaf blight, world maize production declined a relatively modest 6 million tons due to increased production in other countries. With the 1971 United States crop estimated at 142 million tons, worldwide maize production may be approaching 300 million tons. While the 1971 bumper crop may have dispelled fears of scarcity for a time, 1970 starkly illustrates the dangers of over-reliance on one geographical region and on a narrow germ plasm base for nearly half of the world supply of one of the three main cereals.

Since maize has encircled the world and is growing in importance as a cereal grain for food, feed, and industrial purposes, even in countries where the existing local varieties are chance introductions, efforts must be increased to ensure that farmers can obtain high-yielding varieties to combine with improving technology in order to maximize return for their labor. CIMMYT's efforts to assist national maize development programs with information and germ plasm, and to provide leadership in fostering international interchange of ideas and breeding materials are being redoubled to meet the increasing world demand for maize.

An integrated, interdisciplinary approach to developing varieties capable of producing high yields over a wide range of environments, and their improvement through recurrent selection procedures has been instituted with staff plant pathologists, entomologists and breeders working together on the same populations. Full- or half-sib families from these populations are grown at three of four locations in México and also by cooperators on other continents.

The International Maize Adaptation Nursery, in full operation with the first year's results most encouraging, provides not only a vehicle for systematically evaluating—globally—advanced materials from all participants, but also (and this is more important) enables participants to identify and obtain elite germ plasm resources for their breeding programs or for direct release. CIMMYT can use these trials to form wide germ plasm base composites with components of proven merit over an extensive range of environments that can well serve countries with sophisticated varietal development programs plus those whose national programs are still in formative stages.

Encouraging advances have been made by countries using materials supplied by CIMMYT. One of the more remarkable examples at the experimental level is that of Egypt where Synthetic La Posta, a Tuxpeño composite from México, was crossed with American Early, a variety widely grown in Egypt. The F_1 hybrid produced 13.7 tons per hectare. This was 54 percent more than the best double cross hybrid produced locally. The F_2 was 20 percent higher yielding than the same double cross hybrid.

India, using primarily material originally supplied from México and Colombia, posted a 30 percent production increase to 7.41 million tons in 1970. The estimate for 1971 production is more than 9 million tons.

In general, tropical varieties have been stigmatized as being too tall, too late, susceptible to lodging, unable to perform well under intensive cultivation and inefficient in converting photosynthesis to grain. However, having been selected under natural conditions where they were generally subject to massive attack by insects and pathogens, their resistance to these pests has drawn attention of maize workers around the world, but their use in breeding programs has been limited to serving as donors for simply inherited traits. Through persistent and painstaking efforts with large original populations, CIMMYT breeders have succeeded in markedly reducing the height and length of growing season of several high-yielding varieties of tropical maize and apparently increasing yield. This should open new vistas for temperate zone maize breeders for utilization of barely tapped sources of germ plasm. Seed of these populations improved through recurrent selection for plant and ear height and yield are available to interested breeders everywhere.

CIMMYT's maize staff seeks the cooperation of maize workers around the world so that the search for new techniques can be made more productive and the application of new discoveries can be more quickly effected so that the increasing world requirements for maize can be successfully fulfilled.

MAIZE GERM PLASM BANK

Inventory, Seed Increase and Distribution

CIMMYT's Maize Germ Plasm Bank was established to preserve the genetic variation in the species *Zea mays* L. for use in corn improvement, genetics and cytogenetics by all interested persons. The Bank contains more than 12,000 accessions from 47 countries, but most are of American origin.

During 1970, the Bank's activities included:

Inventory: A preliminary, computerized inventory involving 6,843 accessions was completed. It includes accession number, population name, racial classification, location, year, crop, plot number in which the seed was produced, method followed in producing the seed, amount of seed, location of the seed containers in the storage rooms and country of origin of the accession.

All seed has been processed, placed in refrigerated storage and included in the inventory.

Seed Renewal and Propagation of New Accessions: Table M1 shows that 1,164 populations were propagated by plant-to-plant crossing during the summer crop at three locations in México. Nearly 200,000 hand pollinations were made.

Six hundred fifty-six of the maize populations propagated were new accessions from areas in northwestern México which had not been adequately sampled in the early 1950's when the original maize collections were made. Data on maturity, ear size and

TABLE M1. Origin and number of maize populations from the germ plasm bank propagated in 1970.

Origin	Tlaltizapán	El Batán	Roque	Total
Central America	51	—	—	51
Caribbean Islands	4	—	—	4
México	604	351	153	1,108
Pakistan	1	—	—	1
Total	660	351	153	1,164

height, endosperm texture and color, tillering and racial classification were collected on these accessions.

Seed Requests: Eighty-eight seed requests involving 3,337 populations were filled and dispatched to 34 countries (Table M2).

TABLE M2. Shipments and maize populations distributed by CIMMYT during the period of this report.

	Number of shipments	Populations
Argentina	3	13
Bolivia	1	1
Brazil	1	80
Canada	1	65
Ceylon	1	8
Chad	1	149
Colombia	2	41
Costa Rica	2	50
Ecuador	1	7
El Salvador	1	1
France	1	6
Greece	1	5
Guadaloupe	1	32
Guinea	1	135
India	4	384
Indonesia	1	24
Ireland	1	65
Korea	1	2
Lebanon	2	26
Madeira	1	1
Malaysia	1	11
México	16	244
Nicaragua	1	1
Panamá	1	32
Perú	1	22
Philippines	1	29
Puerto Rico	1	92
Romania	1	21
Surinam	1	104
Taiwan	3	120
Thailand	2	392
Tonga	2	266
United Arab Republic	3	326
United States of America	26	582
Total	88	3,237

Cooperative Studies of Maize Phylogeny

Despite evidence from disciplines such as biochemistry, morphology, anatomy, cytology, genetics, archeology, palynology, folklore and linguistics, there remain two principal views about the origin of *Zea mays* (cultivated maize). It is clear that it is of Western Hemisphere origin with its center of diversity and origin in México. But it remains an open question whether it was derived directly from its nearest wild relative, *Zea mexicana* (teocintle, from Uto-Aztec *teocintli,* "God's corn"), or from a wild *Zea mays* now extinct and purported to be represented by archeological material about 7,000 years old.

Evidence for the first and earlier hypothesis goes back about 40 to 50 years and is supported by the fact that modern maize and teocintle hybridize, both naturally and experimentally, to give fully fertile offspring in which the 10 chromosomes of the one species pair normally with those of the other and show normal genetic crossing over in the regions tested.

The second hypothesis is based largely on archeological evidence of small-eared maize plants believed to be wild ancestors on the basis of 80,000-year-old pollen judged by some to be corn pollen, not teocintle; and on the view that teocintle is a relatively recent secondary species derived from naturally occurring hybrids between the postulated wild corn and a member of a third species of the genus *Tripsacum.*

A reexamination of the evidence on the origin of maize was undertaken in 1969 by Dr. George W. Beadle, President Emeritus of the University of Chicago. CIMMYT has provided field facilities for his work.

To get a better understanding of the genetic differences between teocintle and maize, the frequency of recovery of parental types in the second generation and backcross progeny of hybrids between them was determined. To minimize these differences, the most maize-like teocintle was chosen as one parent and the most teocintle-like primitive maize as the other parent. Chalco teocintle, clearly teocintle taxonomically, was chosen as one parent and Chapalote maize, judged to be one of the ancient indigenous Mexican races, was the other.

Of this cross, about 15,000 F_2 plants and 512 backcrosses to teocintle were grown and classified at El Batán, México during the 1970 season.

With *n* independently segregating units, one expects $(1/4)^n$ plants of each parental type in F_2 and $(1/2)^n$ in backcrosses. Although there can be some difference of opinion as to what constitutes good parental types, the data indicate three to five independently segregating units.

Tests of representative parental types, as to whether they breed true, have now been made in a subsequent generation and indicate that the estimated number of independently segregating units is five to eight. Making a reasonable assumption for genetic linkage, the estimate of genetic units would of course be somewhat increased. The results are not inconsistent with those of Mangelsdorf and Reeves based on backcrosses of hybrids to maize.

BREEDING PROGRAM

Developing improved plant materials is the principal objective of CIMMYT's maize breeding program. Part of the work is done on the four experimental stations operated by CIMMYT in México plus two other stations in México in cooperation with the National Agricultural Research Program, and part in cooperation with regional and national programs around the world. The many diverse climates and soils encountered with the rigorous conditions of pests and pathogens found throughout the world necessitate a broad approach. Obviously, not all the varietal improvement work can be done at two or three experiment stations, but must be done where conditions are appropriate for attacking specific problems.

The search for desirable attributes must be continued. Man's need for more and better quality food is well known. In recent years, the quality differences associated with the genetic mutants opaque-2 and floury-2 have stimulated much effort in the field of cereal crop quality. Quality protein investigations constitute a major part of the CIMMYT breeding work in México. In a similar way, other attributes that are important in achieving high-yielding, broadly adapted varieties must be identified. A series of systematic trials are being organized to locate valuable traits of resistances to diseases and pests and to assess dependability of performance in varying environments. Such trials (IMAN, IOMT, etc.) should provide valuable information for breeders everywhere.

As desirable characteristics are cataloged, they must be incorporated into new varieties if they are to contribute to more efficient production of maize. Appropriate genetic procedures must be utilized to combine the new traits into new varieties. Downy mildews attacking maize in Southeast Asia represent a serious threat to production and must be controlled. Sources of resistance must be found and incorporated into varieties for this area.

Production management practices must be considered an important concern in the breeding program. As the need for increased production becomes more urgent, the varieties under development must respond favorably to more intensive production practices of fertilization and plant density per unit of land area. Lodging at high density becomes a serious problem as do diseases and insect pests in the changed microclimate of a dense plant canopy.

Developing Short, Disease- and Insect-Resistant, Agronomically Desirable Populations

Most corn varieties in the tropics tend to grow very tall. This results in serious lodging problems. Most selection schemes to increase yields have produced still taller plants and tended toward later maturing types. These taller and later plants complicate an already serious problem in intensifying management practices with increased fertilizer rates and higher plant densities. A major effort has been made at CIMMYT to produce shorter maize types.

Three separate approaches have been used in attempts to reduce plant height: (1) use of genetic dwarfs; (2) crosses of short types with tall ones, recovering short recombinations in segregating generations and backcrossing to the tall recurrent type; and (3) continuous full-sib recurrent selection within tall types. All three approaches produce shorter plants. The genetic dwarfs provide the most immediate, spectacular contrast in plant height, but it is not yet clear which approach is best for the long term. It appears that selection within the tall materials in a recurrent procedure may be most desirable. The resulting shortened populations are dramatically shorter in height, slightly earlier in maturity and apparently have improved yields, even when tested at conventional plant densities. Their potential under increased planting densities and higher fertilizers rates are being studied.

Several populations are now under selection for shorter plant type using the same procedure. Progress appears rapid in all materials.

Tall varieties that lodged severely are examined by Dr. Charles Francis at the International Center for Tropical Agriculture (CIAT) in Colombia. Short varieties in the background show superior standability.

Flints and dents of both yellow and white endosperm colors are being reduced in height. The height reduction appears to be purely additive in nature.

The apparent yield improvement may be only a more complete recovery of the grain produced compared to the greater losses associated with lodging in the taller original materials. The agronomic differences between the original and the selected materials are striking.

All yields shown in the tables were affected by unfavorable moisture conditions and are lower than normal for this growing cycle at this station. The brachytic-2 results indicate, however, that apparently satisfactory yields can be obtained with the dwarf as compared to normal types. The brachytic-2 Family 4 yields about twice the average of the variety. Also, widely different plant heights can be obtained with the brachytic-2 dwarf gene and extreme variation exists for lodging reaction and days to flower. Such differences provide the base for selection to meet diverse conditions.

TABLE M3. Agronomic characters and yield performance of the original and last cycle of selection for short plant on three tropical corn populations (Poza Rica, 1971A).

Population	Cycle of selection	Days to flower	Height (meters)		Lodging[1]		Yield[2]
			Plant	Ear	Root	Stalk	
Tuxp. Cr. 1	C_0	84	3.00	1.59	3.9	2.0	4434.9
Tux. Cr. 1 Select. Planta Baja	C_7	75	2.43	1.08	1.6	1.3	4989.1
Eto Bl.	C_0	77	2.70	1.21	2.6	1.8	4097.8
Eto Bl. Selec. Planta baja	C_6	72	2.11	0.88	2.0	1.6	4391.3
Mix. 1 x Col. Gpo. 1) x Eto Bl.	C_0	78	2.84	1.38	2.5	1.9	4478.3
Mix. 1 x Col. Gpo. 1) x Eto Bl. Pl. baja	C_4	73	2.16	0.96	1.3	1.3	5065.2
H-507 (check)		82	2.66	1.33	3.1	1.6	5163.0

[1] Scale 1 to 5, 1 = 0.0% lodging, 5 = 100% lodging.
[2] Kilograms per hectare of grain with 15% moisture.

Crosses of the short plants by tall plants results in intermediate F_1 heights. Variability for height is obviously still great after eight cycles of selection. Continued selection will determine how much more height can be reduced.

Another phase involves developing contrasting types of plant architecture as related to leaf size and angle on both tall and short plants. Erect leaf position has been proposed to increase light penetration into plant canopies with the presumed result being increased production per unit of land area. Results reported are not convincing. Use of the liguleless mutants to produce erect leaf types at CIMMYT resulted in problems of poor brace root development and adverse effects on pollen shedding. Erect leaf materials have been developed without using specific mutants and are currently being tested. Preliminary observations indicate that plants with erect leaves tend to be somewhat taller and later in maturity than plants with more horizontal leaves. Tassel branches and ear position appear highly correlated with leaf angle and tend to be erect, also. It remains to be demonstrated that significantly better grain production is possible through modification of leaf angle.

As plant height is reduced, the leaves tend to become more closely packed together and form a very dense canopy. Attempts to reduce the number of leaves per plant and to produce genotypes with narrower leaves are under way to alleviate crowding in the canopy. Reduced leaf size and number is a factor in the efficiency of the plant in producing grain. If a greater percentage of the total photosynthetic product can be recovered as grain, it should be possible to achieve sizable advances in grain yields.

Grain yields in tropical areas are greatly affected by not only the relationships of light, temperature and moisture, but also by losses attributable to diseases and insects. Much more attention must be given to pest resistance than in temperate areas where cold winters interrupt life cycles and reduce inoculum for the next crop cycle. A major effort is required to incorporate adequate levels of pest resistance into maize varieties for tropical areas. Developing broad-based germ plasm pools with good pest resistance has a high priority in CIMMYT's breeding work. Preference is given to the use of broad, general forms of resistance involving many genes rather than to the isolation of single gene types of resistance. As part of this concept, during the development of varieties, progenies are grown in as many different environments as is practical. Results from trials in several countries are considered during selection. For example, the short plant selections in Tuxpeño (Tuxpeño Crema I, Plant Baja) are being grown at two or three locations in México and in several countries of Central America.

In the same way, family selection is being carried out in Eto Blanco, Mix 1 x Col. Gpo. 1, a yellow flint composite, a yellow dent composite and brachytic-2 pools. In the CIMMYT breeding nursery, only a few plants of each entry are protected with insecticide treatment. When possible, stalks are inoculated with stalk rots and ear silks are sprayed with ear rots. Recurrent selection is used for resistance to insects, stalk rots and ear rots. This plan should gradually develop superior levels of resistance as quantitative traits characteristic

TABLE M4. Yield and agronomic traits of selected families from a brachytic-2 variety (Poza Rica, 1971 A).

Material	Days to flower	Height (meters)		Lodging[1]		Yield[2]
		Plant	Ear	Root	Stalk	
Family 1	87	2.11	1.03	3.1	1.0	4185
Family 2	77	1.99	0.89	1.6	1.1	4196
Family 3	83	2.50	1.23	3.3	1.5	4478
Family 4	84	2.43	1.12	3.6	1.1	5239
Parent variety br_2	79	1.74	0.66	1.6	1.3	3783

[1] Scale 1 to 5, 1 = 0.0% lodging, 5 = 100% lodging.
[2] Kilograms per hectare at 15% moisture.

TABLE M5. Locations for progeny tests in the development of CIMMYT's selected pools, 1971.

Material	Locations of progeny evaluations
Trial 509 Short Plant Tuxpeño	México,* Colombia, Nicaragua and El Salvador
Trial 512 White br_2	México,** Colombia and Guatemala
Trial 513 White br_2	México,** Colombia and Nicaragua
Trial 514 White flint br_2	México,** Colombia, Perú and Panamá
Trial 515 Yellow br_2	México,** Colombia and El Salvador

* 3 locations in México.
** 2 locations in México.

This segregating population has both opaque-2 and brachytic-2 dwarf genes.

of the populations rather than isolate inbred lines. Such pools should be useful in many breeding programs over wide areas of the tropics. Progeny testing in several countries is an integral part of the selection procedure.

Additional populations in early stages of formation are for subtropical conditions and for the higher mountain regions within tropical latitudes. One pool involves a series of varieties from each of the Andean Zone countries of Bolivia, Perú, Ecuador, and Colombia plus some germ plasm from México. The other pool includes corns from Argentina, México, the Caribbean and United States. These will be used as long-term bases for developing wide adaptation. By gradually combining the characteristics that have given adaptation to the corns from these different areas, it should be possible to produce varieties with much greater areas of adaptation than any one of the collection going into the pool.

The pool of materials from the Andean Zone of South America includes many individual, locally adapted varieties from selection under specific microclimatic conditions. Most of these have rather large, floury endosperm kernels. They vary widely in color of endosperm and in reaction to diseases—particularly *Helminthosporium turcicum* and *Puccinia sorghi.* A systematic recombination of the different disease resistances should help extend the area of adaptation of this pool of germ plasm. Also, the entries represent latitudes from 20 degrees south of the equator to 20 degrees north of the equator and should vary somewhat in day-length reaction. By growing the pool in several countries and selecting from it over an extended period of years, a valuable resource population should result for the use of breeders in higher elevations of the tropics around the world.

Interchange of breeding materials with regional and national programs is an important part of the breeding work. Regular uniform trials are prepared and distributed as part of the Central American Cooperative Food Crops Program. Varieties from the area—from both private and public sources—are assembled into uniform trials and distributed to cooperators. While most of these trials are planted in Central America, others are sent to Asia, Africa, South America and other areas. Hopefully, linkages and interchanges among the several regional programs of Central America, the Andean Zone, Inter-Asian Corn Program, West Africa, southern South America, and others can be expanded and improved. These interchanges supplement in more detail (by region) the data obtained from the more widely distributed IMAN trials. (See listing of trials.)

Protein Quality

The discovery that major nutritional differences exist in maize associated with the genetic mutants opaque-2 and floury-2 has resulted in the proliferation of efforts to exploit these and to determine whether other similar differences may exist. The original high hopes for use of the opaque gene in human nutrition have not yet been realized because of several difficulties. The investigation of the development of high quality protein maize together with the resolution of the problems surrounding its potential commercial use are the focus of the work at CIMMYT.

Production of opaque-2 maize involves the same agronomic requirements of satisfactory yield and reasonable resistance to pests and diseases as does normal maize. Ear rots, lower yield and unattractive appearance have generally been associated with the opaque-2 mutant. Attempts to understand and overcome these problems constitute the CIMMYT effort in breeding for high-protein-quality maize grain. As part of this work, the developing materials selected for resistance to pests and for better agronomic traits are converted to opaque simultaneously.

In addition to the agronomic traits are more specific problems of protein levels, relative content of lysine and tryptophan, and grain appearance for acceptance by producers and consumers. The dull, soft, unattractive appearance of the opaque-2 kernels is the subject of work in progress. Genetic modifying factors have been encountered that enable breeders to change the appearance of opaque-2 grain. By properly recombining these modifying factors, much harder endosperm types are being recovered that retain the high levels of lysine and tryptophan characterizing opaque-2 maize. Feeding trials with laboratory animals are being initiated in order to determine whether the same high biologic value is also carried by the harder endosperm types. Laboratory chemical analyses must be confirmed by corresponding results in animal feeding trials.

Detailed examinations are being made of kernel size, kernel density, visual appearance, relative protein content and other attributes. The range of germ plasm being utilized in the development of the high-quality protein varieties is shown in Table M6.

Table M7 gives an example of the relationships among different levels of protein and tryptophan in Composite K.

Table M8 shows the range in levels of tryptophan and protein in three different composites.

Variations in the weight of 100 kernels of opaque as compared to their normal counterparts are given in Table M9.

Comparison of protein levels and percent tryptophan in the dull opaque kernels and their hard-endosperm modified equivalent are shown in Table M10.

Table M11 lists an analysis of the relative contribution of the germ and the endosperm in both normal and opaque-2 maize. Obviously, the development of high-quality protein grain is a complex task. The development of these superior quality types must be carried on simultaneously with agronomic improvement in order to have both high-quality protein and excellent production capacity.

TABLE M6. Development of high-quality protein composites.

S. No.	Name of composite	Cycle of synthesis	No. of items or races	Type of materials
1	Composite K	3	6	Tuxpeño, Cuban flints, Antigua 2D, Salvadoreño, West Indies semident, Eto Blanco.
2	Composite J	2	2	Puebla gpo. I and Celaya Comp.
3	Composite I	2	4	Mexico gpo. 10, Hidalgo 8, Pinto Salvatori, Puebla gpo. I.
4	Thai Opaque-2 Composite	2	8	Cuban flints, Caribbean Composites, Ant. 2D, Flint Compuesto amarillo, Four 'CM' lines from India.
5	Thai Floury-2 Composite	2	8	Cuban flints, Caribbean Composites, Ant. 2D, Flint Compuesto amarillo, Four 'CM' lines from India.
6	CIMMYT	1	56	Mexico (27), Pakistan (2), Nigeria (2), Brazil (4), Colombia (6), Thailand (5), Philippines (1), Venezuela (7), Ghana (1), Nicaragua (6)
7	CIMMYT Floury-2 Comp. # 1	1	22	Mexico (17), Philippines (2), Thailand (1), Brazil (2).

TABLE M7. Frequency distribution of harvest ears from composite K(C_2) for percent protein and percent tryptophan in protein.

% protein	Frequency						Total
	0.60-0.70% tryptophan	0.70-0.80% tryptophan	0.80-0.90% tryptophan	0.90-1.00% tryptophan	1.00-1.10% tryptophan	Above 1.10% tryptophan	
5.0-6.0	—	—	—	1	2	6	9
6.0-7.0	—	1	9	21	22	23	76
7.0-8.0	1	7	27	28	53	24	140
8.0-9.0	2	12	47	59	44	5	169
9.0-10.0	2	13	31	17	3	—	66
10.0-11.0	—	3	2	—	1	—	6
Total	5	36	116	126	125	58	466

TABLE M8. Range in protein and tryptophan values of harvested ears from quality protein populations.

S. No.	Population	Cycle of synthesis	No. of harvested ears	Range	
				% protein	% tryptophan in protein
1	Composite I	Second	494	4.50-15:38	0.57-1.78
2	Composite K	Third	384	5.50-13:13	0.55-1.29
3	Composite J	Second	322	4.88-13:30	0.50-1.35

CIMMYT trainees visually sort genetic mutant opaque-2 kernels. Breeding for protein quality improvement is done simultaneously with breeding for agronomic improvement.

TABLE M9. One hundred-grain weight comparison of normal and opaque-2 kernels.

Pedigree	100-grain weight (grams)	
	Normal	Opaques
J_1	23.0	21.0
Syn. 493	25.5	23.5
Sn. Luis Potosí Gpo. 1	31.0	29.0
Tamaulipas Gpo. 1	26.5	24.5
Cuba 11J	26.0	23.5
Puerto Rico Gpo. 1 (E)C_1	21.5	23.0
Colombia Cateto Compuesto	27.0	25.0
Perola Piracicaba	26.0	24.0
Comp. II (C_3)	26.0	24.0
Comp. III (C_3)	27.0	26.0
Comp. (IV)	29.0	28.0
Mex. 5	25.0	23.0
Samaru Comp. III	25.0	24.0
Comp. Grano duro	26.0	26.0
Mix. 1-Col. Gpo. 1 x Eto Blanco	24.0	22.0
Tuxp'. PD(MS)6-Sel. Amar.	27.0	25.0

TABLE M10. Comparison of percent protein and percent tryptophan in protein of opaque-2 and modified opaque-2 kernels.

Ear No.	% protein		% tryptophan in protein	
	Opaque	Modified	Opaque	Modified
69	9.00	9.75	0.84	0.66
79	9.19	10.63	0.89	0.66
125	7.63	10.19	1.05	0.74
147	8.25	9.00	1.09	0.91
151	7.75	8.13	0.90	0.87
159	6.44	7.25	0.98	0.87
162	9.19	9.75	0.97	0.82
164	8.88	9.38	0.72	0.69
196	8.50	9.25	1.01	0.90
250	9.13	12.88	0.72	0.53
279	8.38	11.38	0.93	0.73
292	11.25	11.50	0.63	0.60
297	9.13	9.38	0.78	0.70
63	9.88	9.75	0.89	0.86
67	9.13	8.94	0.82	0.80
175	8.38	8.25	0.80	0.79
278	8.50	8.31	0.88	0.84
144	7.00	7.56	0.96	0.99

TABLE M11. Contribution of the germ to the total grain protein and to the percent tryptophan in protein in normal versus high-quality protein maize.

Group	% protein		% tryptophan		% tryptophan in protein	
	Whole grain	Endosperm	Whole grain	Endosperm	Whole grain	Endosperm
Low protein group						
Normal	8.9	7.7	.061	.036	.67	.47
Opaque	9.2	5.9	.100	.067	1.10	1.15
Medium protein group						
Normal	11.3	10.0	.074	.046	.66	.46
Opaque	11.1	8.4	.113	.181	1.02	.96
High protein group						
Normal	13.3	12.2	.080	.047	.60	.39
Opaque	12.8	10.4	.126	.089	.99	.86

AGRONOMY-PHYSIOLOGY

CIMMYT is concerned with the development of high-yielding, widely adapted maize varieties, particularly varieties which will meet the needs of the developing countries. Many of these countries are in the tropics where yields per crop sown are much lower than in temperate latitudes.

As part of CIMMYT's maize improvement program, a new series of agronomy-physiology field trials was begun in January 1971. These trials are divided into two main parts.

Dry Matter Production and Grain Yield

In the first part the objective is to provide plant breeders with quantitive information on the physiological factors which determine grain yield in tropical maize and to indicate the most probable ways in which factors currently limiting yield can be overcome. To implement this part of the program, trials have been started at each of the main CIMMYT maize experiment stations in México—El Batán, Tlaltizapán and Poza Rica—to examine the rates of dry weight production of different tropical maize materials and the patterns of distribution of dry weight between the grain and other parts of the plant.

The field trials provide a range of populations from 25,000 to 250,000 plants per hectare and include 10 tropical materials from the breeding program selected to represent a range from the shortest and earliest to the tallest and latest materials.

At this stage the objective is to determine whether, in a given radiation climate, yield is limited by the seasonal variation in crop growth rate and the capacity of the canopy to produce dry weight, or whether it is limited by the distribution of dry weight and the capacity of the grains to accept the assimilate produced.

Preliminary results indicate that the crop growth rates and the total dry weight produced by many of the tropical materials is large. For example, at 100,000 plants per hectare, Tuxpeño (a tall tropical variety) produced a total dry weight of 2,500 grams per square meter in 113 days. Of this, 450 grams was grain.

From the results of these and related trials, we expect to be able to provide information that will help determine which materials presently used in the plant breeding program offer the greatest potential for making the necessary yield breakthrough in the tropics. For example, the new short plant selections and the stem rot-resistant materials are the most likely to reward further selection and breeding effort. Also, we seek selection criteria offering the best opportunity for making rapid progress.

Materials which do not perform well when they are managed intensively (for example, Antigua Group 2, which lodges badly, and the tall, late tropical materials which put so much of their dry weight into the stem) will be discarded from these trials and replaced by the most promising new materials coming from the breeding program.

Phenology Studies

Since varieties selected and developed by CIMMYT staff on resident research stations are distributed to many parts of the world, the second part of the agronomy-physiology studies is concerned with providing quantitative information on the response of maize to changes in temperature and daylength. This involves monthly sowings throughout the year at our main experiment sites in México and at sites to the north and south in cooperation with Dr. Paul Crane at Purdue University and Dr. Charles A. Francis at CIAT in Colombia. The same 10 varieties are included in these trials as in the plant population and yield trials, with the addition of entries from our cooperators. Observations are being made to determine how seasonal variations in time from sowing to initiation of the terminal inflorescence and in rate of appearance of leaves affects the length of time from sowing to flowering.

CIMMYT's three experimental sites are at almost the same latitude and the seasonal

Corn plants separated into component parts allows green and dry weight measurements for crop growth comparisons among varieties and treatments.

TABLE M12. The altitude, latitude and longitude of CIMMYT's three experiment sites in Mexico.

Site	Altitude (meters)	Latitude	Longitude
El Batán	2,249	19° 31′ N	98° 50′ W
Tlaltizapán	940	18° 41′ N	99° 08′ W
Poza Rica	60	20° 29′ N	97° 45′ W

variation in daylength is similar at the three stations, but because of the large differences in altitude, the seasonal variations in temperature are different.

Preliminary results from the first six months of these trials indicate that within the range of environments at these three locations, the terminal inflorescence is initiated in as little as 15 days after sowing in early materials such as China I and Zapalote Chico. In late varieties such as Cortezar and Tuxpeño, initiation can take up to 59 days and by extending daylength artificially, this was increased to 72 days at El Batán.

For a given variety, the effect of differences in time to initiation on the number of leaves formed was small. However, the average rate of appearance of leaves varied from one every two days to one every four days, depending on variations in temperature with season and site.

Studies of characteristics of moisture loss from grain of different varieties and from grain of different classes are underway. The principal contrasts included flint versus dent grain and opaque versus normal. Initial results suggest that the differences in moisture content and rate of moisture loss are smaller than expected.

These studies are of special significance in relation to CIMMYT's program for developing high-yielding opaque maize and the associated problems of the susceptibility of opaque grain to insect and fungal damage in the field.

PLANT PROTECTION

Developing Insect and Disease Resistance

The maize entomology and pathology programs of CIMMYT have been integrated since 1970 into a Maize Plant Protection section. The aim is to become fully integrated with the overall breeding effort in order to incorporate field levels of resistance to the most widespread, economically important insect and maize pathogen complexes and in the development of widely adapted and improved germ plasm pools.

During previous selection cycles in searching for resistant sources, efforts were directed towards the identification of specific sources tolerant or resistant to the maize whorlworm* *(Spodoptera frugiperda),* the earworm *(Heliothis zea),* stem borers *(Diatraea saccharalis, Zeadiatraea lineolata* and *Zeadiatrea grandiosella)* and thrips *(Frankliniella occidentalis* and *F. williamsi).* With regard to pathogens, emphasis was on ear rots *(Diplodia maydis* and *D. macrospora),* stalk rots *(Macrophomina phaseoli, Fusarium moniliforme* and *Cephalosporium acremonium)* and stunt disease. Also, in the evaluation of the maize germ plasm other important pests and pathogens *(Diabrotica* spp., *Helminthosporium* spp., *Sclerospora sorghi)* were and are being considered in the attempt to select resistant sources. The insect species listed are of economic importance from the southern United States to Argentina whereas the plant pathogens mentioned (except stunt) have a worldwide distribution. A written survey during 1969-1970 revealed that similar pathogen and insect complexes as those mentioned above contribute to yield instability in Asia and Africa.

The work initiated at Tepalcingo, México in 1967 and followed in five other contrasting environments since 1968 utilizing germ plasm from Brazil, the Caribbean region, Central America, Colombia, México and the United States, revealed that, as a whole, the Caribbean materials were the least injured by the insect and pathogen complexes already mentioned.

Recognizing the widespread use and adaptation of Caribbean germ plasm and its insect and pathogen tolerance, in 1969 it was deemed appropriate to initiate the recombination under isolation of about 166 Caribbean entries in CIMMYT's Germ Plasm Bank. At the end of 1970, this germ plasm complex (designated Caribbean Composite) had been advanced to the third cycle of random mating and is available to interested parties. During the third cycle of recombination, 3,500 S_1 lines were generated to be utilized in screening for insect and pathogen resistance. Using these lines as main sources, the following materials have been developed.

1. With the widely adapted, foliar disease-, stalk rot- and maize whorlworm-tolerant lines selected at Pergamino, Argentina, Farm Suan,

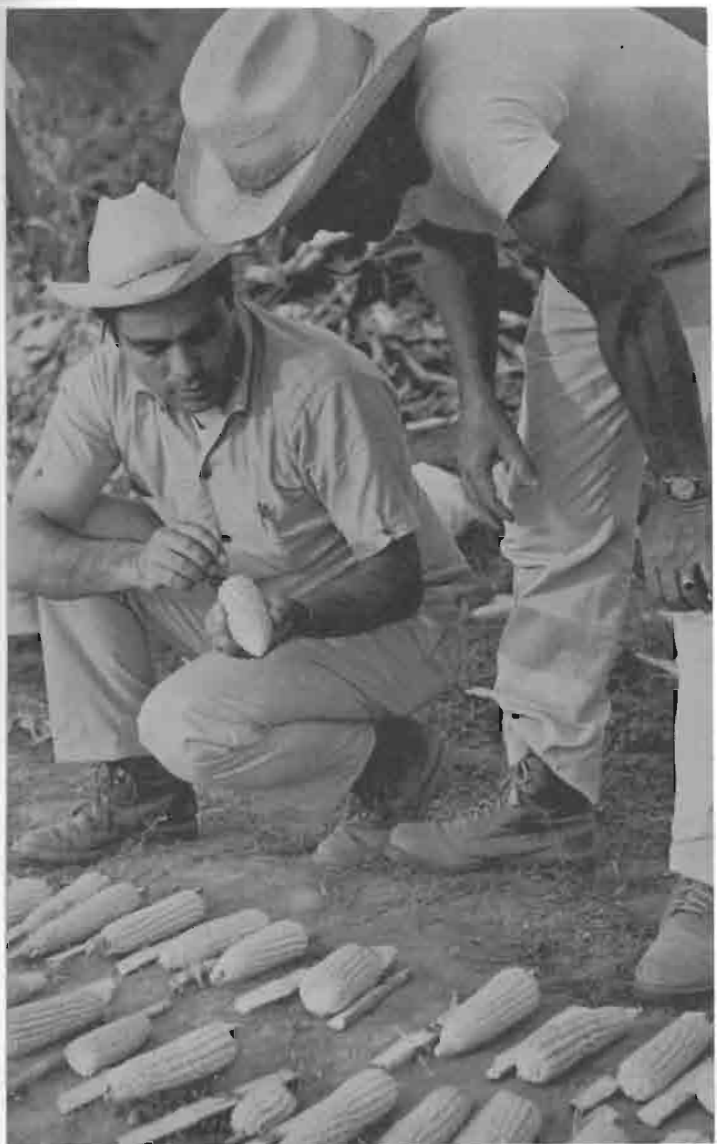
* CIMMYT entomologists have proposed changing "Fall armyworm" to the more descriptive "maize whorlworm."

Thailand, New Delhi, India, and Tlaltizapán and Poza Rica, México, a synthetic is being developed.

2. A composite resistant to stalk rots is being developed. All 3,500 lines were reevaluated for maize whorlworm reaction after tasseling, following the toothpick inoculation technique. Toothpicks contained three stalk rotting organisms: *Macrophomina phaseoli, Fusarium moniliforme* and *Cephalosporium acremonium.*

Several self-pollinations were made within each one of the selected S_1's. Approximately 546 ears (from 216 S_1's) were selected from resistant plants. In early 1971, the S_2's were planted in isolation using the modified ear-to-row method in which the female rows were each one of the selected S_2's and the male rows were a balanced mechanical mixture of the female entries. All female rows were artificially inoculated as previously described

Selecting for ear rot and stalk rot resistance.



and evaluated and 216 were selected at harvest time. These will be evaluated for general adaptation and disease-insect reaction under artificial inoculation and infestation.

Using Caribbean and other germ plasm to select sources of resistance, other materials developed with field levels of resistance are:

3. A composite and a synthetic resistant to corn stunt. Using the stunt resistant Cuba x Dominican Republic Composite, several hundred S_1 lines were developed in 1967. The Composite has been improved for yield and resistance during five cycles of selection and recombination. At the present time, the composite has been turned over to the breeding program for increase and distribution. In previous cycles, the S_1's were artificially inoculated in the greenhouse at the seedling stage by infectious leaf hoppers *(Dalbulus maidis* (DeL. and W.), transplanted to the field, evaluated and selected. The 36 most resistant S_1's were selected and remnant seed was planted under isolation using the modified ear-to-row method. Female rows included all resistant S_1's (detasseled) and male rows were a balanced mechanical mixture of the female entries.

Resistant S_1's were self-pollinated and progenies again inoculated as described. This selection and inoculation was continued until uniform, highly resistant S_4 lines were obtained. These resistant lines have been crossed with highly susceptible resistant ones and backcrosses obtained for studying the mode of inheritance of resistance.

4. A composite resistant to *Diplodia* ear rot has also been developed. From previous cycles, 65 highly resistant S_1 lines were obtained from Caribbean, Central American and Mexican germ plasm. These lines were selected after pollination and artificial inoculation of ears using heavy spore suspensions of the fungi *Diplodia maydis* and *D. macropora.* Selected lines were planted using the modified ear-to-row method where female rows (detasseled) were from each one of the resistant ears and a balanced mixture of these were used in the male rows. Ears were again artificially inoculated in the female rows and selection for plant type was carried out both in the male and female rows. This procedure has been continued for five cycles and selections made within the female rows were planted in three locations in order to measure general adaptation and other characters. Of 653 selected ears, only 145 were selected as high yielding and with widely adapted progenies. Remnant seed will be planted and selected on

the basis of wide adaptation and resistance to insects and other diseases under artificial inoculations and infestations.

5. A thrips-resistant synthetic (see page 43, CIMMYT's 1968-69 Annual Report) has been selected and advanced to a third cycle by modified mass selection.

6. In addition, the following entries have been consistently less infested by stem borers *(Diatraea* and *Zeadiatraea):* Antigua Groups 1 and 2, Antigua Group 2 white selection, Nuevo Leon Group 2, Zapalote Chico, Guadalupe Group 1A, Martinique Group 1, Puerto Rico Groups 1 and 2, Barbados Group 1, Republica Dominicana Groups 2 and 7, Haiti Group 3, Costa Rica Group 6A and Tuxpantigua. These resistant or tolerant material have been made available to maize programs in Brazil, Egypt, Argentina, Colombia, Bolivia, Central America and the United States. Approximately 2,700 full-sibs were generated by making crosses among the tolerant or resistant materials indicated above. This is an attempt to incorporate into one population as many factors of resistance as possible. Since conventional methods of selection deal only with one insect or pathogen, these procedures will receive less attention. Rather, selection against several traits simultaneously has been initiated in progenies like those described above as well as in the elite populations and germ plasm complexes developed at CIMMYT.

Thus, 1970 marked the initiation of an attempt to use the available genetic variability present in maize to develop widely adapted populations (yield stability for seasons and locations with economic levels of field resistance to the major insects and pathogens) by generating 4,000 S_1 lines from the World Composite during the third cycle of recombination.

One thousand lines (generated at Poza Rica, Cotaxtla, Tlaltizapán and El Batán) plus 300 open-pollinated entries (from Tlaltizapán) were finally selected for their healthiness. These materials were evaluated during 1971 in the environments shown in Table M13. Simultaneously, a crossing block was established at Tlaltizapán from which 140 entries were selected on the basis of their good performance in the seven environments previously indicated. A new cycle of selection will be initiated with such entries. In addition, subsamples of the World Composite are being selected and advanced under isolation to the fourth cycle of recombination in the same environments. These subsamples will provide genetic variability when it becomes necessary.

Normal-to-heavy insecticide protection is given against field pests in most maize improvement programs throughout the world, reducing the possibility of discarding insect susceptible materials. In our overall population improvement program, selection is being conducted by planting each entry in paired rows (lengthwise or sidewise). One row receives no protection and is used in evaluating

TABLE M13. Climates, localities and their insect-disease complexes where the Plant Protection Program is in operation.

Environment	Locality	Degrees latitude	Meters above sea level	Insects and diseases*
Humid, hot.	Poza Rica, Ver. (México)	21	60	Stem borers, maize whorlworm, earworm, diabrotica, leaf blights, stunt, rust, downy mildew, stalk rots, ear rots.
Dry with hot and cool seasons. Irrigation available.	Obregón, Son. (México)	27	39	Stem borers, maize whorlworm, earworm, stunt, stalk rots, ear rots.
Subhumid with hot and cool season. Irrigation available.	Río Bravo, Tamps. (México)	26	30	Stem borers, maize whorlworm, earworm, stunt, stalk rots, ear rots, downy mildew.
Humid with definite wet and dry seasons. Warm.	Tlaltizapán, Mor. (México)	19	940	Stem borers, maize whorlworm, earworm, thrips, diabrotica, stunt, stalk rots, ear rots.
Humid with winter dry season. Temperate.	Toluca, Méx. (México)	19	2,640	Aphids, stalk rots, ear rots, rust.
Subhumid, with winter dry season. Temperate.	El Batán, Méx. (México)	19	2,249	Earworm, aphids, stunt, stalk rots, ear rots, rust, leaf blights.
Humid, continental, severe winter. Temperate.	Ithaca, N.Y. (U.S.A.)	42	300	European corn borer, diabrotica, aphids, stalk rots, ear rots.

* For scientific names, see text.

its reaction to insects pests under natural and/or artificial infestation. The other row is protected with a *granular insecticide* and used for artificial pathogen inoculation.

Studies of Chemical Insect Control

Chemical control of maize insect pests will continue to be a necessity. Ecological selectivity of insect control by chemicals has been stressed with the use of granular formulations.

During 1970, trials were conducted in tropical and subtropical environments in the wet and dry seasons to determine possible differences in effectivess against the maize whorlworm and stem borers between granular and sprayed formulations, and to estimate the efficiency of 3 to 5 treatments at 7- and 14-day intervals simultaneously evaluating two relatively new compounds against the two major pests mentioned above.

Relative effectiveness in the three trials was estimated by determining the percentage of plants damaged by the maize whorlworm, the number of stem borer injured internodes and yield. Tables M14, M15 and M16 present results from these tests.

The tests to evaluate performance between formulations (Table M14) revealed that in Tlaltizapán the granular materials were significantly more effective in most instances than the same insecticides applied as sprays against both the maize whorlworm and stem borer. In Poza Rica, a higher rainfall area, the differences were not significant. Overall perfor-

TABLE M14. Relative effectiveness of sprays and granules for control of the maize whorlworm, Spodoptera frugiperda and stem borers, Diatraea saccharalis and Zeadiatraea lineolata in Poza Rica, and S. frugiperda and Z. grandiosella in Tlaltizapán, México, 1970.

Insecticide	Formulation	Active ingredient (gm/ha per application)	% whorlworm damaged plants (weeks after one application) 1	2	3	Stem borer damaged internodes at harvest after two applications		Field weight tons/ha
			TLALTIZAPAN: SUBTROPICAL ENVIRONMENT, RAINY SEASON*					
			Differences between insecticides					
Telodrin	——	120	12a	22a	13a	14a	39a	3.9a
Sevin	——	250	26b	34b	21b	15a	46a	4.1a
			Differences between formulations					
——	Granules	——	4a	21a	17a	12a	31a	4.2a
——	Spray	——	22b	34b	16a	14ab	43b	4.0a
——	Check	——	31c	29ab	16a	18b	55c	3.9a
			Differences between formulations for the same insecticide					
Telodrin 1.5%	Granules	120	1a	13a	8a	10a	17a	4.2a
Telodrin 15%	Spray	120	10b	28b	14a	14ab	41a	4.0a
——	Check	——	25b	25ab	17a	19b	55c	3.8a
Sevin 2.5%	Granules	250	7a	29a	26a	14a	46a	4.2a
Sevin 80%	Spray	250	33a	41a	16a	15a	45a	4.1a
——	Check	——	37b	34a	19a	17a	55a	4.1a
			POZA RICA: TROPICAL ENVIRONMENT, RAINY SEASON					
			Differences between insecticides					
Telodrin	——	120	5a	15a	26a	30a		6.6a
Sevin	——	250	12a	20a	25a	51b		7.5a
			Differences between formulations					
——	Granules	——	7a	18a	26a	39a		6.9a
——	Spray	——	11a	17a	25a	42a		6.9a
——	Check	——	63b	44b	34a	57b		6.4a
			Differences between formulations for the same insecticide					
Telodrin 1.5%	Granules	120	4a	11a	22a	30a		6.6a
Telodrin 15%	Spray	120	7a	18a	30a	29a		6.6a
——	Check	——	69b	50b	37a	52b		5.9a
Sevin 2.5%	Granules	250	8a	25ab	30a	48a		7.5a
Sevin 80%	Spray	250	16a	15a	20a	54ab		7.3a
——	Check	——	57b	38b	31a	60b		6.9a

* Data presented is the average of four replicates. Any two means not followed by the same letter are significantly different at the 5% level. Stem borer estimations from 30 plants/plot at Tlaltizapán and 16 plants/plot at Poza Rica.

TABLE M15. Effectiveness of different number of applications of several insecticides in granular formulation when applied to corn at different intervals to protect against the stem borers Diatraea saccharalis and Zeadiatraea lineolata at Poza Rica, México, 1970 (tropical environment, rainy season).

Insecticide	Active ingredient (gm/ha per application)	Number of applications	Number of days between applications	Average stem borer injured internodes in 24 plants/ha at harvest	Yield tons/ha
		Differences between insecticides			
Birlane 2%	160			61b	4.9b
Telodrin 1.5%	120			73ab	4.4b
Citrolane 2%	160			85a	5.8a
		Differences between number of applications			
		3	7	83a	4.8b
		4	7	78ab	4.9b
		5	7	68bc	5.5a
		3	15	73abc	5.1ab
		4	15	63c	4.9b
	Differences between number of applications for the same insecticide				
Birlane 2%	160	3	7	85a	4.5b
	160	4	7	63ab	5.1ab
	160	5	7	55b	5.2a
	160	3	15	54b	4.9ab
	160	4	15	48b	4.6ab
Telodrin 1.5%	120	3	7	90a	4.6ab
	120	4	7	75ab	3.7c
	120	5	7	66b	4.9a
	120	3	15	74ab	4.6ab
	120	4	15	62b	4.3bc
Citrolane 2%	160	3	7	73b	5.4b
	160	4	7	98a	5.9ab
	160	5	7	82ab	6.3a
	160	3	15	90ab	5.9ab
	160	4	15	80ab	5.8ab
Check*				99	3.0

* Data not included in the statistical analysis. Information presented is the average of four replications. Any two means not followed by the same letter are significantly different at the 5% level.

mance of granular Telodrin was slightly superior to the other formulations tested, although in many instances differences were not statistically significant. Yields were not significantly different among treatments, probably due to an early decline of the maize whorlworm infestation and low stem borer incidence. However, production was higher in the plots treated with Sevin.

Concerning the test to determine the most effective control program in a tropical environment, the results (Table M15) indicated that three applications at 15-day intervals was as efficient against stem borers and in production as several applications, regardless of interval. Previous tests have shown that two applications at 15-day intervals have been as effective as three. Thus, under commercial production, the number of applications (two or three) may be influenced by the severity of the infestation and rainfall coincidence with time of application. Although Birlane was the most effective material against borers, production was significantly higher in plants treated with Cytrolane. All insecticides were equally effective against the maize whorlworm. Birlane, Telodrin and Cytrolane had 4, 4 and 5 percent damaged plants, respectively, while the untreated check had 32 percent.

Appreciation is expressed to the following companies which provided insecticide samples: Bayer Quimicos Unidos, S. A.; Cyanamid de México, S. A. de C. V.; Distribuidora Shell de México, S. A.; Geigy Mexicana, S. A. de C. V.; and Unicarg Commercial, S. A. de C. V. Mention of trade names does not constitute an endorsement by CIMMYT. For other designations of the insecticides mentioned in this report, their chemical names and formula, see: **Entomological Society of America** 1969, 15 (2):85-148.

Estimating Stem Borer Damage

Several procedures have been proposed for estimating stem borer incidence of natural populations on mature maize plants, in insecticide trials and host plant resistance studies.

During 1971 attempts were made to determine the efficiency and accuracy of three methods and the degree of association among them. The three techniques under consideration were: (1) number of holes per stem, determined by outside inspection of the stalk, previous complete defoliation; (2) number of damaged internodes, determined by outside inspection of the stalk, previous complete defoliation (an internode is considered injured when one or more holes are present); and (3) number of tunnels, determined by splitting the stalk without the need for complete defoliation.

Of the three procedures, the number of tunnels should provide the most accurate technique since it measures actual damage. Determining the number of damaged internodes would be next in precision because a tunnel does not always exist for a given injured internode or vice versa. Counting penetration and existing holes would be the least precise technique, particularly under severe infestation, because of the risk of missing holes and maintaining proper counts by unskilled labor.

No matter which technique is used, estimating borer damage is time consuming. However, the two most precise techniques (counting tunnels or injured internodes) would be about equally efficient (approximately 50 seconds per stem examined) compared to estimating holes per stem which requires more time (about 60 to 75 seconds) and is less accurate. In very precise host-plant resistance studies or insecticide control trials, the number of tunnels and their sizes (the amount of tunneling done by the larvae) need to be determined.

There is a high association among the three methods (Table M16), although the highest correlation existed between number of damaged internodes and number of internal tunnels per stem. Thus, either procedure may be utilized in routine evaluations.

TABLE M16. Correlations (r) between different methods of measuring corn stem borer damage (Diatraea saccharalis and Zeadiatraea lineolata).

Methods	r
Number of damaged internodes vs. number of holes	0.7432*
Number of damaged internodes vs. number of internal tunnels	0.8068*
Number of internal tunnels vs. number of holes	0.7805*

* Significant at the 1% level.

Control of Insect Damage in Stored Grain

Stored-grain insect pests continue to be a serious threat in subtropical and tropical environments. Our search for genetic resistance continued, recognizing that it could also be associated with factors such as high amylose or other substances yet to be identified that may render the grain unsuitable for human or animal consumption. Specific factors other than physical hardness may also be found that will provide some resistance.

The importance of opaque-2 corn as a protein source for humans and monogastric animals has been clearly demonstrated. However, the soft endosperm and the nutritive value have been considered characteristics favoring stored-grain insect damage more than with other types of corn. The test reported in Table M17 was conducted to gain information on this. Cacahuacintle, a floury endosperm type, had the highest percentage of damaged kernels and number of offspring emerged. In decreasing order for both damage and emergence were ½ opaque-½ translucent, dent, pure opaque, sweet, normal fint, antigua (flint) and reventador (flint-popcorn). Highly significant differences in damaged kernels and adults emerged were obtained between cacahuacintle and the rest of the types, but not among the succeeding five types. However, they differed significantly from the Antigua Group 1 (flint) and reventador (popcorn). This may be attributed to the variability in the size and shape of the kernels, relative hardness, differences in moisture among kernels, and probably to some of the chemical constituents of the kernels among the different corn types.

Average weight of individual weevils emerged varied significantly among the different types. Adult weevils emerged from the soft endosperm types generally weighed more than those from the hard flint ones. Cacahuacintle produced the heaviest offspring, followed by the two opaque types (pure opaque and ½ opaque-½ translucent).

Percentage of kernels with damaged embryo and the relative degree of damage of the embryo also differed significantly among the corn types studied. Higher percentages of damage to the embryo and kernels with damaged embryo were found in the hard types (antigua, reventador and normal flint) than in the soft

TABLE M17. Reaction of Sitophilus zeamais M. in opaque-2 and non-opaque maize varieties at El Batán, México, 1971.

Types	Kernels damaged %	No. adults emerged/ kernel	Average weight/ adult (mg)	% kernels with damaged embryo (per 10 kernels)	Degree damage in embryo %	Protein %	Tryptophan in protein %	Lysine in protein %
Opaque-2 Composite K								
pure opaque	34bcd	0.29bc	3.4ab	27.5ef	3.9e	8.5fg	.070a	3.9a
½ opaque-½ translucent	38b	0.40b	3.2abc	47.5abcde	8.4cd	11.1b	.034b	2.7b
nonopaque-flint	20bcde	0.21bcde	3.2abcd	55.0abcd	13.4abc	9.9c	.037d	1.7d
Antigua Gpo. 1 (flint)	14ef	0.11f	2.4f	60.0ab	16.8ab	9.5cdef	.032d	1.6d
Cacahuacintle (floury)	68a	0.76a	3.5a	22.5f	3.2e	7.9g	.045bc	2.2bc
Maíz dentado (dent)	36bc	0.36bc	3.1abcd	57.5abc	5.4de	9.8cd	.037d	1.7d
Reventador (pop)	10f	0.08f	2.2f	62.5a	17.5a	9.7cde	.030d	1.6d
Maíz dulce (sweet)	27bcde	0.29bcde	2.7cde	37.5bcde	4.7de	11.2a	——	——
General Mean ($\bar{x}$)	31	0.31	3.0	46.2	9.1	9.7	.049	2.2
C.V. (%)	18	18.01	9.4	14.6	17.1	4.6	4.320	9.9
$S_{\bar{x}}^{2}$ *	3	0.27	0.1	3.1	1.4	0.3	0.09	0.1

CORRELATIONS (r) BETWEEN VARIABLES IN DIFFERENT TYPES OF CORN

Variables	r
No. of adults emerged per kernels vs. ave. weight of insect emerged	+ .78**
No. of adults emerged per kernel vs. % protein	— .26
No. of adults emerged per kernel vs. % tryptophan in protein	+ .58**
Ave. weight of insect emerged vs. % protein	— .19
Ave. weight of insect emerged vs. % tryptophan in protein	+ .64**

** Significant at 1% level.

NOTE: Data presented is the original. For analysis it was transformed to arcsin ($\sqrt{\text{percentage}}$). Data refers to Non-choise test, utiliz-

* Total from 250 kernels, 25 kernels per replicate.

kernel types (cacahuacintle, pure opaque and ½ opaque-½ translucent).

Analysis of percentages of protein tryptophan and lysine revealed significant differences between the sweet corn (11.19%) and ½ opaque-½ translucent (11.06%) and the rest of the types. Pure opaque and cacahuacintle had the lowest percentage of protein, with 8.55% and 7.91%, respectively. For tryptophan and lysine in protein, the reverse is true.

Correlation values of the different variables in the different types of corn are presented in Table M17. The correlations between number of adults emerged and weevil weights were positive and highly significant (r = + .78). This could imply that those types that are more suitable for the development of the insect produce offspring that are heavier compared to those reared on the unsuitable ones.

Positive and highly significant correlations were also obtained for the number of adults emerged and average weevil weights with tryptophan in protein (r = .58 and .64, respectively). As the tryptophan and lysine content of the kernels increased, the number of emerged weevils and weevil weights increased. This could indicate that tryptophan and lysine are of value in weevil nutrition. The correlation between number of emerged weevils and weevil weights with protein content was negative, but not significant. This indicates that high protein content may be detrimental to weevil development. A free-choice test was also conducted. Results were similar to those indicated above.

Available information indicates that at least in some backgrounds the incorporation of the opaque-2 gene does not make them a more suitable nutritive substratum for weevils than other types of corns. This is an encouraging development.

Another test to determine the value of kernels with and without embryoes on the development of maize weevil and Angoumois moth was also conducted in an opaque-2 (composite K) and flint corn types (antigua). More, but lighter, adult weevils emerged in the degermed than in the whole kernels in both types of corn. However, opaque-2 produced more adults compared to flint. This might be due to induced attractiveness of the degermed kernels for oviposition of the rice weevil. For the Angoumois moth, the opposite was observed. More and heavier adults emerged from

TABLE M18. Reaction of Sitophilus zeamais and Sitotroga cerealella in two types of corn at El Batán, 1970.

Type of corn		Sitophilus zeamais: Emerged insects*	Sitophilus zeamais: Average weight per insect (mg)	Sitotroga cerealella: Emerged insects*	Sitotroga cerealella: Average weight per insect (mg)
ANTIGUA	Flint (whole kernel)	196bc	3.12bc	263a	4.2a
COMPOSITE K	Opaque-2 (whole kernel)	172c	3.44a	228a	2.8b
ANTIGUA	Flint (degermed)	237b	3.02c	105b	2.0c
COMPOSITE K	Opaque-2 (degermed)	324a	3.21b	134b	2.0c
	LSD - 5%	47.6	0.17	38.9	0.55

* Total from 250 kernels, 25 kernels per replicate.

the whole than from the degermed kernels. Opaque-2 produced more offspring than the flint in the degermed, but not in the whole kernel. This suggests that the germ fraction is important in Angoumois moth development.

Again, this test indicated that the opaque-2 material does not seem to provide a better substratum for stored-grain insect development.

As with field pests, chemical control is presently the most efficient procedure to reduce losses caused by stored grain insects. It has been determined in our program that relative effectiveness of grain protectants such as Malathion, Gardona or Baythion is enhanced when treated grain is moved from a temperate climate (where the insecticide protection has ceased to be effective) to a tropical or subtropical environment (Table M19). Such performance associated with temperature and insect activity is of value to grain protection, but it also needs to be considered in establishing legal tolerances to protect the consumer.

During 1970-71, the control of a stored-grain insect (*Sitophilus zeamais* on corn) with grain protectants was again investigated at three locations in México—Poza Rica (wet, tropical environment), Tlaltizapán (subtropical environment) and El Batán (high-altitude environment, temperate).

Three grain protectants were tested (Malathion, Gardona and Baythion). Each insecticide was used at three dosages (7.5, 10 and 15 ppm).

Two criteria were used to evaluate the effectiveness of the insecticides. One was the mortality of the insects used to artificially in-

TABLE M19. Percent mortality of Sitophilus zeamais on corn grain treated with three different dosages of Malathion, Gardona, and Baythion. Subsamples transferred from El Batán (temperate) to Tlaltizapán (subtropical) and Poza Rica (tropical).

Days after treatment	Date of observation	Malathion ppm 7.5	10	15	Gardona ppm 7.5	10	15	Baythion ppm 7.5	10	15	Malathion ppm 7.5	10	15	Gardona ppm 7.5	10	15	Baythion ppm 7.5	10	15
		Observed mortality at indicated dates El Batán — Tlaltizapán									Mortality on emerging adult insects El Batán — Tlaltizapán								
431	Oct. 31/70	31	46	49	33	47	84	96	80	100	100	N	N	N	N	100	N	N	N
503	Jan. 11/71	20	20	44	31	51	44	100	100	100	50	67	100	100	100	83	N	N	N
610	April 28/71	54	58	64	37	64	94	100	100	100	75	100	100	100	100	N	N	N	100
683	July 10/71	0	0	0	0	1	8	100	100	100	58	91	88	50	83	66	N	N	N
811	Nov. 15/71	0	10	5	0	0	0	94	97	99	3	36	21	13	66	83	N	N	N
		El Batán — Poza Rica									El Batán — Poza Rica								
431	Oct. 31/70	50	65	85	63	71	86	100	99	100	N	N	N	N	N	N	N	100	N
503	Jan. 11/71	4	5	13	7	8	16	100	100	100	100	100	100	N	N	100	100	100	100
610	April 28/71	5	16	22	0	6	24	100	100	100	62	82	85	27	71	75	100	100	100
683	July 10/71	0	0	1	0	0	1	82	95	99	11	24	74	2	6	29	100	100	N
811	Nov. 15/71	—	—	—	—	—	—	43	66	62	D	D	D	D	D	D	84	99	100

D: Grain destroyed by insect activity.
N: No emergence took place.
Data based on four replicates.

fest the treated grain. The second was the mortality of the adults emerging from the treated grain.

The results (Tables M20, M21 and M22) indicate that the three insecticides were effective in controlling *S. zeamais* in the three locations for almost a year or more, except Malathion at Tlaltizapán. Even at the highest dosage (15 ppm), Malathion controlled only 45 percent of the insect population 142 days after the seed was treated.

The insecticides were effective longer at El Batán than at Tlaltizapán or at Poza Rica. This was especially true with Baythion, which at El Batán was still effective (98% control) 806 days after the seed was treated, while at Poza Rica the grain was destroyed by insects 809 days after treatment and at Tlaltizapán the insecticide was controlling only 49 percent of the insect population 811 days after treatment.

The other criteria used to evaluate the effectiveness of the insecticides (mortality of the emerging adults) seems to indicate also that Baythion was the most effective and more persistent of the three insecticides tested.

Regarding the quality of kernels infected by fungi in the field, such as *Diplodia* spp. and *Fusarium moniliforme*, information obtained by

TABLE M20. Percent mortality of Sitophilus zeamais on corn grain treated with three different dosages of Malathion, Gardona, and Baythion at Poza Rica, México (wet, tropical environment).

Days after treatment	Date of observation	Malathion ppm			Gardona ppm			Baythion ppm			Malathion ppm			Gardona ppm			Baythion ppm		
		7.5	10	15	7.5	10	15	7.5	10	15	7.5	10	15	7.5	10	15	7.5	10	15
		Observed mortality at indicated dates									Mortality on emerging adult insects								
94	Nov. 28/69	99	99	100	95	96	97	100	100	100	—	—	—	—	—	—	—	—	—
179	Feb. 21/70	13	24	88	24	37	97	100	100	100	87	50	73	70	89	67	N	N	N
239	April 22/70	97	100	100	81	91	98	100	100	100	70	100	92	70	83	79	100	100	100
307	June 29/70	4	27	85	16	26	78	98	99	100	74	73	80	73	79	78	67	N	N
400	Sept. 30/70	3	4	7	0	2	5	60	88	98	3	35	64	2	10	49	86	100	100
468	Dec. 7/70	D	3	8	D	2	0	51	76	83	D	1	10	D	0	1	96	75	100
564	Mar. 13/70	—	D	D	—	D	D	28	34	43	—	D	D	—	D	D	92	100	100
652	June 9/71	—	—	—	—	—	—	0	28	27	—	—	—	—	—	—	38	51	35
750	Sep. 15/71	—	—	—	—	—	—	8	25	27	—	—	—	—	—	—	53	88	96
809	Nov. 13/71	—	—	—	—	—	—	D	D	17	—	—	—	—	—	—	0	58	86

D: Grain destroyed by insect activity.
N: No emergence took place.
Data based on four replicates.

TABLE M21. Percent mortality of Sitophilus zeamais on corn grain treated with three different dosages of Malathion, Gardona and Baythion at Tlaltizapán, México (subtropical environment).

Days after treatment	Date of observation	Malathion ppm			Gardona ppm			Baythion ppm			Malathion ppm			Gardona ppm			Baythion ppm		
		7.5	10	15	7.5	10	15	7.5	10	15	7.5	10	15	7.5	10	15	7.5	10	15
		Observed mortality at indicated dates									Mortality on emerging adult insects								
81	Nov. 15/69	95	100	100	89	94	99	100	100	100	—	—	—	—	—	—	—	—	—
142	Jan. 15/70	19	27	45	62	75	85	100	100	100	50	N	N	100	86	N	N	N	N
207	Mar. 21/70	39	44	57	89	96	98	99	100	99	59	100	60	75	90	77	N	N	N
274	May 27/70	37	35	53	93	100	99	100	100	100	75	N	N	100	100	100	N	100	N
375	Sept. 5/70	20	23	23	84	95	98	97	100	100	73	100	100	N	N	N	N	N	N
431	Oct. 31/70	24	32	39	55	78	88	100	100	100	13	43	100	100	100	100	67	100	N
503	Jan. 11/71	11	14	25	14	18	35	72	84	98	6	44	31	37	100	67	N	100	N
610	April 28/71	0	6	18	20	56	53	89	93	100	2	26	59	65	73	100	100	N	N
683	July 10/71	D	D	0	0	0	0	70	90	95	1	35	81	64	77	75	N	N	N
811	Nov. 15/71	—	—	0	0	0	1	42	58	49	D	D	9	2	15	21	84	84	100

D: Grain destroyed by insect activity.
N: No emergence took place.
Data based on four replicates.

TABLE M22. Percent mortality of Sitophilus zeamais on corn grain treated with three different dosages of Malathion, Gardona and Baythion at El Batán, México (high-altitude environment, temperate).

Days after treatment	Date of observation	Malathion ppm			Gardona ppm			Baythion ppm		
		7.5	10	15	7.5	10	15	7.5	10	15
		Observed mortality at indicated dates								
6	Sept. 1/69	100	100	100	72	81	74	100	100	100
43	Oct. 13/69	99	100	100	66	80	77	100	100	100
90	Nov. 24/69	26	35	100	21	31	27	100	100	100
132	Jan. 5/70	25	36	100	19	34	46	100	100	100
174	Feb. 16/70	10	19	30	12	24	22	100	100	100
216	March 30/70	32	57	74	49	77	93	100	100	100
258	May 11/70	20	26	44	74	81	85	100	100	100
300	June 22/70	18	18	22	45	65	79	100	100	100
344	Aug. 5/70	6	17	31	39	52	75	100	100	100
384	Sept. 14/70	12	22	23	51	54	60	100	100	100
426	Oct. 26/70	8	19	35	20	23	30	100	100	100
468	Dec. 7/70	2	4	7	4	7	9	100	100	100
573	March 22/71	0	1	2	0	3	3	100	100	100
617	May 5/71	1	3	4	4	5	9	100	100	100
653	June 10/71	0	3	3	49	60	46	100	100	100
708	Aug. 4/71	5	5	10	4	7	33	100	100	100
769	Oct. 4/71	5	4	9	8	15	39	100	100	100
806	Nov. 10/71	6	0	10	4	4	8	89	98	98

Data based on four replicates.

TABLE M23. Average gain in weight of chicks fed with maize kernels* inoculated with two different ear-rotting fungi,[1] México, 1970.

Diet	Average gain (grams) 5 replicates
Commercial diet[2]	263.8a[4]
⅓ Fusarium + ⅔ commercial	80.8b
Check[3]	47.6c
⅔ Fusarium + ⅓ commercial	38.4c
⅓ Diplodia + ⅔ commercial	19.2d
⅔ Diplodia + ⅓ commercial	14.8d
Fusarium alone	5.2d
Diplodia alone	— 4.2d

* During 24 days, weighed every 4 days.
[1] Diplodia maydis and Fusarium moniliforme.
[2] Commercially available diet (Purina).
[3] Maize kernels water-soaked, but noninoculated.
[4] Any two means not followed by the same letter are significantly different at the 5% level.

feeding chicks with infected kernels has shown that a powerful mycotoxin is synthesized in *Diplodia*-rotten ears. They are normally used by farmers in the tropics for feeding animals. Mycotoxins developed by *F. moniliforme*-infected ears have been previously reported. Co-operative efforts with the National Institute for Livestock Research seek to isolate and purify mycotoxins produced by *Diplodia*-infected ears. Results obtained after a feeding trial are shown in Table M23.

AGRONOMIC TRIALS METHODOLOGY RESEARCH

Research is being carried out on problems related to the operation of production programs. For example, the conventional approach to determining packages of production practices is often inadequate for rainfed agriculture involving considerable risk and uncertainty due to climatic variability. Since most of the regions in México and other Latin American countries where small, subsistence farms predominate consist mainly of rainfed agriculture, or agriculture that receives very little irrigation, it is important that an efficient methodology for studying production practices under these conditions be developed. Work is presently being carried out on aspects of treatment design and the analysis of data that will contribute to a more adequate methodology. Dr. Foster B. Cady, Cornell University, is participating in these methodological studies.

Estimation of Yield Equations for Predictive Purposes

A major objective in the interpretation of data from a series of field experiments is the determination of a general yield equation. For example, in fertilizer trials at multiple sites, several site variables which cannot be controlled are measured. The functional relationship between yield and the applied fertilizer variables as influenced by the site variables is calculated and then used in estimating fertilizer needs for specific conditions.

The agronomist prefers a general yield equation with regression coefficients that are meaningful in both a qualitative and quantitative sense. The estimated general yield equation is obtained by multiple regression analysis, usually using a stepwise procedure in which predictor variables are selected if the entering variable statistically lowers the residual sum of squares. Work of this kind has often resulted in unsatisfactory results since certain important variables may not appear in the final yield equation.

A new procedure, called PRESS, has been developed for selecting predictor variables from a large number of potential ones.

The stepwise regression procedure was compared with PRESS using data from a series of experiments conducted in the Bajío area of México over a four-year period. The 33 potential predictor variables included controlled applied nitrogen variables, uncontrolled site variables and interactions. Using the stepwise regression procedure and a significance level of .05, 20 variables were included in the estimated yield equation.

Stepwise regression resulted in estimated coefficients that were difficult to interpret agronomically. In addition, nine site variables would have to be measured in order to use the estimated yield equation selected by stepwise while only five are needed in the equation from PRESS.

Treatment Design for Two-Factor Studies

In the planning of a study to produce the information needed in estimating a continuous function in two variables, a decision has to be made as to the levels of each factor that will be used in the combinations called treatments. The treatment design problem is how to select a small number of treatment combinations that will generate the data necessary for an adequate estimation of the desired function.

The treatment design selected depends on the specific objectives and knowledge the experimenter has of the production system and two major considerations are involved: (a) variance of the estimated parameters, and (b) bias, a measure of the difference between the true model and the estimated model.

Past work has shown that designs which are good for minimizing variance error are not the best for minimizing bias error. Unfortunately, in order to study bias, the true model has to be known, a situation usually not found in practice. Consequently, in most past studies, variance considerations have received major attention. Recent studies, on the other hand, have shown that the magnitude of bias is sufficiently large so that in fertilizer use studies, it is better to select a treatment design primarily to minimize bias and control variance error primarily through replication.

During the past year an empirical study has been done comparing several commonly used two-factor treatment designs, including designs which theoretically have been shown to be best in protecting against bias. A square root model was selected for the true model and a quadratic polynomial used for the estimated or fitted model. It is conjectured that similar results would have been obtained if a cubic polynomial had been used for the true model.

In general, the bias, or the integrated volume between the estimated quadratic polynomial response surface and the true square root response surface, is decreased by restricting the treatment combinations to an area of the factor space not including the borders. This restriction leads to larger deviations at the borders of the factor space, but over most of the area of interest, including that where the economic optimum is expected to occur, the estimated quadratic polynomial more closely approximates the true model. Not having treatment combinations at the corners of the factor space increases the variances of estimated parameters, for example, the variance of the estimated interaction coeficient. Variance error, however, can be maintained at an acceptable level by adjusting the number of replications employed.

Small Treatment Designs for Multifactor Experiments

Experimental evidence gathered during the period 1967-69 in the Puebla Project area indicated that the interactions among production factors were often large. Information collected during this period suggested that treatment matrices selected for generation information on crop production practices should provide for measuring the interactions among the important controllable factors of production. In Puebla these factors were planting date, rate and time of applying nitrogen and phosphorus, plant density and plant genotype.

Design matrices for producing data to estimate the functional relationship between yield and four or more factors require large numbers of treatments. For this reason such experiments are seldom conducted under field conditions. An alternative approach, involving discrete comparisons of selected levels of the several factors, was used in Puebla in 1970. An example of the treatments used and the results obtained is given in Table M24. Based on previous experience only treatment combinations were selected that were expected to give information of practical value for farmers. High rates of nitrogen, for example, were only studied in combination with high plant densities.

The data in Table M24 illustrate the importance of multifactor experimentation. The application of 40 kg/ha of P_2O_5 together with 105 kg/ha of nitrogen had no significant effect on the yield of the May 5 planting but increased the yield of the June 14 planting by 139 percent. Also, a comparison of treatments 2 and 3 with 4 and 5 for the May 5 planting date shows a strong tendency for phosphorus to increase yields at high levels of nitrogen but not at low levels. Such nitrogen-phosphorus interactions are very common. Another interesting comparison is treatment 6, which apparently has sufficient nitrogen and phosphorus, with treatment 8 that has an additional 10 ton/ha of chicken manure. Although the added effect of the manure is significant for the May 5 planting, it is relatively much larger for the later plantings. It is suspected that the larger effect of the manure in late plantings, which has been confirmed at many locations, is related to a greater need for immobile nutrients —particularly phosphorus, potassium and zinc —possibly because of more limited root development by the late corn. At one location, for example, the application of 50 kg/ha of K_2O had no significant effect on yield of an early planting and increased grain production by one ton per hectare in a late planting.

Due to the importance of the interactions among productivity factors, attention is being given to the selection of small treatment matrices for studying the functional relationship between yield and several factors. It is believed that general knowledge of how crops respond to productivity factors can be used in selecting the treatment combinations. It is known, for example, that if increasing rates of nitrogen are applied to a soil deficient in both nitrogen and phosphorus, the response curve will reach a maximum at low rates of nitrogen; if phosphorus is added together with the nitrogen, however, the maximum will be reached at much higher rates of nitrogen. It should be possible to use such knowledge to reduce the size of treatment matrices without significantly reducing the usefulness of the experimental data.

Following this line of reasoning, a family of matrices is being considered that is based on a 2^n factorial (complete or fractional) plus treatments outside the factorial space.

An "augmented 2^n" treatment matrix was used in 1971 in a large number of field experiments in México, Honduras, Colombia and Perú. The analysis and interpretation of the results obtained in these experiments will provide an opportunity to evaluate the usefulness of this matrix.

TABLE M24. The influence of fertilization, plant density and planting date on maize yields in an experiment in Puebla.

Treatment	Nitrogen kg/ha	Phosphorus kg/ha	Chicken manure ton/ha	Population density 1,000 plants/ha	Yield in kg/ha of maize planted on		
					May 5	May 25	June 14
1	0	0	0	30	2061	1434	395
2	105	0	0	30	4580	3004	896
3	105	40	0	30	4780	4477	2144
4	130	0	0	50	5894	4042	1748
5	130	40	0	50	6547	5702	2923
6	160	40	0	60	7188	7291	2696
7	190	40	0	60	7388	6906	2407
8	160	40	10	60	8691	9076	4210
	LSD 5%				717	1266	503

Fertility Studies on Andosols

Andosols are volcanic ash soils with high moisture retention capacities, high organic matter contents, low bulk densities, and clay fractions dominated by amorphorus aluminum silicates. They are widely distributed in México, Central America, Colombia, Ecuador, Chile, Japan, New Zealand and other volcanic regions of the world.

A study of the fertilization of maize on Andosols was begun in 1969 in the Sierra Tarasca, Michoacán, México. Field experiments have been conducted to study rates and methods of applying phosphorus and chicken manure, sources of phosphorus fertilizer, effects of lime and calcium silicate, residual effects of phosphatic fertilizers and chicken manure, etc.

Results obtained in 1969 in the study of rates and methods of applying phosphorus showed that the application of superphosphate by broadcasting and plowing-in was more effective than banding, and that hill application was least effective. Similar results were obtained at three locations in 1970. As shown by the data in Table M25, broadcasting the phosphorus, the application method resulting in greatest contact between the soil and the fertilizer, was at least as effective and frequently more effective than the banding and hill methods. Also, again confirming the findings in 1969, the results indicated that the phosphorus deficiency of these soils for maize production is only moderate in intensity.

Experiments were carried out in 1970 to measure the interactions between several factors known to affect maize yields. The treatment matrix consisted of ½ replication of a 2^5 factorial involving nitrogen, phosphorus, chicken manure, limestone, and calcium silicate; the two rates of each factor were zero and 150 kg/ha, 300 kg/ha, 5 tons/ha, 10 tons/ha and 5 tons/ha, respectively. Results from three locations are presented in Table M26. There is a negative interaction between phosphorus and lime and also between phosphorus and chick-

TABLE M26. Main effects and interactions of five controlled factors on maize yield at three locations in the Sierra Tarasca, México.

Effects	Casas Blancas kg/ha	San Gregorio kg/ha	Camembaro kg/ha
Least significant effect (5%)	+696	+1,255	+1,521
Nitrogen	+756*	+ 172	+ 758
Phosphorus	− 54	+ 963*	+ 746
C. Manure	+696*	+1,245*	+1,521*
Limestone	+260*	+ 167	+ 668*
Ca-Silicate	+ 49	+ 420*	+ 346*
Nitrogen x phosphorus	+ 3	+ 271*	+ 268
Nitrogen x C. Manure	−449*	− 21	− 147
Nitrogen x Limestone	+ 15	+ 52	+ 154
Nitrogen x. Ca-Silicate	− 14	− 2	+ 344*
Phosphorus x C. Manure	−120	− 364*	− 363*
Phosphorus x Limestone	+ 6	− 331*	− 438*
Phosphorus x Ca.-Silicate	− 49	− 20	− 210
C. Manure x Limestone	+ 22	− 238	− 331
C. Manure x Ca.-Silicate	+111	− 40	− 148
Limestone x Ca.-Silicate	−140	− 148	− 681*
Least significant effect (5%)	185	265	344

* Effects are significant at the 5% level.

TABLE M25. Corn yields in kg/ha of grain at three locations as affected by the rate and method of applying superphosphate to Andosols in the Sierra Tarasca.

Treatment	Nitrogen kg/ha	Phosphorus kg/ha	Method of application	San Gregorio	La Calera	Paramuén
1	0	0		1439	1162	262
2	150	0		1652	2981	618
3	150	100	band (B)	2997	4764	1934
4	150	200	band (B)	3179	4407	2266
5	150	400	band (B)	3275	5025	2540
6	150	100	hill	2239	4438	1211
7	150	200	hill	2707	5039	1751
8	150	100	broadcast (V)	3186	4280	3155
9	150	200	broadcast (V)	2754	5089	3650
10	150	400	broadcast (V)	3374	5261	3950
11	150	800	broadcast (V)	3343	5180	4114
12	150	100B-300V		3444	4933	3920
13	150	100B-700V		3621	5102	4683
14 *	120	200	band	4438	6808	5359
Coefficient of variation (%)				17.33	10.17	17.67
Least significant difference (5%)				874	796	847

* This treatment included an application of 20 tons of chicken manure per hectare.

en manure. These interactions suggest that both lime and chicken manure tend to correct the same deficiency as phosphorus; that is, they tend to substitute for phosphorus rather than supplement it. Calcium silicate had a positive effect on yield at two locations and no significant interaction with phosphorus.

INTERNATIONAL MAIZE TESTING PROGRAM

The International Maize Testing Program involves a series of coordinated efforts by CIMMYT and many maize research and production programs around the world for systematically evaluating breeding materials and facilitating exchange of germ plasm among maize researchers in all areas where maize can be grown economically.

The International Maize Testing Program includes: (1) evaluating unimproved sources of germ plasm; (2) evaluating more highly bred materials still highly variable genetically; (3) trials including improved materials that may be used directly as varieties in some countries; (4) evaluating high-quality protein materials to be used as sources for improvement or for immediate distribution to farmers; (5) establishing specific disease and insect nurseries according to the economically more important diseases or insects in different areas of the world; and (6) conducting agronomic trials for specific studies on physiology and important plant-environment relationships.

Aside from the obvious benefits that a program like this will produce, perhaps the most important long-range benefits from this worldwide activity will be generated by the information which is returned to the central processing offices at CIMMYT. Here the data is assembled, analyzed and published for general distribution.

Several institutes and national and international agencies also conduct various international tests. An effort has been made to establish the needed links between these agencies and CIMMYT, to increase the coverage, scope and efficiency of the international testing program, and very importantly, to collect the many pieces of information which, when assembled and properly analyzed at CIMMYT, will provide a generalized and more useful understanding of areas of adaptation, sources of resistance to insects and diseases, etc.

Such an internationally coordinated testing program is considered by the breeders of the world as one of the most important reference sources for breeding materials.

Contacts have been established with the Inter-Asian Corn Improvement Program, which represents an organized approach to the movement and evaluation of germ plasm in 14 countries of Southeast Asia. Most of the participating countries are also receiving trials directly from CIMMYT and are actively participating in this worldwide effort.

Through the Food and Agriculture Organization of the United Nations (FAO), the CIMMYT International Maize Testing Program has sent 16 trials to be planted this year in the Near East, the Mediterranean Region, East Africa and other areas.

The Central American Cooperative Project for the Improvement of Basic Food Crops (PCCMCA), which has been successfully operating for several years, has also been integrated into the international testing network.

CIAT in Colombia and CIMMYT have already established the necessary coordination for conducting 13 experiments in South America. The experimental data will be sent to CIMMYT for analysis and general publication.

Also, many agricultural advisors of the foreign aid agencies, universities in Canada, Nigeria, Perú, Panamá and many other countries, and the United States Department of Agriculture are participating in these activities.

The International Maize Testing Program was started in 1970 and a CIMMYT staff member took responsibility for assembling and distributing the experiments, and is the overall coordinator for these activities.

Much work will be required for the proper evaluation of all the maize germ plasm available in the world. But it is only through testing materials from widely different environmental, genetic and geographic situations, over a wide range of latitudes climates, fertility conditions, water management, and disease and insect complexes, that the adaptability of any material can be properly assessed. Furthermore, these tests will provide a means of testing promising materials on a much broader basis than most breeders can. The tests have already often served as sources of genetic materials for use by cooperators, either directtly or in crosses.

These short plant selections exhibit tar spot infections. A series of internatoinal trials help locate traits of resistance to diseases and pests.

The International Maize Testing Program is using the world as an experimental field and coordinating the efforts of many scientists in their struggle toward increasing production and improving the nutritive value of maize.

There are several series of experiments within the International Maize Testing Program.

International Maize Adaptation Nurseries (IMAN)

IMAN was designed to test the adaptation of maize materials from many areas of the world. In 1970, 38 trials were distributed to 26 countries. These trials included materials from Brazil, Canada, Kenya, Perú, Jamaica, Indonesia, Nicaragua, México, Thailand, Australia, Iraq, Colombia, Argentina, Japan, Egypt, India and Ivory Coast.

In 1971, 76 trials were distributed to 47 countries. These trials include materials from Brazil, México, Honduras, Angola, Jamaica, Nicaragua, Colombia, Uganda, Tanzania, Perú, Pakistan, Philippines and Guatemala.

In 1971 the IMAN trials have been grown in the Near East, Cyprus, Tunisia, West Pakistan, Afghanistan, Egypt, Japan, Indonesia, Ceylon, Thailand, India, Nigeria, Tanzania, Angola, Ivory Coast, Jamaica, Philippines, Ghana, Canada, Nicaragua, United States, Colombia, Perú, Ecuador, Brazil, Argentina, Chile, Uganda, México, Kenya, Algeria, Ethiopia, Iran, Iraq, Jordan, Lybia, Nepal, Saudi Arabia, Syria, Yemen, Somalia and Turkey.

In 1970, data were collected on yield and seven other characters. Since the IMAN trials were designed to assess the performance of germ plasm sources from widely different environmental and geographical situations, the performance of some trials precludes the statistical analysis of the data for some locations. A preliminary evaluation of yield performance across 23 locations has been made. The top 25 entries are listed in Table M27. The remaining information is being assembled and analyzed for publication.

Tables M28-M31 show the top 10 varieties for each locatoin in North and Central America, South America, Asia and Africa with the rank listed in parenthesis.

TABLE M27. Yield in kg/ha of grain with 15% moisture for the top 25 entries of the 1970 IMAN (average of 23 locations and assuming a constant 80% shelling percentage, 1970).

Variety	Origin	Yield
QK-37	Australia	4989
Pioneer X-304 A	Jamaica	4769
Agroceres 501	Brazil	4545
H-512	Kenya	4235
H-511	Kenya	4176
Centralmex	Brazil	4120
Comp. L. (ME) C_2	CIMMYT	4009
Poey T-66	Mexico	4007
Poey B-15	Mexico	3947
(Mix. 1 x Col. Gpo. 1) Eto Blanco	CIMMYT	3943
H-507	Mexico	3929
Eto Blanco	Colombia	3924
H-613B	Kenya	3669
Pioneer X-306 A	Jamaica	3667
Comp. Norteamericano	Peru	3608
Kisan	India	3550
Vijay	India	3539
Nicarillo	Nicaragua	3500
Sin. Lin. Res. Arch.	CIMMYT	3487
Comp. Caribe C_3	CIMMYT	3473
PMS-264	Peru	3439
(USA x Carib. Comp.)	CIMMYT	3429
Comp. B (C_2)	CIMMYT	3408
H. Abati 2	Argentina	3332
Harapan	Indonesia	3319

TABLE M28. Yield in kg/ha of grain with 15% moisture for the top 10 entries from the first IMAN, assuming 80% shelling (North and Central America, 1970).

Variety No.	Pedigree	Origin	Nicaragua (La Calera)	México (CIMMYT)	United States (Mississippi)
3	Agroceres M-206	Brazil			3943(9)
4	PMS 264	Perú	1662(9)*		4406(4)
5	Pioneer X-304 A	Jamaica	2685(2)	4566(1)	
6	Harapan	Indonesia	2115(4)		
9	Sin. Lin. Res. Achap.	CIMMYT	2577(3)	2985(10)	
11	Comp. Caribe C_3	CIMMYT	1800(6)	3404(5)	
16	Eto Blanco	Colombia	1800(7)		4397(5)
17	Centralmex	Brazil		3822(2)	
18	Sin. 10 lin. Am. Crist.	CIMMYT	1790(8)		
19	INIA H-507	México		3506(3)	4252(7)
22	(Mex. 1 x Col. Gr. 1) (Eto Bl.)-C_6	CIMMYT		3264(8)	
26	Poey T-66	México	2006(5)		
28	Chalqueño Hgo. 8-P-C_4	CIMMYT			5368(1)
30	Agroceres 501	Brazil		3329(7)	
31	PMS 263	Perú			5051(2)
35	Metro	Indonesia			3907(10)
40	H. Pergamino Guazú	Argentina			4188(8)
43	Comp. L(ME) C_2	CIMMYT		3441(4)	
45	Pioneer X-306 A	Jamaica	2695(1)	3190(9)	4779(3)
48	Comp. B (C_2)	CIMMYT	1662(10)	3339(6)	
49	Jaune de Bouaké	Ivory Coast			4324(6)
	Local Variety		1505	2111	6287

* Numbers in parentheses indicate rank.

TABLE M29. Yield in kg/ha of grain with 15% moisture for the top 10 entries from the first IMAN, assumming 80% shelling (South America, 1970).

Variety No.	Pedigree	Origin	Colombia (Antioquia)	Colombia (Palmira)	Argentina (Pergamino)	Brazil (Paraná)	Brazil (Piracicaba)	Perú (V. Chillón)
2	H-511	Kenya		2664(7)				
4	PMS 264	Perú	4224(6)*	2881(5)				
5	Pioneer X-304 A	Jamaica	4157(7)		5915(4)	7637(1)		10037(6)
6	Harapan	Indonesia		2420(9)			4570(8)	10120(4)
8	Sin. Lin. Res. Achap.	CIMMYT				4321(9)		
9	P. B. 5	Thailand		2446(8)				
11	Comp. Caribe C_3	CIMMYT		3125(3)			5122(3)	
12	Tuxp. Comp. C_3	CIMMYT					4697(7)	
13	Cortazar M-C_4	CIMMYT	3371(10)					9443(10)
14	H-512	Kenya		3521(2)	6172(3)			
16	Eto Blanco	Colombia	4555(3)			4482(6)		9600(9)
17	Centralmex	Brazil	5578(1)			4554(5)	4425(10)	
19	INIA H-507	México		3009(4)			4842(6)	12132(1)
21	Comp. Norteameri-cano	Perú		5314(1)	4230(10)			
22	(Mix. 1 x Col. Gr. 1) (Eto Bl.)-C_6	CIMMYT	4738(2)	2676(6)				10131(3)
23	H-613-B	Kenya	3834(8)					
24	H Abatí 2	Argentina			4765(7)			
26	Poey T-66	México	4501(4)	2407(10)		4464(7)	5014(4)	
27	Poey B-15	México				4607(4)		11048(2)
29	QK-37	Australia	3575(9)		7163(1)		5312(2)	10079(5)
30	Agroceres 501	Brazil	4448(5)		4494(5)	4939(2)	5439(1)	
31	PMS 263	Perú						9954(7)
34	INIA H-507E	México			6985(2)		4950(5)	
36	Nicarillo	Nicaragua				4285(10)		
39	Kisan	India			4557(9)			
40	H. Pergamino Guazú	Argentina			4567(8)			
43	Comp. L (ME)C_2	CIMMYT				4822(3)	4444(9)	9746(8)
45	Pioneer X-306 A	Jamaica				4338(8)		
47	Vijay	India			4794(6)			
	Local Variety		5837	2023	4845	5163	3330	10042

* Numbers in parentheses indicate rank.

TABLE M30. Yield in kg/ha of grain with 15% moisture for the top 10 entries from the first IMAN, assuming 80% shelling (Asia, 1970).

Variety No.	Pedigree	Origin	India (Pantnagar)	Thailand (Pakchong)	Pakistan (Nowshera)
1	Funks G-43	Canada			3913(10)
5	Pioneer X-304 A	Jamaica	4517(1)*	3630(2)	
6	Harapan	Indonesia	3078(9)		
7	Sint. Nicaragua 2	Nicaragua			4615(4)
8	Sin. Lin. Res. Achap.	CIMMYT		2508(7)	
11	Comp. Caribe C_3	CIMMYT	3374(4)		
14	H-512	Kenya			4453(5)
17	Centralmex	Brazil		2138(10)	
18	Sin. 10 lin. Am. Crist.	CIMMYT	3037(1)		
19	INIA H-507	México	3907(2)	2270(8)	
24	H. Abatí 2	Argentina			5398(2)
26	Poey T-66	México		3234(3)	4116(8)
29	QK-37	Australia	3268(5)	4422(1)	4972(3)
30	Agroceres 501	Brazil		2574(5)	
33	Nab El-Gamal	Egypt			4332(7)
34	INIA H-507 E	México	3244(7)		
35	Metro	Indonesia		2561(6)	
36	Nicarillo	Nicaragua	3102(8)	2152(9)	
39	Kisan	India	3262(6)		
40	H. Pergamino Guazú	Argentina			4035(9)
43	Comp. L(ME) C_2	CIMMYT	3617(3)		6747(1)
45	Pioneer X-306 A	Jamaica		3076(4)	
47	Vijay	India			4426(6)
	Local Variety		1616	1280	3738

* Numbers in parentheses indicate rank.

TABLE M31. Yield in kg/ha of grain with 15% moisture for the top 10 entries from the first IMAN, assuming 80% shelling (Africa, 1970).

Variety No.	Pedigree	Origin	Ivory Coast (Bouaké)	Tanzania (Mwanza)	Angola (N. Lisboa)	Angola (Malanje)	Uganda (Kampala)	Ethiopia (Bako)
2	H-511	Kenya			7598(3)	4749(3)	5883(10)	6851(4)
3	Agroceres M-206	Brazil				4706(4)		
5	Pioneer X-304 A	Jamaica	2806(2)*		6349(8)			6206(6)
10	Atherton Dent	Australia				3936(9)		5314(9)
11	Comp. Caribe C_3	CIMMYT	2387(8)					
13	Cortazar M-C_4	CIMMYT	2405(7)					
14	H-512	Kenya			9231(1)	4500(6)	6480(4)	7050(2)
15	Laltine	Iraq		1730(7)				
16	Eto Blanco	Colombia			6315(9)			5121(10)
17	Centralmex	Brazil	2499(6)	1934(4)		3936(10)	6214(6)	5630(8)
19	INIA H-507	México	2751(3)	1581(10)	6683(6)			
20	(USAxCarib. Comp.)	CIMMYT		1841(6)		4090(7)		
21	Comp. Norteameri-cano	Perú		2325(1)	6554(7)			
22	(Mix. 1 x Col. Gr. 1) (Eto Bl.)-C_6	CIMMYT	2870(1)				6058(8)	
23	H-613 B	Kenya		2158(2)	8206(2)		7225(2)	9009(1)
24	H. Abatí 2	Argentina		1879(5)				
26	Poey T-66	México	2537(4)				6053(9)	
27	Poey B-15	México			7350(4)		6134(7)	6889(3)
29	QK-37	Australia	2345(9)		7136(5)	5254(1)	7842(1)	6684(5)
30	Agroceres 501	Brazil				4980(2)	6685(3)	5810(7)
32	Comp. Res. Thrips	CIMMYT			6263(10)	4629(5)		
34	INIA H-507 E	México	2537(5)					
36	Nicarillo	Nicaragua	2332(10)					
42	Oax. 179	México		1618(9)				
43	Comp. L(ME)C_2	CIMMYT					6346(5)	
46	Fukko No. 8	Japan		1972(3)				
47	Vijay	India				4090(8)		
48	Comp. B(C_2)	CIMMYT		1637(8)				
	Local Variety		2114	893	6212	3705	4821	6188

* Numbers in parentheses indicate rank.

International Opaque-2 Maize Trials (IOMT)

These trials are designed to test materials produced by CIMMYT and those from many breeding programs around the world. The trials aid the many attempts being made to improve the quality and quantity of the protein in the maize kernel in order to improve diets in countries where maize is the chief food of the poor.

In 1970, opaque-2 maize trials were sent to 17 locations in 13 countries: Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica, Panamá, Brazil, Colombia, Philippines, México, India, Thailand and West Pakistan.

For 1971, the protein trials have been sent to 30 locations in 22 countries, including the ones mentioned before plus Venezuela, Perú, Argentina, United States, Iran, Egypt, Jamaica, Chile and Ghana.

Central American Cooperative Project for the Improvement of Basic Food Crops (PCCMCA)

This program, which has been successfully operating for several years, has also been integrated into the international testing network.

The program comprised yield trials of the series: BA (16 commercial hybrids), ME (35 commercial hybrids) and SCA (28 experimental single crosses).

Tables M33 to M36 summarize yield data collected at several locations in Central America and the Caribbean area.

TABLE M32. International Opaque-2 Maize Trial results, 1970.

Entry No.	Pedigree	Origin	Yield in kg/ha at 15% moisture					Average	Rank
			México	Costa Rica	Colombia	Thailand	Panamá		
18	Agroceres 501 (o_2o_2)	Brazil	6218	3342	7085	4178	2475	4660	2
25	ICA H208	Colombia	5327	2940	8022	3438	2288	4403	6
24	ICA H255	"	5415	2484	7403	4166	2957	4485	3
12	(Mix. 1 x Col. Gpo. 1 x Eto Bl. (o_2o_2)	México	4957	3099	7645	2765	2192	4132	12
4	La Posta (o_2o_2)	"	5089	3375	7649	3204	2714	4406	5
9	Cuba 11J-Eto Am.-PD(MS)6-Gr. Amar. (o_2o_2)	"	4970	3095	7721	3781	2693	4452	4
26	T-o_2-11	Poey H.	5045	2610	8783	2409	1640	4097	13
1	Nicarillo (o_2o_2)	México	4398	3162	7800	3003	2731	4219	11
8	PD(MS)6 x Gr. Amar. (o_2o_2)	"	4443	3237	8473	3061	2597	4362	8
13	Tux. x PD(MS)6 Sel. Amar. (o_2o_2)	"	4712	2702	7265	2417	2777	3975	15
16	Tux. x Ant. Gpo. 2 Sel. Bl. (o_2o_2)	"	4718	3091	8277	3070	2233	4278	9
17	Comp. Blanco Caribe (o_2o_2)	"	4562	2936	7474	2171	2409	3910	18
21	Comp. K(C_2)-o_2fl_2	"	4670	3421	7319	3605	2212	4245	10
5	Comp. Grano duro (o_2o_2)	"	4524	2844	7399	2882	2606	4051	14
7	Eto Amar. x Gr. Amar. (o_2o_2)	"	4085	2894	6750	3772	2376	3975	16
11	Tux. Cr. 1 (o_2o_2)	"	4279	3471	8708	3149	2380	4397	7
22	Ver. 181-Ant. Gpo. 2 (o_2o_2)	Thailand	3997	3296	5897	4203	2024	3883	19
14	Gr. Amar. x Cuba 11J (o_2o_2)	México	4154	2982	7160	2710	2727	3947	17
28	Comp. Jamaica (o_2o_2)	"	3865	2129	4743	2865	1163	2953	26
3	Antigua Gpo. 2 (o_2o_2)	"	3495	2622	5588	2472	2054	3246	23
2	Francés Largo (o_2o_2)	"	3545	2702	5086	2706	2463	3300	22
6	Eto Blanco (o_2o_2)	"	3683	2836	7403	2844	2442	3842	21
15	Población Cristalina (o_2o_2)	"	3514	2267	6478	1552	2087	3180	24
30	Normal (Check Variety)	"	4242	5019	8578	3952	2752	4909	1
10	Azteca Opaco	Nicaragua	3094	2049	5291	2706	1192	2866	27
23	Antigua 2 D (o_2o_2)	México	3106	1690	3601	1807	1054	2252	28
27	T-o_2-38	Poey H.	2993	——	5257	2376	1518	3036	25
20	Western white (o_2o_2)	Nigeria	1983	——	4111	1903	749	2187	29
29	Opaque-2 (Check Variety)	México	2089	4709	7574	3158	1815	3869	20
19	Opaque-2 dent	Pakistan	634	——	1071	837	——	847	30

TABLE M33. Yield (kg/ha) of grain with 15% moisture for the top 10 entries from the trials of commercially available hybrids, white or yellow kernels (average of 7 locations), Central America, 1970.

Variety	Origin	Yield
Pioneer XB-101	Jamaica	3611
H - 5	El Salvador	3445
Pioneer H -306	Jamaica	3431
Pioneer X -304	Jamaica	3398
H -101	El Salvador	3357
Poey T - 66	México	3139
Poey T - 23	México	3135
H - 1	El Salvador	3069
H - 3	El Salvador	3053
Pioneer X -302	Jamaica	2983

TABLE M34. Yield (kg/ha) of grain with 15% moisture for the top 8 entries from the trials of experimental hybrids (average of 5 locations), Central America, 1970.

Variety	Origin	Yield
Pioneer X -330	Jamaica	3593
Pioneer X -304A	Jamaica	3423
Poey T - 80	México	3404
Cuyuta H - 2	Guatemala	3320
Poey T - 84	México	3120
Poey T - 82	México	3069
Pioneer XB-103	Jamaica	2993
Poey T - 86	México	2867

TABLE M35. Yield (kg/ha) of grain with 15% moisture for the top 10 entries from the opaque-2 trials (average of 4 locations), Central America, 1970.

Variety	Origin	Yield
Comp. Bl. Caribe O_2	CIMMYT	2947
Comp. Jamaica x CIMMYT (1)	CIMMYT	2887
La Posta x CIMMYT (1)	CIMMYT	2882
(Mix. 1 x Col. Gpo. 1 Eto Bl x (1)	CIMMYT	2638
Etjo Am. x Gr. Am. x CIMMYT (1)	CIMMYT	2536
$PD(MS)_6$ x Gr. Sm. x CIMMYT (1)	CIMMYT	2534
Comp. Gr. Duro x CIMMYT (1)	CIMMYT	2501
Tuxp. Gr. I x CIMMYT (1)	CIMMYT	2361
(Tuxpeño x $PD(MS)_6$ Sel. Am. x (1)	CIMMYT	2342
(Gr. Am. x Cuba 11J) x (1)	CIMMYT	2321

TABLE M36. Yield (kg/ha) of grain with 15% moisture for the top 8 entries from the Central American trials (average of 4 locations, 1970).

Variety	Origin	Yield
Pioneer X-304	Jamaica	3500
Pioneer X-306	Jamaica	3320
(x) 216-3-3-1 x A6	CIMMYT	3142
(x) 119-1-1-1 x A6	CIMMYT	3100
Ant. Gpo. 2 (1) 606-2-1	CIMMYT	3068
(x) 606-2-1-1 x A6	CIMMYT	3039
Ant. Gpo. 2(x)3-1-4 x A6	CIMMYT	2970
Ant. Gpo. 2(x)606 x 526-2-2-1	CIMMYT	2949

Inter-Asian Corn Improvement Program (IACP)

This program seeks to foster cooperation between national research and production programs in 14 countries of Southeast Asia, as well as the exchange of ideas, information and germ plasm.

In 1970 IACP separated the varieties to be tested into two trials. Trial 1 consisted of varieties and hybrids from the nine temperate-like regions. Trial 2 entries were adapted to the lower tropical areas of Asia.

Fifty-five sets of trials were distributed to cooperators in 15 countries. Data were recorded for yield and other plant and kernel characteristics. The experimental results have been published in the "Summary Report of the 1970 IACP Uniform Yield Trials." Summaries for grain yield are listed in Tables M37 and M38.

If the relative success of an international testing program can be determined by the increased number of scientists and organizations participating, the International Maize Test-

TABLE M37. Yield (kg/ha) of grain with 15% moisture for the IACP Trial No. 1 (average of 17 locations, 1970).

Variety	Origin	Yield
Tuxpeño x Cornbelt Comp.	Pakistan	3498
Local Check		3423
DMR Composite # 1	Taiwan	3279
Cornbelt x Caribbean Comp.	Pakistan	3250
Tainan # 5	Taiwan	2857
J_1 x Cornbelt Composite	Pakistan	2718
Syn 2	Pakistan	2690
Syn 66	Pakistan	2360
Pandu	Indonesia	1821

TABLE M38. Yield (kg/ha) of grain with 15% moisture for the top 10 entries from IACP Trial No. 2 (average of 17 tests, 1970).

Variety	Origin	Yield
Vertig. x Cuba Gr. 1	Thailand	4067
Ganga 5	India	3986
UPCA VAR 1	Philippines	3960
Bogor Comp. 2	Indonesia	3936
Khumaltar Yellow	Nepal	3884
JML 236	India	3879
Expt. Hybrid 4207	India	3855
Local Check		3851
Ver. 181 x Ant. Gr. 2	Thailand	3788
Composite DI	India	3768

ing Program which CIMMYT helped organize will have to be considered very successful, not only because of the increase in cooperating parties, but also for the quality of the scientists involved in these activities and their increasing enthusiasm.

Other Activities

The International Maize Testing Program also includes disease and insect nurseries and activities to coordinate the many efforts made in these fields, following the same philosophy which guides our adaptation nurseries, protein trials and the remainder of our international testing program.

MAIZE TRAINING

CIMMYT's maize training program is considered an essential part of its outreach. Unless each maize growing country has the opportunity to develop a competent group of maize scientists for research within its country, and maize agronomists to assist with extension activities, there is no possibility of mounting the production programs which these countries require.

During 1971 there were 13 maize trainees from 10 countries undergoing up to one year of training at CIMMYT in breeding, production and farm management. There were also senior scientists, postdoctoral fellows, and predoctoral candidates in residence at CIMMYT for varying periods of time.

The Maize Plant Protection section has provided guidance, materials and facilities to nine Latin American graduate students for their M.S. work and to four Ph.D. candidates.

From its year of establishment in 1966, CIMMYT has received maize trainees, but in the early years these young scientists were assigned as assistants to a CIMMYT breeder, pathologist or agronomist. The results were good, but only a few trainees could be handled in this way.

In 1971 the program was reorganized to provide a full time training director, Dr. Alejandro Violic, who now manages a program for agronomists and research assistants. The trainees spend much time in the CIMMYT research fields and laboratories engaged in work such as the trainees will be expected to do on returning to their home countries. They also receive lectures and seminars conducted by CIMMYT staff to explain fundamental and basic techniques.

The maize trainees are provided experience in production not only on the research station but also in commercial maize yields. For example, CIMMYT trainees are working with a maize farm at an orphanage near CIMMYT headquarters, which supplies 300 kilograms of maize per day to 700 orphans. Here the trainee must learn to work within a limited budget and with insufficient equipment,

Trainees check field books to determine pollinations to be made.

and thus simulate the conditions of many maize growers in the trainees' home countries.

Through the Mexican national extension service, CIMMYT is arranging for the trainees to work with Mexican maize growers on private lands.

Other types of maize training for more advanced scholars at CIMMYT are:

Senior Scientist Travel Grants for Developing Countries: Up to two months for familiarizing selected scientists with CIMMYT methods.

Research Fellows: One or two years of research at CIMMYT for recent terminal degree holders who plan to work for a national or international organization.

Research Scholars: One to two years for graduate students who will work on their thesis problem under the direction of CIMMYT staff.

Agricultural Administrators: Up to two weeks for senior government officers at the decision-making level in national agricultural programs, to familiarize themselves with CIMMYT activities.

OUTREACH PROGRAM

CIMMYT measures the ultimate success of its maize program by the degree to which CIMMYT maize technology moves into national and regional programs, and the degree to which those programs are able to increase yields and the nutritional value of the maize crop, throughout the world, and especially in developing countries.

During 1970 and 1971 CIMMYT international trials of maize populations were grown in 47 countries. In the same two-year period, CIMMYT provided maize training in México for 33 government maize workers from 12 countries.

CIMMYT provided germ plasm, consulting visits and training for the following regional maize programs which involve a total of 31 participating governments.

World Regional Maize Improvement Programs to Which CIMMYT Serves as Consultant.

Program	Number of participating governments
1. Central American Maize Program	6
2. Andean Maize Program (headquarters at CIAT, Cali, Colombia)	5
3. West African Maize Program (headquarters at IITA, Ibadan, Nigeria)	4
4. East African Maize Program (headquarters at Kitale, Kenya)	4
5. East Asian Maize Program (headquarters Bangkok)	12
Total	31

CIMMYT's relationship to regional programs is that of consultant and supplier of germ plasm, test nurseries and training. Within each of the above regional programs there is a regional testing program and annual workshop. CIMMYT staff participate in these activities.

Besides regional outreach, CIMMYT works directly with some national projects, either by recurring visits of CIMMYT consultants or by stationing resident CIMMYT members in those countries. Such cooperation includes Pakistan, India, Nepal, Egypt and Zaire.

CIMMYT has a staff member in Pakistan who assists with the national maize programs. Dr. Takumi Izuno and his Pakistani colleagues work very closely with IACP and with CIMMYT.

Another CIMMYT staff member, Dr. N.L. Dhawan, is stationed in Egypt to work directly with the national program and to provide assistance to national programs in neighboring countries.

Arrangements are being worked out to station three CIMMYT staff members in Zaire, one in Nepal and several in other countries in Asia and Africa to assist in the establishment of national maize improvement programs. These activities, besides fulfilling their primary function of helping build strong national programs, enable the CIMMYT staff to extend specific assistance to other countries with similar environmental conditions.

PAKISTAN

During 1970-71 two of the four provincial governments of West Pakistan decided to embark upon a five-year program of upgrading their hybrid maize seed production units into maize and millet research institutes with CIMMYT technical assistance and with funding from the Ford Foundation and the Norwegian Agency for International Development. A third province, encouraged by its potential for maize production as indicated by the winter maize nurseries planted there during the last two years, decided to establish a maize and millet section within its provincial agricultural research institute.

Basically, the plans are: (1) to develop teams composed of breeders, agronomists, plant pathologists, entomologists, a cereal technologist, a seed production specialist and an economist-statistician; (2) to provide pertinent, practical training for the teams, either at the IACP Training Center in Thailand, at CIMMYT in México, or in the United States; and (3) to equip them properly so that they will develop and disseminate materials for increasing maize and millet production in their respective provinces.

Three Pakistani breeders and two agronomists were sent to the United States for advanced degrees during the last few years. One of them has returned and the remainder will return within two years to greatly augment staff capabilities.

Maize production has fluctuated in the past five years between 620,000 and 800,000 tons (due mainly to weather conditions) on 650,000 hectares. The final figures for 1971 are expected to remain within that range. The overall impact of the accelerated maize improvement project on production (begun in 1968) is now beginning to be felt in the west Punjab where about 40 percent of the maize acreage is planted to improved varieties, and in the Northwest Frontier Province where the corresponding figure is 15 percent.

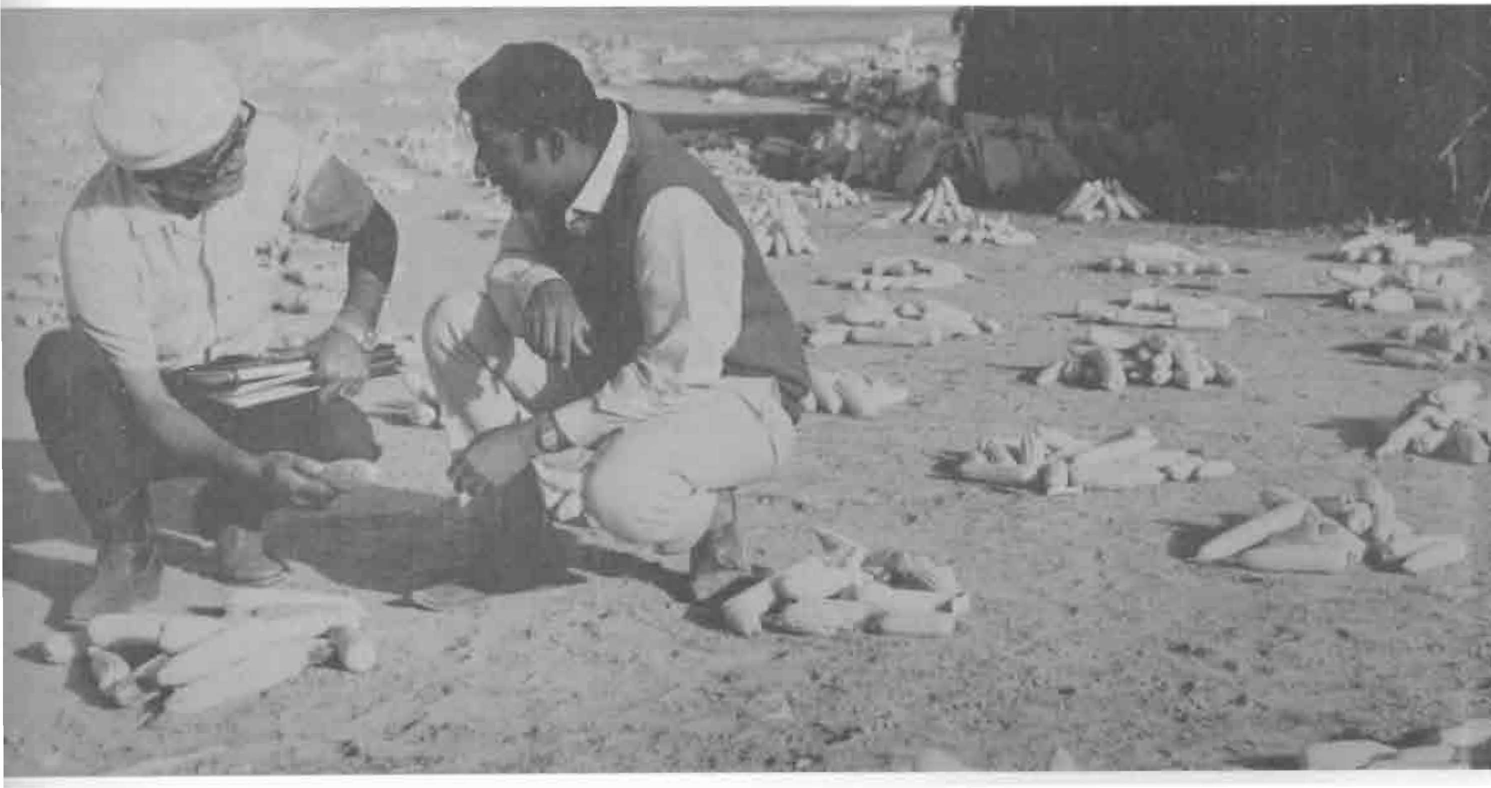
The significant development during the year was the total conversion of the government operated seed production units from the hybrid seed production programs utilizing large inbred lines imported from the United States many years ago to the production of open-pollinated, broad based composite varieties developed during the last three years.

Since West Pakistan lies just outside the tropics at 25° to 37° North latitude with most of the rainfall coming during the summer months (inadequate in quantity and distribution), the breeding program has emphasized crossing temperate and tropical materials and backcrossing to the temperate. In this way, several high-yielding composites have been developed for production under irrigated conditions.

These composites include, primarily, Tuxpeño, Antigua, Caribbean Composite, and Eto Blanco from the tropics and elite inbred lines from the central U.S. Corn Belt. Seed production of these composites during the summer of 1971 was done on 400 hectares on government farms and 500 hectares on farmers' fields.

Plant introductions made in 1969-70 from CIMMYT, the USDA's North Central Plant Introduction Station, IACP cooperators and from commercial sources, were crossed with one

Dr. T. Izuno and colleague select ears at Pirsbak, Pakistan.



of the basic composites (Akbar). Yield trials were conducted during two seasons in 1971 at three locations. These materials, now available in the F_1 and F_2 generations, offer a complete range of conceivably useful choices of maturity, kernel characteristics and plant types. They ranged in yield from 50 to 150 percent of Akbar when grown under irrigated conditions. When compared to local varieties, yields were doubled and 20 to 25 percent later. How these new varieties will perform under natural rainfall conditions, which constitute 40 percent of the maize acreage, will be tested in 1972.

With the demand for maize for feed and industrial purposes increasing faster than the supply, the price of US$95-100 per metric ton is presently attractive enough without a government support price. The cooperation developed during the past several years between the research and extension services in extending the results from the maize research stations should go a long way toward increasing production during the next year as long as fertilizer, water and pesticides can be made available.

The availability of inputs and educating the growers as to their proper use appear to be the remaining hindrances to a marked increase in production. Arrangements are being made to station a second CIMMYT staff member, a production agronomist, in Pakistan during 1972 to provide leadership in this next step toward increased production.

Dr. Joginder Singh examines some representative ears from the Indian maize breeding program.

INDIA

Though CIMMYT does not have a staff member stationed in India, the steady flow of germ plasm continues and close ties are maintained with the national program by the postdoctoral fellow and visiting scientists programs at CIMMYT in México.

During 1969-70, maize production in India registered a spectacular 30 percent increase from 5.67 million tons to a record 7.41 million tons. Increasing availability and use of fertilizer and water, and seed of improved, open-pollinated varieties based on germ plasm from the southern United States, México, the Caribbean, and South America, enabled farmers to set the yield record during an average growing season, surpassing the previous high of 6.27 million tons obtained in the very favorable 1967 season.

The 7.41 million tons produced in 1970 represents an 82 percent increase in total yield, and a 53 percent increase in average yield per hectare of the preceding decade with most of the increase during the last five years as the national programs succeeded in developing and propagating disease-resistant, insect-tolerant, full-season, open-pollinated varieties based primarily on germ plasm supplied by the CIMMYT maize program.

Varieties bred in India are now moving into neighboring countries through IACP for use as advanced breeding materials or for direct adoption.

EGYPT

High-Yielding Varieties

The immediate objectives of the cooperative Egyptian Maize Improvement Program were to develop high-yielding, disease-resistant varieties responsive to fertilizer and appropriate soil and water management practices. The aim was to obtain a significant-breakthrough in maize yields. To achieve this, a composite approach to varietal improvement was implemented.

A total of 300 newly developed germ plasm complexes and composite varieties were tested at the Sids and Gemiza experiment stations. Yield data on certain of the outstanding complexes are presented in Table M39. The top performing population (Synthetic La Posta x American Early) produced a mean grain yield of 13.7 tons/ha in the F_1 generation. This yield was 51 percent and 54 percent more than the locally cultivated variety American Early and the double cross hybrid Giza 186, respectively. The F_2 generation of the cross was also significantly higher yielding than the two checks.

The outstanding complexes will again be tested in the 1971-72 crop season, along with other newly developed populations.

TABLE M39. Grain yield (tons/ha) at 15 percent moisture of outstanding F_1 variety crosses and their F_2 progeny, mean for two locations, Egypt, 1970-71.

Pedigree	$\frac{F_1}{F_2}$ yield	F_2 as % of F_1	$\frac{F_1}{F_2}$ as % of Giza D.C. Hybrid 186
Syn. La Posta x AE*	13.7 / 10.7	78	154 / 120
Tep 5 x AE	12.0 / 10.0	83	134 / 112
Mex. June x AE	10.7 / 9.3	87	120 / 104
Syn. La Posta x (Ant 2D x AE F_2)	10.1 / 8.9	93	113 / 100
Kitale Syn x (Ant. 2D x AE F_2)	9.6 / 9.8	102	107 / 110
AE (check)	9.1	—	—
Giza 186	8.9	—	—

* AE: American Early.

Screening for Resistance to Late Wilt Disease

A wide spectrum of base varieties from different areas of the world were screened for resistance to late wilt disease *(Cephalosporium maydis)* under field conditions (wilt sick soil) and in the laboratory under artificial infection. Sources offering a certain measure of resistance are listed.

Variety	Origin
Shebein El-Koum 82	Egypt
Hickory King	USA
PI221845	USA
Helminthosporium Comp.	USA
Tep 5	México
Tep 6	México
Ver 122	México
Ver 132	México
Tamps 51	México
Chapalote (Sinaloa)	México
Kitale Syn. 11	Kenya
Potshetstross Pearl	Spain

Some of the resistant sources form parents of the germ plasm complexes developed in the country.

Winter Nursery

A very successful winter maize nursery was grown for the first time in Egypt in November 1968 and is now a regular feature of the Maize Improvement Project. This has considerably accelerated the varietal development program.

Development of Experiment Stations and Production Techniques

With the help of agricultural machinery brought into the country, the experiment fields at Sids and Gemiza have been reshaped and levelled, and a drainage and siphon irrigation system installed. Considerable effort was expended in obtaining uniform plant stands, control over quantity of water applied, eradication of weeds and uniform application of chemical fertilizers.

The data obtained from the experiments demonstrated two salient aspects of the new management system and production technique. First, the overall yield increased by about 25 percent. Secondly, while the coefficient of variability (CV) was from 25 to 35 percent in trials carried out previously, under the improved cultural operations, the CV was reduced to between 8 and 15 percent. This indicates that the maize scientists could now justifiably place more confidence in the data obtained from their field experiments.

Development of Cold Storage Facilities

Storage facilities for valuable maize germ plasm was previously virtually absent. Now insect- and rat-proof, air-conditioned seed storage has been constructed and put into operation at Sids and Gemiza, and at the headquarters of the maize program at Giza. A walk-in cold room for long-term storage of a small world collection of important varieties is also functioning.

Expanded Research and Production

With the expansion of the varietal base and a significant increase of the existing yield plateau, the project is nearly ready to recommend the release of a few new varieties and a package of practices for their cultivation.

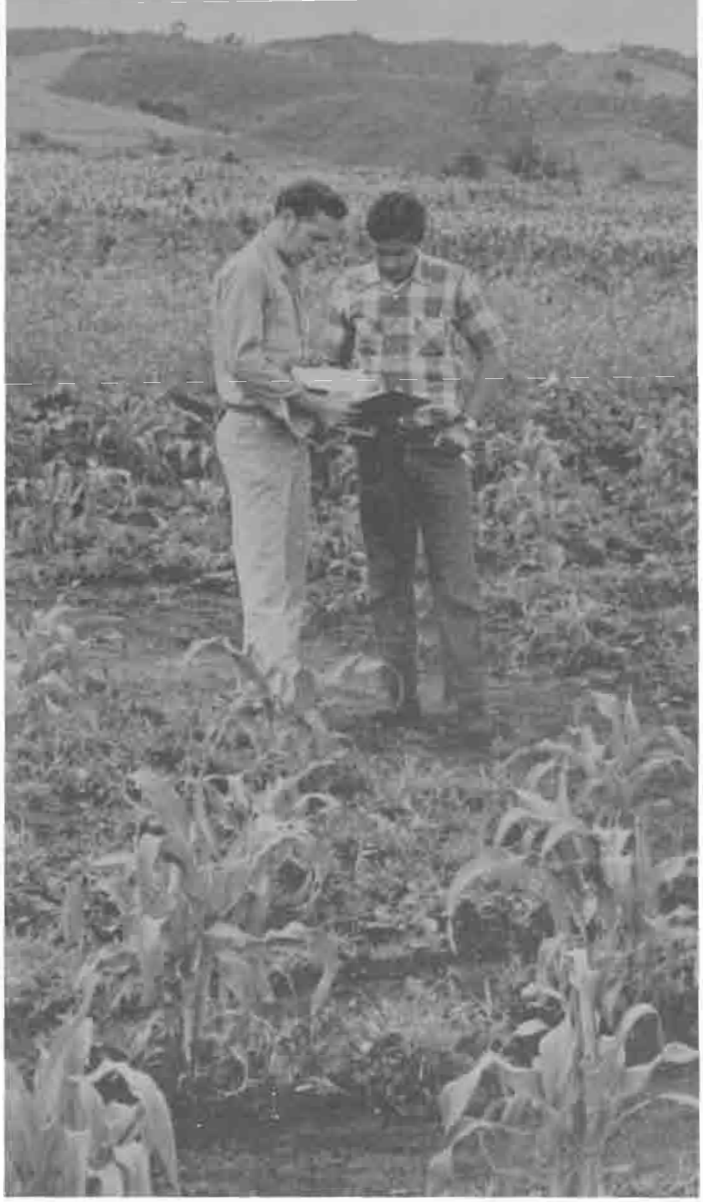
Training

Several young Egyptian maize scientists have completed a training program at CIMMYT, México. The group of young Egyptian scientists in the project now constitute a well-knit team of dedicated researchers who are providing excellent leadership.

THE PUEBLA PROJECT AND RELATED ACTIVITIES

This program began in 1967 with a pilot study, the Puebla Project, in cooperation with the Mexican Ministry of Agriculture, the state of Puebla and the Graduate College of the National School of Agriculture at Chapingo. This project is basically an experiment to develop and test strategies for rapidly increasing maize yields among small farmers producing at subsistence levels with traditional methods. It is located in the northwestern part of the state of Puebla in an area comprising 116,000 hectares of cultivated land and 47,500 farmers. It is operated by a small team of agronomists that develops packages of recommended practices for farmers from information generated in field trials conducted in the project area, extends new information immediately to the farmers, assists farmers in obtaining credit, fertilizers, etc., and studies the agronomic, social and economic factors influencing farmer utilization of modern technology.

Progress in the Puebla Project has been gratifying, if not as rapid as originally hoped. By 1969 there were 2,561 participating farmers with 5,838 hectares of maize managed according to project recommendations. Also, by this time much had been learned about how to conduct research in such an area, how to contact, inform, organize and assist farmers, and how to coordinate activities of the farmers, team members, and agricultural agencies serving the farmers.



Two researchers discuss a field study comparing several cropping systems in the Oriente Antioqueño Project.

Consequently, in late 1969, the decision was made to promote similar production programs in other regions of México and Latin America. Funding was made available for this activity in early 1970 by a United Nations Development Program grant to support the development and utilization of high-lysine maize varieties. Visits were made to Bolivia, Colombia, Ecuador and Perú to inform agricultural and political leaders about the Puebla Project and encourage them to study the feasibility of similar programs in their countries. Many people from México and other countries were informed about the Puebla Project in visits to the area. Two international conferences in Puebla in August 1970 were attended by representatives of 15 Latin American countries and 15 international development organizations to study strategies for increasing production on small holdings as used in the Puebla Project and other operating programs.

In early 1970 agricultural leaders in Colombia decided to move ahead in the development of a producton program similar to the Puebla Project. Five Colombian agronomists arrived in México in July 1970 for a two-year training experience, including an M.S. degree at the Graduate College at Chapingo and in-service training in the Puebla Project. Three other Colombians received training in the Puebla Project for several months in the fall of 1970. Three regions—Oriente Antioqueño, Caqueza and García Province—were carefully considered as possible project areas before selecting the first in late 1970. The Oriente Antioqueño Project began field operations in January 1971.

An extension specialists for the Cajamarca-La Libertad Project explains to farmers their duties in assisting the installation of an experiment.

Peruvian leaders also decided in early 1970 to initiate a production program. A Peruvian agronomist, with an M.S. degree in communications from the Graduate College at Chapingo and experience in the Puebla Project, made a study in the fall of 1970 of four possible project areas: Cuzco, Mantaro Valley, Callejón de Huaylas and Cajamarca-La Libertad departments. In December the Cajamarca-La Libertad area was selected for the production program. Four Peruvian agronomists arrived in México in February 1971 for six months of in-service training at CIMMYT. Field activities in the project area began in September 1971.

In Honduras a crop production program was initiated in late 1970 in the Francisco Morazán department. A Honduras agronomist with training in communications at the Graduate College at Chapingo and experience in the Puebla Project was named coordinator of the program. Field activities began in May 1971 with the installation of maize experiments. CIMMYT is providing technical assistance to the program and will help train personnel.

Two new production programs were initiated in México in early 1971. These are located in the states of México and Tlaxcala. Three former members of the Puebla Project are participating in these programs. CIMMYT is providing technical assistance and some of the personnel for these programs are being trained at the Communications Department of the Graduate College at Chapingo and in the Puebla Project.

Progress in the Puebla Project

The Puebla Project has continued with activities oriented toward accomplishing three objectives: (1) assist farmers in the project area to increase their maize yields; (2) understand better what is needed to achieve rapid increases in yields; and (3) train people for carrying out similar programs in other areas.

A basic strategy of the Project has been to conduct within the area the adaptive research needed in generating reliable packages of

Installation of a maize experiment in the Siria Valley, Francisco Morazan, Honduras.

production practices. Recommendations for maize on rates and time of applying fertilizers, plant density and dates of planting are presently available for 15 different production conditions in the area. Careful use of these recommendations is resulting in higher yields and lower production costs. The research program was expanded in 1970 to include beans, the second most important crop in the area. Recommendations on varieties and production practices were made available to farmers in 1971.

The number of farmers participating directly in the Project continues to increase. They are organized into groups and receive technical assistance from the Project team and production credit through public and private institutions. The number of participating farmers has increased from 2,561 in 1969 to 4,833 in 1970 to 5,240 in 1971. The number of hectares planted by these farmers were 5,642 in 1969, 12,500 in 1970 and 14,438 in 1971.

The amount of credit provided to participating farmers was US$447,713 in 1969, U.S.$795, 273 in 1970 and US$608,068 in 1971. The reduction in credit in 1971 as compared to 1970 was due primarily to three things: (1) fertilizer costs were lower in 1971, which resulted in a shortage of fertilizer in the project area; (2) a larger proportion of the plantings in 1971 was made in Zone 5, the part of the project area where only nitrogenous fertilizer is needed, and (3) dry weather at the beginning of the crop season.

The second stage in the evaluation of progress in the Project was planned and carried out in 1971. Interviews were conducted with 550 farmers, including both participants and nonparticipants. Dr. Delbert T. Myren, US Agency for International Development, and Ing. Heliodoro Díaz, doctoral candidate at the University of Wisconsin, collaborated in managing the evaluation study. Information was collected in the interviews that will permit the evaluation of the changes that have occurred since 1967 in the three participants sectors—farmers, institutions and team members.

Training

The Puebla Project and the Communications Department of the Graduate College at Chapingo are training agronomists for regional production programs similar to the Puebla Project. On arrival in Mexico, trainees are given a general orientation on the philosophy, objectives, organization and operation of production programs. If their training period is for six months or more, the trainees assume responsibility for a specific role in the Puebla Project and function as a member of the Project team. About 90 percent of their time is devoted to direct participation in Puebla Project activities and the remainder to seminars and reading on related subjects. Two-year trainees work toward an M.S. degree at the Graduate College at Chapingo and receive in-service training in the Puebla Project. Trainees may specialize either in applied research activities directed toward generating information on crop production practices or in coordination, organization, extension and evaluation activities.

Farmers participating in the Puebla Project hear an explanation of the effects of fertilizer on maize yields at a field day.

COMMUNICATIONS

INDEX

INTRODUCTION

The Communications Program contributes to CIMMYT's work in maize and wheat improvement with the following activities:

1. Editing CIMMYT printed publications and assembling mailing lists.
2. Preparing audiovisual materials required for CIMMYT programs, including still photographs, slides and motion pictures.
3. Distributing information about CIMMYT to special audiences including: the worldwide network of maize and wheat scientists, scientists and the general public visiting CIMMYT in México, government agencies of México and the press.
4. Participating in CIMMYT maize and wheat production programs by supervising international trainees in agricultural communications and advising on extension methods for Plan Puebla.

During the year the Communications staff helped prepare the following publications written by CIMMYT scientists:

Research Series

No. 15, Results of the Third International Spring Wheat Yield Nurseries, 1966-67 (1970)

No. 16, Results of the First and Second International Screening Nurseries, 1967-69 (1970)

No. 17, Progress in Developing Triticales as an Economic Crop (1971)

No. 18, Results of the Fourth International Spring Wheat Yield Nursery, 1967-68 (1971)

No. 19, Results of the Fifth Spring Wheat Yield Nursery, 1968-69 (1971)

No. 20, Chemical Screening Methods for Maize Protein Quality at CIMMYT (1971)

No. 21, A Survey on Leaf Rust Resistance in the USDA World Durum Collection (1971)

No. 22, Results of the Third International Bread Wheat Screening Nurseries (Series A and B), 1969-70 (1971)

Special Publications

CIMMYT Annual Report 1969-70 (English and Spanish)

Strategies for Increasing Agricultural Productivity on Small Holdings (English and Spanish)

The Rockefeller Foundation Program in Corn and Wheat in México (English and Spanish)

CIMMYT. An inauguration brochure.

Proceedings of the First Maize Workshop

Proceedings of the First Wheat Workshop

Materials for International Nurseries Collaborators

Seedling and Adult Plant Response to Stem Rust for the 7th International Spring Wheat Yield Nursery 1970-71, August 1970

Seedling Response to Stem Rust for the Second International Durum Yield Nursery 1970-71, August 1970

Preliminary Summary of the First International Elite Selection Yield Trials (1 and 2). A Spring Wheat Yield Nursery, 1969-70.

Report on the Identification of Stem and Leaf Rust Resistance for the Fourth International Screening Nursery (A) 1970-71, November 1970

Preliminary Summary of the First International Durum Yield Nursery, 1969-70, March 1971.

Instructions for the Management of the International Spring Wheat Yield Nursery (ISWYN), (1970)

Instructions for the Management of the International Triticale Yield Nursery (ITYN), (1970)

Instructions for the Management of the International Durum Yield Nursery (IDYN), (1970)

Instrucciones para el Manejo del Ensayo Internacional de Adaptación de Maiz (IMAN)

Seedling and Adult Plant Response to Stem Rust for the Second Elite Selection Yield Trials 1 and 2, 1970-71 (1971)

Grain Quality Data on the Entries in the Fifth International Bread Wheat Screening Nursery, 1971 (1971)

Instructions for the Management of the International Yield Nurseries: Spring Wheat (ISWYN), Durum (IDYN), Triticale (ITYN). 2nd printing (1971)

CIMMYT News

CIMMYT News Vol. 5, No. 9-10, 1970

CIMMYT News Vol. 5, No. 11-12, 1970

Materials for the Puebla Project

Circular letters for farmers ("El Plan Puebla Informa", 5 issues) Reports for the annual meeting (1971)

Training Manuals

Training manuals prepared by CIMMYT wheat staff, to guide the work of wheat trainees, were translated and published.

Reprints

CIMMYT reproduced and distributed to its mailing lists some outside publications on CIMMYT work, including:

"Norman E. Borlaug, Hunter Fighter," by Dr. Don Paalberg, USDA. "The Father of the Green Revolution," from Reader Digest, English and Spanish.

Mailing Lists

CIMMYT mailing lists now include 5,867 names of individuals, institutions and libraries in 114 countries. The distribution by region is as follows:

United States and Canada	1,707
México	795
Central America and Caribbean	410
South America	1,454
Europe	374
Middle East and Near East	155
Africa	229
Asia	642
Australia and New Zealand	101
	5,867

Audiovisual Materials

A new movie, *La Caja de Ahorros* (The Savings Association), was completed in 1971. This is a 12 minute, 16mm color film narrated in Spanish. Based on this movie, a slide set was also prepared. This movie deals with small farmers participating in the Puebla Project and the benefits they obtain from increased maize yields. It is intended for use in Plan Puebla as motivational material.

The following movies and slide sets were in preparation at the end of 1971.

1. *Collection and Inoculation of Rust in the Greenhouse:* Intended for trainees and technicians, it shows how to collect rust, how to inoculate, how to read the severity of the attack, and how to identify rusts according to Stackman tables and Loegering tables.

2. *Collection and Inoculation of Rusts in the Field:* Intended for trainees and technicians, it shows inoculation techniques and reactions in different wheat materials.

3. *CIMMYT Training:* It shows activities performed by CIMMYT maize and wheat trainees.

4. *Increasing Productivity Among Small Holders:* Based on the Puebla Project, this movie shows research methodology in Plan Puebla, the participation of farmers and credit institutions, and how coordinated work brings results.

CIMMYT audiovisual materials are in wide use. Copies of the movie and slide set *How to Emascualte and Pollinate Wheat* have been sold to Denmark, United States, Lebanon, Canada, Iran and Colombia. Copies of the slide set *Diseases of Wheat* have been sold to Morocco, Tunisia, Brazil, Korea, Ethiopia, Turkey,

CIMMYT staff provide communication skills training to graduate students and trainees. Communication skills are an important tool for both extension and research workers.

Jordan, Egypt and Syria. Copies of *Field Technique for Fertilizer Experiments* have been sold to Trinidad and United States. This movie is now used in México and Colombia.

Cooperation with Other Media

CIMMYT cooperates with mass media interested in reproducing or adapting CIMMYT informational materials.

Requests were especially numerous following the nomination of Dr. Norman E. Borlaug as Nobel Peace Prize Laureate in December 1970. This event centered worldwide attention upon CIMMYT, and the Communication Program received requests for information from all over the world, and there was a harvest of magazine and newspapers articles, and TV and movie reports on CIMMYT work.

Academic Training in Communications

The Communications staff continue to assist the Graduate School of Agriculture at Chapingo. During the year, five CIMMYT fellowship holders completed their M.S. degrees in communications at Chapingo—one Peruvian, one Mexican and three Colombians. Their theses were directed by CIMMYT staff. Two CIMMYT fellowship holders completed one year of nondegree training at Chapingo, one from Honduras and one from Uruguay.

Library Services

The CIMMYT library has been enlarged with journals and books. Acquisitions are reported through a special sheet issued every two weeks.

Visitors to New CIMMYT Headquarters

After inauguration of the new CIMMYT headquarters at El Batán, 45 kilometers outside México City in September 1971, the number of visitors to CIMMYT rose steadily, and reached a rate, calculated on an annual basis of more than 3,000 per year by the end of 1971.

The Communications staff is helping to prepare booklets, charts and museum-type displays to enable CIMMYT to give proper attention to these visitors, with minimum disruption to the work of the CIMMYT scientists in the headquarters offices, laboratories and research fields.

1971 CIMMYT FUNDING

I. Core Operations, Unrestricted Funds[1]		
A. Income for 1971:		
Operating funds carried over from previous years (1-1-71)		US$ 90,000
Ford Foundation grant		750,000
Rockefeller Foundation grant		740,000
US AID grant		769,000
Income from administrative charges on special grants, and sales		240,000
	Sub-Total	2,589,000
B. Expenses for 1971:		
Wheat		686,000
Maize		636,000
Experiment Stations		304,000
Information Services		135,000
General Service Laboratories		80,000
Library		12,000
General Administration		659,000
	Sub-Total	2,512,000
C. Operating Funds carried to 1972: (A minus B)		77,000
II. Core operations from Restricted Grants, Actual Expenses[2]		
A. Maize Protein Quality, UNDP Global I contract		343,000
B. Triticale research, Canadian Government grant		82,000
C. Puebla Project in Mexico		
a) Rockefeller Foundation (3 grants)		116,000
b) Ford Foundation		2,000
D. Protein Quality Laboratory, Rockefeller Foundation grant		16,000
E. Winter Wheat Project, Rockefeller Foundation grant		39,000
F. Seven miscellaneous projects, Rockefeller Foundation		55,000
	Total	653,000
III. Capital Expenditures, 1971		
A. El Batán construction, Rockefeller Foundation grants		1,581,000
B. Experiment stations development, Rockefeller Foundation grant		275,000
	Total	1,856,000
IV. Outreach Program (Funded by individual grants from the listed sponsors, showing actual expenditures in 1971).		
A. Wheat		
a) North Africa, Ford Foundation		342,000
b) North Africa, US AID		159,000
c) Turkey, Rockefeller Foundation (3 grants)		46,000
B. Maize		
a) Argentina, Ford Foundation		17,000
b) Central America, Rockefeller Foundation		13,000
c) Egypt, Ford Foundation		31,000
d) Zaire Government Project		26,000
C. Maize and Wheat		
Pakistan, Ford Foundation		142,000
D. Training		
a) Eight special grants, Ford Foundation		17,000
b) Government of Ecuador Training Grant		3,000
c) Inter-American Development Bank (BID) grant		72,000
d) M.S. Latin America Scholar Program, Rockefeller Foundation		29,000
	Total (A-D)	897,000
V. Other Grants for Purposes Specified by Donor		
Potato projects, Rockefeller Foundation		143,000

[1] Unrestricted Funds: Funds available for core operations without restriction as to use, within the budget as approved by CIMMYT Trustees.

[2] Restricted Funds: grants from donors limited to an activity specified by the donor.