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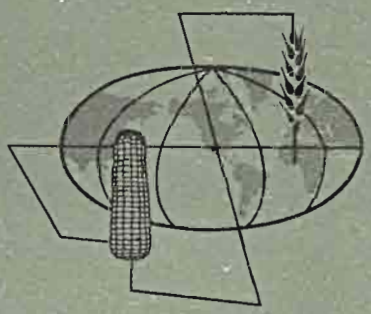
1969-70 / REPORT

ON PROGRESS TOWARD INCREASING YIELDS OF MAIZE AND WHEAT



Annual Report 1969-1970

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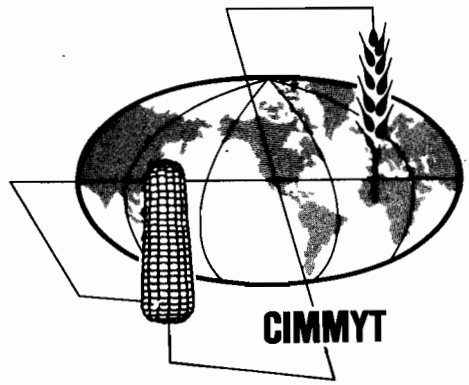

CIMMYT is an autonomous, international research institution which has evolved from crop improvement work begun in Mexico more than 25 years ago. The Government of Mexico is a participating sponsor and provides part of the land and various facilities.

Financial support for general operating expenses and special programs come from the Ford and Rockefeller Foundations, the U.S. Agency for International Development, the United Nations Development Program and the Inter American Development Bank. CIMMYT conducts research in wheat and corn, and is an international training center for scientists concerned with these crops.

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Introduction

Throughout the developing world during the past decade, maize and wheat production has advanced as never before. In Mexico, for example, average yields of wheat progressed from about 2,200 kg/ha in 1960 to 3,200 in 1969-70. Maize production was increased from about six million tons in 1960 to almost nine million in 1968, years with comparable rainfall.

With high yielding varieties and production technology imported from Mexico, Pakistan raised its wheat production from 4.6 million tons in 1964-65 to about 8.4 million tons in 1969-70. Similarly, India increased production from 12 million tons in 1965, to over 20 million in 1970.

These phenomenal successes have been referred to as the Green Revolution and have stimulated other countries to greater activity with hopes of becoming self sufficient in their basic food grains.

From Pakistan, the CIMMYT-Mexican varieties and technology have spread rapidly into Afghanistan. Turkey, with seed imported directly from Mexico, almost doubled production in the spring wheat Mediterranean coastal area over a four year period.

Iran is considering importing large quantities of INIA 66 seed for the coming crop year. A report from Tunisia indicates that 50 percent of the total soft wheat production was produced by CIMMYT-Mexican varieties planted on only 19 percent of the total acreage. Morocco claims similar results. Algeria planted the CIMMYT-Mexican varieties for the first time this past season, with striking success, and hopes to expand acreage as rapidly as seed supplies will permit.

In Europe, Denmark is producing large quantities of some CIMMYT-Mexican varieties and has become an important seed distribution center for other parts of Europe, the Near East and North African regions.

In Latin America, Ecuador, Peru and Bolivia have organized production programs based on the Colombian and CIMMYT-Mexican varieties with the hope of reaching self sufficiency in a few years. As a result of these expanded activities, the total area planted to the improved varieties has grown from about 800,000 hectares in 1964 to about 8 million in 1969, representing 10 times the total acreage planted to wheat in Mexico. During the 4 year period from 1965-1968, Mexico exported approximately 100,000 tons of seed —most of it going to India, Pakistan and Turkey. This represents the largest transfer of seed from one region to another ever recorded.

In the early stages of CIMMYT's International Maize Program, the breeders concentrated on the identification and isolation of the outstanding germ plasm complexes from about 200 races collected and described in Latin America. Six races were finally isolated; namely, Tuxpeño (Mexico), Cuban Flint (Cuba), Coastal Tropical Flint (West Indies), Salvadoreño (El Salvador), Eto (Colombia) and U.S. corn-belt synthetic variety. These have been widely distributed throughout the lowland tropics, singly and in various combinations. The pay off has been enormous.

The varieties developed from the various mixtures of these complexes are revolutionizing maize production around the world in the tropics and sub-tropics from 0 to 1,000 meter elevations.

In Central America the new surge in production is primarily coming from the high yielding Tuxpeño-Salvadoreño hybrids and varieties. In Venezuela, the high yielding varieties and hybrids are largely Tuxpeño-Eto combinations. In Colombia, the good varieties for intermediate elevations were mostly derived from combinations of Eto X Caribbean Flint-dents. In the lowlands of Colombia, Ecuador, Peru and Bolivia, new lands are being planted with varieties developed from the Tuxpeño-Caribbean Flint composites. In Peru, hybrids developed from these materials have flourished in the coastal irrigated areas and are responsible for the rapid development of poultry industry, meat and egg production. In the lowlands of Bolivia, a Caribbean composite is being grown widely, as made up by CIMMYT.

An outstanding example of the value of exotic germ plasm has been demonstrated in Brazil. There, the first hybrids were made from the local flints in the early 1940's with

yields 25 to 30 percent higher than the better open-pollinated varieties of this type. Yields have climbed steadily since then, first with the incorporation of germ plasm from the variety Tuxpan (Texas), next with a yellow Tuxpeño from Mexico, and finally with the introduction of a number of Caribbean composites developed by CIMMYT. Yield potential of the present hybrids is more than double that of the first hybrids. And, perhaps most important of all, open-pollinated varieties have been developed from the latest CIMMYT materials which equal or better the yields of the hybrids.

In Argentina, it appears that the new composites made up from mixtures of local flints, Caribbean flints and corn belt dents, will raise yield levels to new highs.

Striking advances have been made with new germ plasm mixtures in Southern and South East Asia and in Tropical Africa. Thailand is expanding acreage in the lowland tropics and production is increasing at the rate of 100,000 tons per year. India has increased production by 50 percent in the last five or six years. Pakistan increased production by 30 percent last year.

On the African continent, East Africa recently has become self-sufficient in corn production, using highland varieties developed from a combination of Kenya flat white with varieties introduced from the highlands of Ecuador and Costa Rica in a cooperative program with CIMMYT. This combination raised yield levels by 40 percent. In the East Africa lowlands, varieties developed by CIMMYT for Central America have shown themselves to be well adapted and much superior in yield to native materials.

In West Tropical Africa, the Tuxpeño varieties and the Tuxpeño-Caribbean composite derivatives are rapidly replacing all other varieties.

New high-yielding varieties are being developed in Egypt through a cooperative program with CIMMYT using a wide-base germ plasm complex including the Tuxpeño types of Northern Mexico. This breeding work is the first step in a long range program for doubling maize production in Egypt.

The tremendous advances made throughout the tropics and sub-tropics in the production of maize and wheat can be attributed for the most part to a combination of three principal factors: (1) the development and utilization of high yielding disease resistant varieties; (2) the development and use of a package of improved agronomic practices including better seeding rates and more adequate use of the right kind of fertilizer, and (3) a favorable relationship between the cost of the inputs and the price the farmer receives for his product.

With differences of 50 to 100 percent in yield and profits between the new technology and the old, adoption has spread very rapidly among the commercial farmers. This is especially true in regions under irrigation, or with generally adequate and good rainfall distribution, where risks tend to be lowest. With controllable good moisture conditions, the extension of the new science-based technology has been almost "auto-catalytic" clearly demonstrating that the acceleration of production is not so much a question of changing a farmer's old traditional methods, customs and attitudes, but more a matter of giving him a technological package with which he can make a profit. The bigger the profit, the faster the technology moves.

Without doubt, the basic technological factors sparking the Green Revolution have been the high-yielding, widely-adapted disease-resistant, fertilizer-responsive varieties. In maize, this variety does not have to be a hybrid, it could be a good open-pollinated variety highly responsive to improved scientific production techniques.

If the Green Revolution is to extend further, the breeding programs must be reinforced. There are many areas for which no improved varieties are available as yet. Also, in areas where improved varieties are being distributed, new materials will be needed periodically to combat the ever changing complex of diseases. CIMMYT, therefore, will continue to focus major attention on varietal development.

In order to meet expanding requirements, the wheat breeding work has been highly internationalized. CIMMYT breeders have gone into partnership with national breeders throughout the world in an attempt to develop varieties needed for 50 million hectares grown in Latin America, North Africa, Turkey, the Near East, Afghanistan, India and Pakistan.

Climates, diseases and agronomic practices vary immensely over this vast region. The main regional cooperative substations for breeding, production-oriented field research, and demonstration programs, are located in Argentina, Brazil, North Africa (with central axis in Tunisia) Lebanon, Turkey, India and Pakistan. A system of international nurseries has been designed and put into operation whereby thousands of segregating families, lines and varieties are tested in about 50 different environments every year. In this way information on adaptation, yield, disease re-

sistance, etc. is obtained in one year which never could be acquired at a single location. This nursery is a tremendous help in identifying germ plasm with resistance to a broad spectrum of diseases. It also is extremely useful in maintaining a strict vigilance for new races of rust and other diseases.

With this wide spread range of activities spearheaded by central program staff, varieties can be developed in a matter of a few years for almost any set of conditions. About 2,000 crosses among highly selected, widely different, elite materials are made each year in Mexico. After an initial screening, the segregating progenies from the crosses flow out to all cooperators. The best materials are returned along with other segregating lines from crosses made by cooperating national scientists. Thus these far flung efforts become a single network of variety factories.

The CIMMYT-Mexican semi-dwarf wheat varieties, which extended the Green Revolution to India and Pakistan, have probably reached their upper limit in acreage. They are rapidly being replaced by their derivatives with more suitable qualitative characters for the region concerned, and with a still broader type of disease resistance. Cooperative breeding programs in Argentina, Brazil and North Africa have produced varieties with resistance to a wider spectrum of diseases including the *Septoria, Fusarium* and powdery mildew, which often cause devastating losses in these areas in years of high rainfall. High yielding varieties developed from a cross of Sonora x Klein Rendidor —an Argentinian variety— are being multiplied for distribution in North Africa and Argentina where they appear to be superior to all other varieties in both yield and resistance to prevalent diseases.

Although CIMMYT's major effort has been devoted to the spring bread wheat types, the program in recent years has been enlarged to include the winter wheats, durums and triticales. A program for the blending of the winter and spring wheat germ plasm-complexes has been established in cooperation with the University of California at Davis and with the Oregon State Agricultural Experiment Station at Corvalis. This new broad-based program financed in part by the Rockefeller Foundation is aimed at the development of new high yielding varieties for the high plateau region of Turkey and the southern-Euro-Asian winter wheat belt.

The Durum wheats are in great demand as a basic food grain in North Africa and for the manufacture of maccaroni type products. In order to prevent these types from being replaced by the higher yielding spring bread wheat varieties, the CIMMYT breeders have greatly strengthened their efforts in the development of semi-dwarf durum types comparable to the bread wheats in yield and disease resistance. Rapid progress is being made and some of the new very promising varieties are being extensively tested in North Africa.

A real break-through has been achieved in the further improvement of the triticales. The problems of sterility and shriveled grain have largely been solved. This will allow the breeders widening the germ plasm base and concentrate heavily on the development of high yielding varieties. The triticales show promise of having a much higher yield potential than any of the other small grains, and if some of the present lines are indicative, varieties much higher in protein quantity and quality can be developed.

Wheat Production Programs

As high yielding varieties become available for new areas, production techniques often need to be greatly modified. Fortunately, in India and Pakistan about 80 percent of the production technology developed in Mexico for the CIMMYT-Mexican varieties was applicable. However, as the Green Revolution moves to North Africa, Argentina, Brazil and other regions where wheat is grown almost exclusively under varying rainfall conditions, a new package of production practices must be worked out. For this reason, CIMMYT has undertaken to help with the organization and execution of an intensive field research program in North Africa, (with direct support from U.S. AID and the Ford Foundation) designed to determine the package of practices indicated for maximum production in the different rainfall regimes. This includes land management, rates, dates and manner of seeding and kinds, rates and timing of fertilizer application. Although it is fully realized that the ideal package may vary from one region to another, it is hoped that much of what is learned in North Africa will be broadly applicable to other dry-land areas. In any event, the experience gained by certain CIMMYT staff members in this region will be extremely useful in assisting other nations with similar types of problems.

CIMMYT has a similar, less intensive, type of corn and wheat program underway in cooperation with the National Agricultural Technological Institute of Argentina. This program, supported in part by the Ford Foundation, is

aimed at identifying the kind of agronomic practices needed at the farm level for maximizing yields of the new varieties under different moisture conditions.

Corn Breeding

CIMMYT's corn breeding program also is aimed at the development of improved varieties for about 50 million hectares in the tropics and sub-tropics. In this vast area, corn is grown from sea level to 12,000 feet elevation and under conditions ranging from 300 mm of rainfall to 4,000 mm annually. Many different kinds of improved varieties are needed if requirements are to be met. Cooperative work is underway with national breeders in most of Latin America, East and West Africa, Egypt and South and Southeast Asia.

The central research team devotes most of its time to the development of widely adapted, open-pollinated, high yielding, disease and insect resistant, more nutritive populations which in certain areas may be increased and distributed directly as they are, but which may be readily molded to fit requirements of more specific conditions. Much of this work is being done in cooperation with various breeders throughout the lower latitudinal belt around the world. CIMMYT's central team is made up of geneticists, cytologists, physiologists, pathologists, entomologists, agronomists and chemists, who work together as a unit for the development of the basic, highly biological efficient breeding materials and varieties.

Development of High Quality Protein Varieties

In cooperation with the United Nations Development Program, special emphasis is being given to the formation of higher quality protein varieties starting with the two known genes, opaque-2 and floury-2. It has been demonstrated that the protein in this new type of corn is almost equal to milk in biological value. Children, pigs and the young of other monogastric animals grow nearly twice as fast on the opaque-2 type corn as on ordinary corn. Now in its initial stages, this work is centered in Mexico, Central America and the Andean zone of South America where maize is a major part of the human diet. The long range goal is to substitute high quality protein types for present varieties in this part of Latin America. These efforts are a tremendous challenge, not only to the breeders and agronomists, but also to the government officials, private industry, credit agencies and in many respects all the people of the area. If the job is to be done, there must be a thorough understanding of the problems involved and complete cooperation among all concerned. This extremely worthwhile effort could quickly alleviate the present protein malnutrition problems of Latin America and other parts of the tropics where maize is used directly as a food.

In this program, special emphasis will be given to the small subsistence farmer who is concerned primarily with producing enough for himself and his family to eat. An estimated 50 percent of the people in Latin America are in this category.

The Problem of the Small Farmers

As noted previously, the Green Revolution has spread most rapidly among the better commercial farmers in areas where risks are relatively low. In a protest-weary world, it is very urgent that the new science-based technology be directed toward the small subsistence farmer who has benefited less from this new production revolution. In many countries, the small subsistence farmer occupies from 40 to 70 percent of the good agricultural land presently under cultivation. It is not likely that many countries can reach self-sufficiency in food production with half, or more, of the land producing only about 20 percent of its potential. Thus a way must be found whereby production can be accelerated among the subsistence sector at a cost that these countries can afford. To help find a way, CIMMYT has established a pilot program in the State of Puebla in Mexico. This region consists of about 116,000 hectares with 50,000 families. The average farm is about 2.5 hectares in size and maize is grown almost exclusively in a centuries-old traditional system. These farmers have little to buy or sell and in their present situation contribute little or nothing to the economic development of their country.

The pilot program is a cooperative one with the Mexican Ministry of Agriculture, the Post Graduate School at Chapingo and the Government of the State of Puebla, it is designed to develop a low cost strategy for the rapid acceleration of maize production among non-commercial small farmers, and to bring them into the overall money economy of their country with real benefit to themselves and their nation. Progress made to date has attracted world-wide attention. It appears that the strategy being developed and tested in

Puebla can be readily transferred and adapted to a range of production situations. Although the project is only in its fourth year, results have been so striking that it is being extended to other areas of Mexico and to South America in connection with the high quality protein maize project. It is believed that a Puebla-type project is one of the simplest ways of getting more nutritive corn into the diets of the subsistence farmers and their growing children.

The crop production and communications sections of CIMMYT, as well as many of the local research, credit and extension agencies are deeply involved in the project. It is hoped that in a few more years, all the farmers in the project area will have changed from subsistence to commercial farmers, regardless of the size of their farm.

Training

Training is one of CIMMYT's most important activities. Emphasis is on the preparation of young men who can be immediately effective in the strengthening of national and regional programs in all aspects of breeding and production. Priority is given to trainees from countries with a strong desire to improve the efficiency of their maize or wheat production. Most of CIMMYT's training is of the in-service type and is production oriented. More and more emphasis is being placed on the development of breeding and production teams that can organize and execute accelerated production programs and promote the kinds of government policies which would let such programs flourish.

Special attention is being given to the development of teams of young technicians (five on each team) who can initiate and carry on projects of the Puebla type, for the acceleration of production on small subsistence farms. It is extremely urgent that the Green Revolution include these types of farmers.

Nearly a hundred young men spent varying amounts of time in CIMMYT's in-service training program last year. These young technicians not only return to their countries with boxes of seed and new inspiration, but also serve to tie the maize and wheat workers together in one large fraternity of cooperating scholars. It does not seem likely, for example, that the almost miraculous increases in West Pakistan could have been achieved without the large numbers of young Pakistanis who received their original orientation and inspiration in the wheat program in Mexico.

Cooperative Projects with Institutions in the Developed World

As a matter of general policy, CIMMYT does not enter into basic research that can be done more efficiently elsewhere. In line with this policy, some of the more basic work in the development of high lysine maize varieties will be done in cooperation with scientists at Purdue University. A project designed to gain a better understanding of the various physiological processes of the maize plant is now planned with the University of Guelph in Canada. Some of the more basic work on triticales is being done in collaboration with scientists at the University of Manitoba.

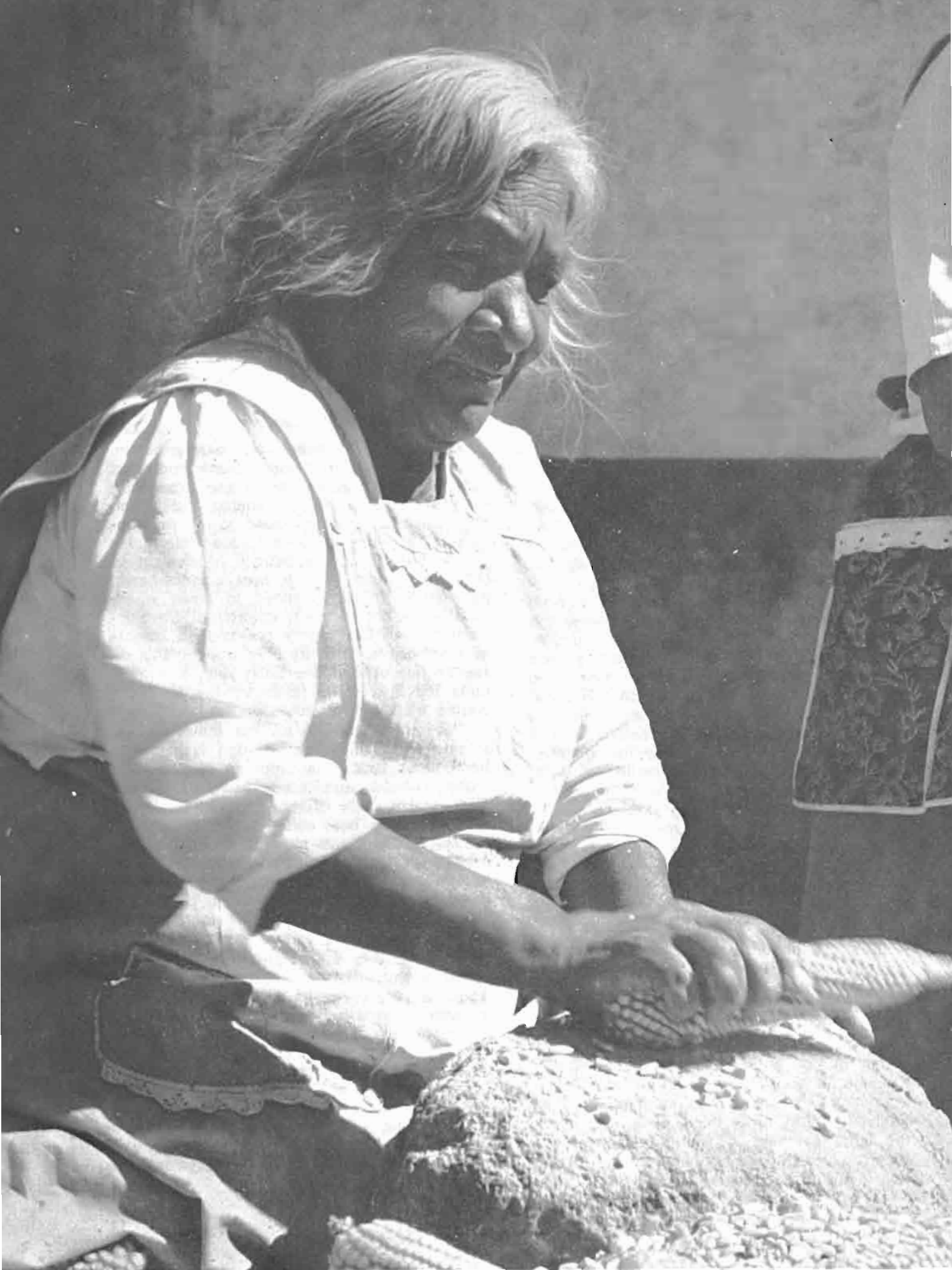
Looking Ahead into the Seventies

The Green Revolution has barely begun. If it is to be kept moving, many additional varieties must be developed and production problems solved. In both maize and wheat, more attention must be given to the development of varieties resistant to the vicissitudes of weather, especially periods of drought or too much water, if the new science-based package is to be extended to areas where moisture is not so easily controlled. Development of varieties highly resistant to insects seems feasible, but very little work in this direction has been done. Each year, a tremendous toll in corn is taken by the fall army worms, stalk borers, thrips and red spiders.

The conversion of all the maize in the tropics and sub-tropics to high lysine is a tremendous task. The breeding of wheat for higher nutritive quality has just begun.

In maize, little is known about the types of architecture best suited for most efficient use of sunlight and minerals from the soil. Also, the physiological mechanisms that control the reaction in maize to changes in day-length and to different climatic conditions, must be better understood if more widely adapted, super-varieties are to be developed.

These efforts will require additional man power with reinforced training programs. Above all, if progress in production is to keep up with demand and serious social problems are to be avoided, the benefits of the Green Revolution must be extended to the subsistence farmers who occupy about 40 percent of the good cultivable land in the world today and represent about half of the world's population. This is a formidable task and will require a well-planned strategy involving the cooperative efforts of many people and institutions.



MAIZE

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INTRODUCTION

As demands for cereal grain production increase and maize plantings further encircle the globe, CIMMYT's work arena has expanded to keep pace. Brief reports from some participant countries reflect this enlarged scope.

Thailand: set another record high in maize production in 1969. An estimated 1.7 million metric tons of grain were produced on an estimated 800,000 hectares. These figures are part of a 10-year trend which shows production and planted area increases amounting to an average of 100,000 metric tons and 52,000 hectares per year over the past decade.

West Pakistan: reported a 30 percent increase in yield over the past year, with maize production reaching 800,000 metric tons in 1969, compared with 620,000 tons in 1968. Planted area increased six percent.

India: pushed production per hectare still higher. India's area planted to maize has been boosted 40 to 50 percent since 1960.

Kenya: popularized the use of hybrid maize with simple "package deal" demonstrations so that total hectares planted to corn has soared. Kenya now has consistant surpluses in maize production, whereas expensive imports were necessary in the mid 60's.

In support of these global efforts, CIMMYT's maize programs concentrate on disease and insect control, protein quality improvement, population improvement and further development of the germ plasm bank.

Truly amazing progress is being made in developing new varieties and hybrids. CIMMYT, in collaboration with host country researchers, now has varieties or hybrids in production over much of the globe. (See below.)

CIMMYT has reinforced one of its productive activities by formally establishing an International Nurseries section to test varieties and breeding materials of both maize and wheat over a wide range of ecological conditions. This program prepares and distributes uniform nurseries and other seed materials to interested collaborators, collects genetic materials, and assembles data from the nurseries to be shared by CIMMYT and fellow plant breeders throughout the world. (See Wheat Section, also.) It has been found that the International Nurseries are a very effective way of distributing useful germ plasm.

Some of the more stubborn problems hindering production are under continued attack; for example, development of resistance to several of the more destructive insects and diseases. The Downy Mildew complex in Asia and stunt virus in Central and South America are being studied extensively. A much higher degree of tolerance to these diseases is being developed and satisfactory field resistance seems close at hand.

CIMMYT and UNDP (United Nations Development Program), have signed an agreement whereby CIMMYT with UNDP financing will spearhead a worldwide cooperative effort in the development and utilization of high protein varieties of maize. This will involve a search for new genes; development of high yielding, disease resistant varieties through the incorporation of the presently known genes Opaque-2 and Floury-2; help in the promotion of high protein quality maize production programs; and training the manpower needed to convert large areas in which maize is the main source of subsistence to use of high protein quality corn.

The majority of people in developing countries obtain about 65 to 75 percent of their protein from cereals. Unlike animal proteins, these cereal proteins are generally deficient in one or more of the essential amino acids, especially lysine and tryptophan. Thus, protein malnutrition is widespread, especially among children, within those countries which depend primarily upon cereals for their food requirements.

There is little likelihood that this dietary deficiency can be overcome soon by incorporating high-cost animal proteins. The best solution seems to be the improvement of total protein level and amino acid balance in cereals.

CIMMYT has mapped a strategy for protein improvement which calls first for new knowledge about the protein level and amino acid profile of base genetic materials used in its globe-circling research. Plans are underway to systematically collect, analyze and improve these materials. Equally important studies are being made of the various foodstuffs derived from maize.

In areas of the world where flint or dent grain types of maize are preferred, there continues to be a problem in gaining acceptance for grain types having the floury type endosperm associated with the superior quality protein of the Opaque-2 type. As a partial answer of this need, CIMMYT has expanded its research on the development of high lysine flint types. Several factors have slowed progress in converting floury type maize to the high quality protein with the Opaque-2 gene. This is unfortunate, as the floury type maize is a basic food in many countries. Problems of developing high lysine varieties of through the introduction of the Opaque-2 and Floury-2 genes, and those of subsequent maintenance and distribution of seed stocks, remain to be solved.

INTERNATIONAL MAIZE ADAPTATION NURSERY

Contains 50 varieties, hybrids or populations from different conditions of climate, altitude, latitude, etc. for testing at 40 different sites throughout the world.

CIMMYT has designed its program to provide a regular flow of information and materials to cooperating breeders around the world. Just as importantly, the program seeks a feedback of information and materials from these same locations, so as to serve as a clearing house and collection center for all corn breeders.

CENTRAL RESEARCH PROGRAM

PROTEIN IMPROVEMENT

CIMMYT's maize program seeks to raise protein quantity and improve protein quality through a series of breeding, genetic, biochemical and cultural studies.

Nutritional value of maize can be improved by increasing the quantity of its protein and raising the content of the essential amino acids in the protein. The low nutritional value of this cereal is due mainly to a deficiency in the essential amino acids, lysine and tryptophan. Opaque -2 and Floury-2 mutants modify the amino acid balance of endosperm protein and improve the nutritional value of maize by raising the level of lysine and tryptophan.

The Opaque-2 mutant has been incorporated into a series of widely different germ plasm backgrounds varying in agronomic characteristics. Yield trials of these materials are underway in Mexico and other countries and preliminary evaluations of this material have confirmed the nutritional value of Opaque-2 when fed to animals.

The Floury-2 gene also is being incorporated into many of the populations used as backgrounds for the Opaque-2 to form a parallel series of Floury-2 varieties. Nutritional studies on this material have shown, low responses, in general, when compared with those obtained with the consistent Opaque-2 maize results. However, part of the reduced response in the case of Floury-2 may be due to dosage effect. Floury-2 acts as a partially dominant gene in certain genetic backgrounds, and test samples used in feeding trials have not been uniformly homozygous for this gene.

In the case of Opaque-2 populations, ear rots and diseases have been found to cause greater damage than in hard endosperm corn. This greater susceptibility of Opaque-2 maize may be due to the differential amino acid balance available as a substrate for fungus growth, or simply as a result of the soft starch texture. The specific reasons for increased rots are not clear. Data must be obtained to clarify the possibility of detrimental toxin accumulations in grains attacked by microorganisms.

As kernels with harder endosperm are developed, chemical and biological tests will be conducted to insure increased lysine content accompanied by high nutritional value.

Search for New Mutant Modifiers of Protein Quality

Mutants in maize, other than Opaque-2 and Floury-2, which can influence protein quantity and quality have been investigated by CIMMYT's program since 1968. The studies were facilitated by the rapid colorimetric method which allows analysis for tryptophan on a single kernel basis, with analyzed seeds suitable for planting.

In 1968, S_1 families in 19 populations were developed and analyzed for protein and tryptophan content on a 10 kernel sample basis. These populations are listed in Table 1. The

TABLE 1. Maize populations from which S_1 families were evaluated for Thryptophan during 1969.

Identity	No. of families Analyzed	(%) Protein	(%) Tryptophan in Protein	(%) Tryptophan in Sample
Bolita	38	8.81-14.94	.34- .58	.035-.056
Cacahuacintle	52*	7.44-14.63	.37-. 65	.040-.070
Celaya-II	300	8.38-15.50	.23- .52	.027-.059
Comiteco	30*	8.94-15.11	.34- .61	.043-.066
Cónico	43*	10.50-17.06	.34- .58	.043-.071
Chapalote	30*	12.63-18.63	.26- .43	.042-.060
Puebla Gr. IA	200*	7.31-15.75	.25- .70	———
Harinoso de ocho	44*	9.62-15.81	.27- .55	.028-.079
Nal Tel	53	11.00-18.56	.30- .60	.039-.060
Maiz Dulce	88*	9.06-18.38	.30- .58	.039-.082
Pepitilla	117* (S_2's)	8.13-16.25	.26- .66	.039-.078
Pinto Salvatori	102* (S_2's)	7.31-14.31	.36- .80	.034-.074
Reventador	37	9.63-16.38	.25- .43	.033-.062
Tabloncillo	51*	10.00-14.00	.30- .51	.039-.053
Comp. E.	83*	9.00-17.50	.36- .58	.043-.093
Caribbean Comp.	501	6.25-13.63	.23- .68	.024-.056
Salvadoreño	300	8.13-13.63	.25- .68	———
Santa Catalina	302	3.50-11.63	.31-1.41	———
Cipa	38	7.44-15.94	.29- .55	.031-.056

* Source of potential new high lysine mutants.

After field selection, the chemical analysis to determine protein quality is performed on an individual kernel basis.

populations that seem to be a source of potential new high lysine mutants are shown with asterisks. Some of these populations need to be sampled more adequately.

The promising S_1 families have been regrown to produce S_2 ears for studying genetic segregations. Some of the S_1 families which warranted further study are given in Table 2. Promising S_2 families along with their protein and tryptophan values are listed in Table 3.

S_1 families also were developed in some Mexican racial crosses (Table 4); their protein values ranged from 6.1 to 14.3 percent. Tryptophan content in the protein was low in general, ranging from 0.3 to 0.6 percent with a few exceptions shown in Table 2.

TABLE 2. Promising families selected for further study in search for high protein quality mutants.

Identity	S_1 Designation	% Protein	% Tryptophan in Protein	% Tryptophan in Sample
Harinoso de ocho	4	14.12	.48	.068
Harinoso de ocho	23	14.81	.42	.062
Maíz Dulce	6	13.75	.50	.069
Maíz Dulce	7	12.88	.50	.065
Maíz Dulce	18	12.94	.57	.074
Tabloncillo	23	11.25	.52	.058
Comiteco	—	12.50	.61	.076
Pinto Salvatori	132	9.50	.73	.069
Pinto Salvatori	228	11.69	.56	.066
Pinto Salvatori	243	13.50	.55	.074
Pinto Salvatori	255 a	12.63	.52	.066
Pinto Salvatori	269	12.25	.51	.062
Pinto Salvatori	326	8.38	.67	.056
Pinto Salvatori	339 a	12.56	.54	.068
Pinto Salvatori	365 a	11.81	.57	.067
Pinto Salvatori	373 a	9.00	.80	.072
Chapalote	30	15.88	.43	.068
Harinoso de ocho	15	12.50	.54	.067
Harinoso de ocho	30	15.81	.50	.079
Maíz Dulce	28	15.06	.44	.067
Maíz Dulce	4	15.56	.53	.082
Maíz Dulce	20	13.63	.54	.074
Maíz Dulce	7	9.25	.58	.054
Tehua x Maíz Dulce	3331	12.38	.60	.075
Cónico Norteño	33	10.88	.58	.063
Composite E	189	12.88	.56	.072
Composite E	5	9.00	.60	.054
Composite E	58	10.00	.56	.056
Composite E	239	13.00	.50	.065
Composite E	202	15.13	.48	.072
Composite E	248	13.00	.60	.078
Composite E	114	11.25	.58	.065
Composite E	232	16.25	.57	.093
Cacahuacintle	42	10.44	.60	.063

TABLE 3. Some promising S_2 families investigated by individual kernel analysis in population/population crosses during the year 1969.

Identity	Line Designation	% Protein	% Tryptophan in Protein	% Tryptophan in Sample
Pepitilla	P_1 -4	12.63	.55	.069
	P_4 -5	13.13	.49	.064
	P_7 -3	12.00	.57	.068
	P_8 -9	14.25	.48	.068
	P_9 -1	10.56	.61	.064
	P_9 -2	9.81	.66	.065
	P_{10}-5	12.31	.54	.067
	P_{10}-6	13.25	.59	.078
	P_{10}-9	10.50	.62	.065
Guerrero 50	P_{15}-2	14.94	.56	.083
	P_{15}-3	16.13	.48	.077
	P_{15}-4	13.38	.54	.072
	P_{16}-4	10.88	.61	.067
	P_{17}-1	11.25	.56	.063
Olotillo	5090-88-4	12.06	.50	.060
	5090-88-8	14.19	.47	.067
Salvadoreño	278-8	15.44	.46	.072
	278-9	13.81	.47	.065

TABLE 4. Racial crosses from which S_1 families were evaluated for tryptophan during the year 1969.

Identity	No. of Families Analyzed	(%) Protein	(%) Tryptophan in Protein	(%) Tryptophan in Sample
Tehua x Cónico Norteño	12	9.31-11.50	.34-.46	.035-.049
Jala x Celaya	9	8.88-12.25	.32-.44	.032-.041
Comiteco x Harinoso de ocho	11	8.00-13.25	.29-.48	.031-.043
Maíz Dulce x Harinoso de ocho	13	9.81-12.75	.31-.51	.034-.058
Celaya x Harinoso de ocho	10	7.06-14.31	.31-.48	.034-.044
Celaya x Maíz Dulce	16	7.50-11.56	.31-.48	.030-.045
Jala x Harinoso de ocho	13	8.50-11.38	.35-.44	.039-.046
Pepitilla x Harinoso de ocho	13	8.25-11.88	.32-.44	.031-.045
Celaya x Comiteco	6	10.50-11.75	.31-.40	.034-.046
Tehua x Maíz Dulce	23	6.12-12.38	.35-.61	.026-.075
Comiteco x Pepitilla	14	9.13-12.88	.31-.45	.034-.047
Puebla Gr. I br_2 br_2	14	7.75-11.69	.35-.46	.032-.048
Celaya x Puebla Gr. I	145	7.50-13.50	.31-.57	.030-.062

High Protein Quality Mutants from Pepitilla

Search for new mutants that are likely to be recessive has led to the tentative identification of a mutant which may affect protein quality in Pepitilla. This mutant is comparable to normal Pepitilla and Opaque-2 Tabloncillo in amino acid content, as shown in Table 5. These data suggest that the mutant is different from Opaque-2 in its effect. The various essential amino acid percentages (except for leucine) in the protein are lower than in the Opaque-2 Tabloncillo and higher than in the normal Pepitilla. The new mutant appears much higher in total protein than the normal Pepitilla and the Opaque-2 Tabloncillo.

In interpreting these data, it must be kept in mind that the Pepitilla mutant and the Opaque-2 mutant are in different genetic backgrounds. Moreover, the seed used for the analyses were produced in different seasons. Therefore, further comparisons must be made of the mutants on the same genetic backgrounds and raised in similar environmental conditions before valid conclusions can be made. The preliminary data, however, suggest that the mutant is different from Opaque-2 and may be useful.

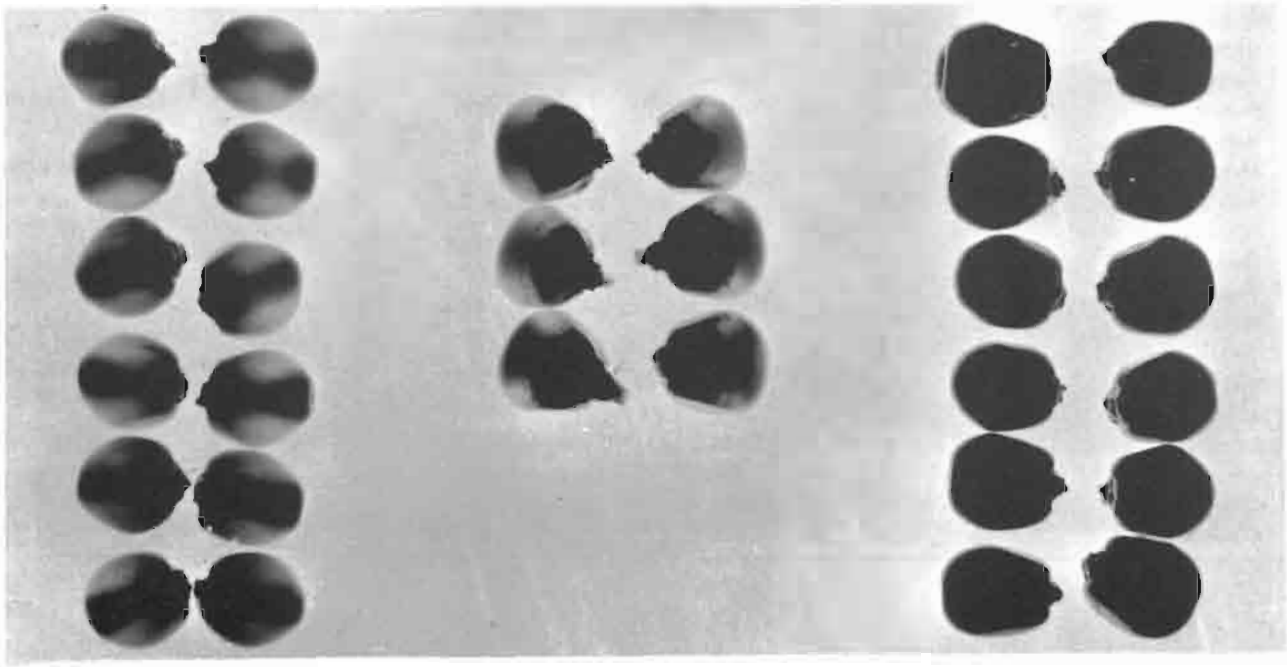
Phenotypically, the mutant is floury in nature but is does not seem to be quite as soft as Opaque-2. An allele test was made with both Floury-2 and Opaque-2 for proper identification during the winter planting at Tlaltizapan.

TABLE 5. Amino acid analysis for a new Pepitilla mutant, Pepitilla normal and a Tabloncillo o_2/o_2 stock.

Amino acid	P10-6 New Mutant %		Pepitilla Normal %		Tabloncillo o_2/o_2 %	
	in Protein	in Sample	in Protein	in Sample	in Protein	in Sample
Lysine[1]	2.53	0.366	1.90	0.185	4.54	0.409
Histidine	2.67	0.385	2.50	0.244	3.27	0.294
Arginine	3.90	0.563	3.53	0.344	6.89	0.620
Aspartic Ac.	9.88	1.427	6.61	0.645	9.85	0.887
Threonine[1]	3.72	0.538	3.25	0.317	4.23	0.381
Serine	5.30	0.766	4.99	0.487	5.67	0.510
Glutamic Ac.	26.17	3.780	21.02	2.050	21.33	1.920
Proline	7.89	1.140	9.56	0.932	7.40	0.666
Glicine	2.73	0.395	3.05	0.297	5.00	0.450
Alanine	9.56	1.380	8.93	0.871	8.24	0.742
Valine[1]	5.12	0.740	4.77	0.465	5.89	0.530
Methionine[1]	0.89	0.128	1.12	0.109	1.31	0.118
Isolencine[1]	3.98	0.574	3.75	0.366	4.04	0.364
Leucine[1]	16.54	2.389	15.90	1.550	12.17	1.095
Tirosine	4.76	0.688	4.70	0.458	4.63	0.417
Phenilalanine[1]	5.23	0.756	5.15	0.502	5.25	0.473
Tryptophan*[1]	0.58	0.084	0.41	0.040	0.88	0.079
% Protein	14.44		9.75		9.00	

* Enzymatic Hydrolis. [1] Essential amino acids.

Opaque-2 corn kernels showing different patterns of hard and soft starch development in the endosperm. The dark kernels are fully "opaque" and are associated with high levels of lysine. The mottled hard and soft starch areas show different levels of lysine and tryptophan content but not necessarily in proportion to the amount of hard starch. There seem to be possibilities for selecting kernels with an almost normal appearance and high lysine content.



Study of Modifier Genes Affecting Density, Weight and Appearance of Opaque-2 Kernels

Recent reports indicate that kernel density, kernel weight and phenotypic appearance of Opaque-2 kernels can be improved by selecting for modifier genes. As a first step, CIMMYT breeders felt it was important to determine the relationship between the percent of translucent area in the kernel and the lysine-tryptophan content of the endosperm. Five types of kernels(on the basis of degree of opaqueness) were sorted out in some S_1 progenies developed from a tropical Opaque-2 composite. These were analyzed for protein and tryptophan content. Preliminary observations suggest that in some progenies it is possible to select kernels possessing near normal weight (in some cases, the tryptophan content is as high as in their opaque counter parts). S_1 lines with different kernel types are being selfed to develop S_2 to study the inheritance pattern and to see if such types can be genetically fixed.

Incorporation of Opaque-2 and Floury-2 Genes in Diverse Germ Plasm

Composites containing both Opaque-2 and Floury-2 genes are being developed which will serve as source stocks for further selection over a wide range of ecological conditions, varying in altitude from sea level to 2200 meters.

The composites have been synthesized from Opaque-2 and Floury-2 conversions in different genetic backgrounds through a varying number of backcrosses. The basic materials included in the formation of such composites are given in Table 6. The three composites shown in the table have undergone one cycle of mass selection for high protein.

TABLE 6. Varieties included in the formation of the components.

S No.	Population	Varieties Included
1	Composite I	Mexico Gpo. 10 Hidalgo 8 Pinto Salvatori Blanco Rubin
2	Composite J	Puebla Gpo. I Puebla Gpo. I Celaya C II
3	Composite K	Tuxpeño Salvadoreño Cuba Flint Antigua 2 D West Indies semi dent. Eto Blanco

Combinations Among Different Endosperm Mutants for Improved Nutritional Value

To improve the texture and digestibility of opaque kernels, Opaque-2 and Floury-2 versions of Celaya populations were crossed to a waxy source, and selfed to obtain the F_2 generation. Several ears segregated for opaque-waxy and floury-waxy and are now being synthesized into Opaque-2-waxy, and Floury-2-waxy populations, which in turn will be advanced to Syn. 2. The protein level and quality of these combinations, as well as their "tortilla" making quality are under study. Syn. 2 seed also will be used in animal feeding trials to determine its nutritive value.

Protein values for the harvested sample, and the selected sample from the mass selection program for high protein are shown in Table 7. Indications are that further gains in total protein can be made in all the three populations by means of a second cycle of mass selection. The selection differential values were in the order of 7.9 percent, 10.06 percent and 12.1 percent, in composites K, J, and I respectively.

TABLE 7. Total protein values for harvested ears in the mass selection program for high protein quality populations for the year 1969.

S No.	Cycle of Selection	Total Protein					
		Harvested Sample			Selected Sample		
		No.	Mean	Range	No.	Mean	Differential
1	Composite I (2200 m) 2nd.	368	8.73	(5.56-12.38)	147	9.79	1.06
2	Composite J (1800 m) 2nd.	365	10.00	(6.38-13.13)	175	11.06	1.06
3	Composite K (40 m) 3rd.	408	10.57	(7.50-13.56)	223	11.40	0.83

Several Mexican races and promising materials from other countries are being converted to Opaque-2 and Floury-2. They have undergone different numbers of backcrosses ranging from 1 to 3. About 40 varieties are included in this conversion program. The resulting converted populations should provide germ plasm adapted to a wide range of environmental conditions. At present, uniform variety tests are underway in Central America including some of these materials.

Quantitative Approach in Improving Protein Quality

An attempt to improve protein quality through a quantitative approach was initiated in the Caribbean Composite and Puebla Gpo. 1 populations during 1969.

Several S_1 lines were developed and each population analyzed for protein and tryptophan content. Families with high protein and tryptophan values were submitted to individual kernel analysis on a sample of 10 seeds per family. Two seeds with the highest tryptophan values per family were selected and their embryos were grown in peatcups and later transplanted to the field. Mean protein and tryptophan values are given in Tables 8 and 9.

S_1 lines in each population show wide variation in values for protein and tryptophan. This suggests the possibility of making improvement in protein quantity and quality through different selection schemes.

The plants from individual kernel analysis in each of these populations will be intercrossed to form high tryptophan composites and a new set of S_1 lines will again be derived for the second cycle of selection.

TABLE 8. Protein and tryptophan analyses of S_1 families in composite C (Caribbean Composite) during the year 1969.

Identity	Number	Protein (%)	(%) Tryptophan in	
			Protein	Sample
Composite C	500	9.54	0.40	0.038
Selected S_1 Families	53	10.19	0.49	0.050
High Seeds 2/Family	80	10.37	—	0.052
Selection Differential	—	0.83	—	0.014
Selection (%)	—	8.7	—	37.8

Regression of % Tryptophan in protein on total protein $b = -.03$.

TABLE 9. Protein and tryptophan analysis of S_1 families in Puebla Gpo. I during the year 1969.

Identity	Number	Protein (%) (Average)	(%) Tryptophan in	
			Protein	Sample
Puebla Gpo. I	200	10.24	0.44	.045
Selected S_1 Families	32	10.70	0.53	.057
High Seeds 2/Family	57	—	—	.064
Selection Differential	—	—	—	.019
Selection (%)	—	—	—	42.2

MAIZE GERM PLASM COLLECTION, DISTRIBUTION AND MAINTENANCE

CIMMYT corn materials have been observed world-wide and the most useful introductions have proven to be those from areas with similar ecological conditions, including corresponding latitude and elevation above sea level. For example, corns from the United States spread readily to Europe, Chile, Argentina, South Africa and like locations. In parallel fashion, the varieties from Mexico, Central America and the Caribbean moved to central and northern Africa, Thailand, India, the Philippines, South America, Australia and to many islands throughout the tropics.

Clearly, combinations which would permit superior yields over wider ecological ranges would represent a big advance. As a move in this research direction, heat-unit and day-length responses are being studied to determine the extent to which they are involved in the adaptation of given varieties of maize.

Two pools of germ plasm have been established by CIMMYT in a long range attempt to provide materials for investigating some of the determinants of varietal "adaptation". One of these is called a "world composite". The other includes germ plasm from all latitudes in the western hemisphere, ranging from Alaska to Argentina. It has had five generations of mixing. If specific genetic factors for day-length response exist in maize, they should be included in these pools. Sampling from these pools and systematic evaluation by breeders at different points in the world can provide useful information over a span of several years.

Maize Germ Plasm Bank

At its maize germ plasm bank, CIMMYT maintains a reservoir of the genetic variability found in the species *Zea mays* L. Germ plasm is collected, maintained and distributed to interested breeders who, in turn, develop the varieties needed by maize growers through out the world.

The Bank's activities in 1969 included:

Inventory: A complete inventory of the 4,655 maize populations stored under refrigeration was finished in 1969. Inventory information has been transferred to IBM cards and a preliminary listing printed. This list includes accession number, population name, racial classification, location, crop year, and plot

number in which the seed was produced, number of ears saved, mating system used to produce seed, grams of seed available, and location of the seed containers in the refrigerated area. Handling of seed requests, and listing of populations that need to be propagated, have been greatly simplified, and a continuous inventory of the seed supply of each population is maintained.

Seed requests: Requests from 31 countries were received in 1969, involving a total of 101 seed requests and 2,817 samples. Table 10 summarizes the seed distributions by country, while Table 11 presents a summary by World Regions.

The Western Hemisphere made greatest use of the Germ plasm Bank, with 74.8 percent of the populations going to American countries. Mexico received the largest proportion (52.9 percent) of these.

Seed propagation: Of the 4,091 maize populations from which seed were produced in 1969, 3,626 were collected in Argentina, Brazil, British Virgin Islands, Bolivia, Colombia, Cuba, Guayana, Mexico, Paraguay and Uruguay, under the sponsorship of the Committee on Preservation of Indigenous Strains of Maize. These seeds were propagated in Tepalcingo, Morelos, Mexico, during the winter crop of 1969. The remaining 455 populations formed part of the bank inventory, with 432 propagated at Tlaltizapán, Morelos, and 23 propagated at El Batán. A total of 13 hectares was planted and over 100,000 hand pollinations made.

Agronomic information: Agronomic information was recorded for a total of 5,694 maize populations planted during 1969, and a racial classification was assigned for most of these populations.

INTERNATIONAL NURSERIES

As a supplement to work already underway in CIMMYT's Maize Program, an International Maize Adaptation Nursery has been assembled, containing 50 varieties, hybrids or populations from different conditions of climate, altitude, latitude, etc., for testing at 50 different sites throughout the world.

The long range objective of this project is to provide the first substantive information in terms of a world-wide adaptation of maize.

TABLE 10. Shipments and Maize Populations distributed to different countries in 1969.

Country	Number of Shipments	Number of Populations
Argentina	7	177
Australia	2	31
Bolivia	3	6
Brazil	5	41
Cameroun	3	39
Costa Rica	1	2
Ethiopia	1	35
Fiji	1	3
France	3	7
Ghana	1	33
India	2	28
Indonesia	2	10
Iraq	1	47
Ivory Coast	1	1
Japan	2	106
Lebanon	1	10
Malaya	1	9
Mexico	17	1,490
Nigeria	1	10
Pakistan	1	13
Peru	3	15
Philippines	1	91
Sierra Leone	2	59
Surinam	1	2
Sweden	1	6
Tonga	1	36
Thailand	1	43
United Arab Republic	1	80
United States of America	32	373
Venezuela	1	2
Yugoslavia	1	12
Sum	101	2,817

TABLE 11. Regional Summary of CIMMYT Maize Seed Shipments in 1969.

Destination	Shipments		Populations	
	Number	Percent	Number	Percent
Africa	10	9.9	257	9.12
America	70	69.3	2,108	74.83
Asia	12	11.8	357	12.67
Europe	5	5.0	25	0.89
Oceania	4	4.0	70	2.48
Sum	101	100.0	2,817	99.99

BREEDING

In CIMMYT's maize breeding program, yield and yield stability improvement is the overriding concern and a variety of approaches focus on this objective. Since maize grain is basically an energy food, yield improvement can be thought of as a means by which more energy is obtained from each unit of land devoted to the crop.

For example, In tropical areas, many possibilities exist for revised crop sequences and altered growing cycles and combinations which might be fitted to appropriate maize varieties for increased total production.

The development of a single, high yielding variety —regardless of growth cycle, plant height, or other characteristic— does not seem to be a realistic goal. Different crop needs in diverse areas may require totally different plant type requirements, along with appropriate agronomic practices for each region. The most efficient approaches to yield improvement remain to be established.

Two highly associated phases of CIMMYT's breeding program are: (1) development and accelerated production of highly nutritive varieties, and (2) evaluation of breeding procedures.

With thousands of varieties and strains of maize available, the initial selection of materials and choice of breeding procedures represent major decisions. CIMMYT considers both choices vital to the success of maize improvement.

At present, breeding work devoted to improving nutritional quality makes extensive use of Opaque-2 and Floury-2 mutants. However, other mutants are being sought and scientists are exploring alternative possibilities for achieving improved food quality of the grain, without sacrificing yield.

Trainees at CIMMYT receive basic instruction and practice in working in varietal improvement programs that they can apply upon returning to their own countries. The corn plant has the male and female organs located on different parts of the plant so that controlled pollinations and crosses are relatively easily made. The pollen from the tassel can be readily collected and carried to other plants. In the development of the new improved quality protein corns, great care must be taken to insure that the proper crosses are made.

Mass Selection

In the lowland tropical research program at the Poza Rica Station (Mexico), mass selection for yield is being conducted on several populations. These include Tuxpeño Crema 1, Mix 1 x Colima Group 1, [(Mix 1 x Colima Group 1) x Eto Blanco] and Eto Blanco. The Tuxpeño population is being studied to determine the effects of two cycles of selection per year, compared to the effect of a single cycle. The others are being selected individually as varieties, and as cross composites, to obtain data on the most desirable type of population base with which to begin mass selection. All are high-yielding, relatively good agronomically, and could be used directly as improved varieties.

One of CIMMYT's studies in lowland areas of Mexico involves a comparison of the yields of flint varieties with dent varieties. Several cycles of mixing and separation into flints and dents have been conducted and yield comparisons will begin this year. Samples of these materials have been provided to maize breeders in several areas, and some have been put directly into commercial use. The Santa Cruz lowland area of Bolivia is now growing more than 1,000 hectares of a yellow flint variety from this study, only two years after receiving a sample of seed.

Improved Populations

This work involves the formation and exposure of an heterozygous and heterogeneous population to the action of natural and artificial selection under varying environments.

Objectives are: (1) development of an improved population, *per se;* as well as an improved source of breeding material for development of high yielding varieties and/or hybrids for a broad area, (2) development of a germplasm pool with a high degree of resistance to crop hazards, (3) improvement of food quality through incorporation of genetic factors contributing to high lysine content, and (4) strengthening of cooperative research activities among interested maize research workers.

The method used in this project (for the formation of a widely adapted variety from a Tuxpeño germplasm complex) is referred to as *convergent-divergent* selection. A modification of the ear-to-row selection method is being used to insure a high degree of recombination.

The *convergence* phase of the project involves the synthesis of a composite containing most of the Tuxpeño material in CIMMYT's germplasm bank adapted to altitudes ranging from 0 to 1,000 meters above sea level. Seven hundred and ninety two varieties of the Tuxpeño race have been grown under isolation for four generations of synthesis. The composite should reach a workable level of genetic equilibrium in the fifth generation.

The *divergence* phase of the project will be started in 1971. Sublots of the basic composite then will be sent to collaborators around the world. Mass selection for prolific, highly productive, and healthy plants of moderate height will be made at harvest. After two or three generations of mass selection, a sample from each collaborator is to be sent to CIMMYT where compositing will be done to start the next cycle of *convergence.* After one generation of recombination, the new population will again be divided and a sample sent to the same collaborators for planting and resumption of the divergence phase. The plan can be continued as long as it is productive. Each collaborator may continue to select in his own population for future improvement at his own location.

This method seems useful in adaptation of a population to a wide area. Each subgroup will become characterized by a particular combination of traits to the extent that different environmental effects exist in the several locations involved. Through successful selection, resistance to different crop hazards would become a characteristic of the population.

Development of a World Composite

Local gene pools have in recent years been enriched through use of exotic germplasm sources.

A number of maize scientists have suggested that the formation of a world composite in maize could be a worthwhile long-range approach to the effective use of available genetic materials and to the selective improvement of more complex traits. Exotic stocks generally have been used to search for single genes responsible for simply inherited traits, such as disease resistance. The value of these stocks for breeding greatly exceeds that commonly attributed to them, but a different approach is needed in their management and use.

To generate a maize population of maximum variability, CIMMYT has begun to put together, into a single composite, seed from 5,000 of the more than 10,000 collections available in the germplasm bank in Mexico. Six composites were made by taking 15 seeds of each collection. These composites were planted at ten-day intervals in a neutral environment at Tlaltizapan in the State of Morelos. Plants of the third and fourth sowing dates were detasseled. Natural selection was important in eliminating some of the collections insofar as seed production was concerned but some plants, which did not produce seed, probably produced pollen which was represented in the seed harvested. The extent of differential loss is not subject to determination. Reaction to soil temperature and climate probably resulted in variable elimination of several of the collections, also.

Approximately 20,300 ears of the de-tasseled rows from this first cycle of synthesis were used to prepare two balance composites. One composite was formed by taking ten seeds from each ear harvested. Twenty seeds were taken for the second composite.

The first composite was subdivided by taking 87,000 seeds to plant the male rows at three different sowing dates for the second cycle of intercrossing during the winter of 1969-1970. The remaining 116,000 seeds were use to plant the female rows, which were de-tasseled. This arrangement permitted maximum recombination among early, intermediate, and late genotypes.

The second composite will be developed with the remaining collections. Then, the two resulting composites will be planted together to form the complete "world composite". Following this compositing, the material will be divided, and recombination and selection will be continued at low, intermediate and high elevations.

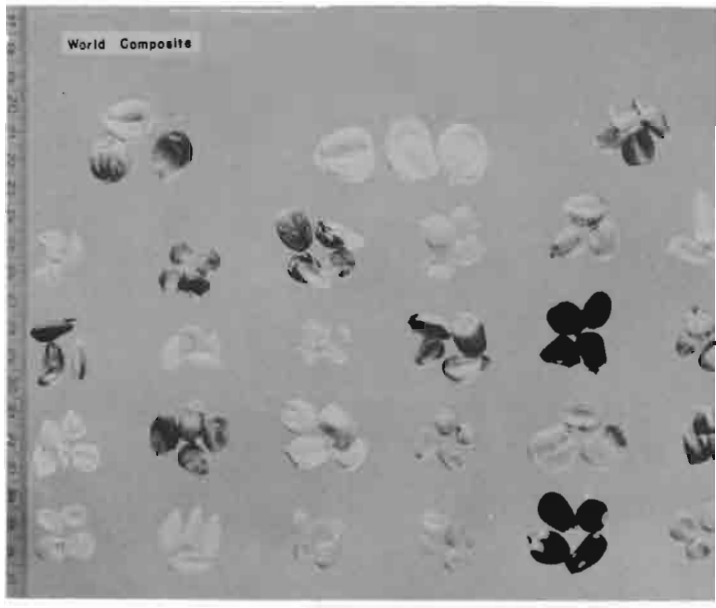
All potentially useful genes and/or gene combinations are not likely to be present in any single gene pool. Hence it is unlikely that such a utopian population will be created through the formation of a "world composite". It is likely, however, that a far broader mixture of genetic materials is being made than has existed before, and this may be of considerable value to maize improvement efforts everywhere.

Plant Height Studies

Most tropical corn plants grow too tall and are vulnerable to lodging. Even moderate winds exert tremendous force on very tall plants. In order to maintain plant standability, and to consider higher fertilizer levels aimed at higher production, it appears that varieties with shorter plants must be developed. Two separate avenues of approach are being followed to achieve shorter plants. Genetic dwarfs are being studied as one possibility, while another attempt is through recurrent selection of ear-to-row plantings and hand pollination among selected rows.

The genetic dwarfs being used are brachytic 1, brachytic 2, brachytic 3, anther ear, d_1 short, d_1 tall, and pygmy. Others, as yet not identified, are being studied. The brachytic 2 has been used to convert several diverse germplasm pools to dwarf plants. Modified ear-to-row mass selection for yield is being carried out in Tuxpeño Crema I-brachytic 2. Problems of irregularity of plant height, husk cover, ear position, and other difficulties remain, but the materials appear promising. The other dwarf populations have not progressed as far, but some show real promise.

CIMMYT has begun to put together, into a single composite, seed from 5,000 of the more than 10,000 collections available in the germ plasm bank in Mexico. The aim is to generate a maize population of maximum variability... a "World Composite".



Ear-to-row recurrent selection for plant height is being applied to several composite populations, as well as to those subjected to mass selection for yield. Thus far, effects of plant height reduction on yield have not been adequately assessed. It seems probable that modifications of cultural practices must accompany any major change in plant height.

Sunlight as a Limiting Factor in Dwarf Corns

To investigate the importance of light as a limiting factor when moisture and soil fertility were optimum, a variety homocygous for brachytic-2 was grown at El Roque, Guanajuato during during the summer of 1969, under conditions intended to provide four levels of light interception. (The brachytic 2 gene tends to telescope the plants with little space in between the leaves.)

Four treatments of canopy organization were used: (1) leaves above the ear positioned upright with transparent plastic bands (positioned at about 10° from the vertical) from the beginning of the flowering period. (2) plants oriented so that all leaves emerged and grew in an East-West direction with seedlings oriented by hand ten days after emergence. (3) leaves oriented east-to-west and positioned upright; and (4) control. (See Table 12.)

These four treatments of canopy organization were tested in a randomized complete block experiment with two replicates, and with a rate of planting of approximately 61,000 plants per hectare. Resulting yields greatly exceeded yields normally obtained with locally adapted hybrids and varietes of normal plant size.

TABLE 12. Mean grain yields at 15.5% moisture for the 4 systems of canopy organization.

Treatment	Mean Yield Ton/ha	Yield in % of Control
Leaves positioned upright	10.71	108
Leaves oriented East to West	11.10	112
Leaves positioned upright and oriented East to West	12.15	122
CONTROL	9.93	100

These yields exceed by far the normal yield obtained with locally adapted hybrids and varieties of normal plant size.

Treatment 1 showed an increase in productivity of 8 percent over the control. Treatment 2 showed a 12 percent increase; while treatment 3 showed a statistically significant 22 percent increase.

The yield increment obtained in treatment 3 was a little more than the sum of the increments obtained from treatments 1 and 2. This seems to indicate that light continued to be a limiting factor for maximum yield per unit area, even for the treatment "upright leaves and oriented east to west."

In view of these results, and other recent findings on the importance of sun light as a limiting factor for maximum productivity, it appears that the brachytic-2 plant type is very inefficient in its use of incoming light.

For corn breeders working with brachytic-2, it is fortunate that several other genes considerably modify its expression in several ways. allowing selection of desirable dwarf types. For example, two inbred lines were found in Puebla Group 1 brachytic, which consistently showed interesting plant types.

One of these lines produces short internodes and horizontal leaves below the ear, with normal internodes and erect leaves above the ear. This growth habit may be of great utility if easily transmittible to other materials.

The other inbred line produced extremely dwarfed plants with erect stiff leaves, and two relatively good sized ears. Thus, the modifications of the maize plant to obtain more efficient types appears to be a distinct possibility through proper breeding methods.

Introduction of the Brachytic 2 Gene into Tuxpeño Types

In 1966, the brachytic-2 gene was crossed into 10 varieties of the Tuxpeño race and seed of all 10 crosses was bulked and planted at San Rafael, Veracruz, where it was sibbed and crossed to other materials. The original and other crosses with Tuxpeño types were planted in an isolated block until 1968. In 1968 one cycle of mass selection was conducted and 400 plants were selected to begin a program of modified ear-to-row selection.

The yield performance of these brachytic-2 Tuxpeños appears quite promising, even though no superiority can be claimed for them when compared to the normal height corn. They are however, much less susceptible to lodging and stalk breakage. To provide the next step, the brachytic-2 Tuxpeño population has been crossed to a wide range of tropical corns. These were selected to for other attributes including earliness, narrow and fewer leaves, resistance to disease, and broader adaptation to the humid tropics.

Selection for Grain-to-Stover Ratio

The efficiency of a corn plant can be measured on the basis of the relationship between production of stover and grain. This ratio, in tropical corn, falls between 0.3 and 0.7, which compares to more than 1.0 in improved wheat, rice and sorghum varieties.

During the past year, grain-to-stover ratios were used in: (1) a mass selection scheme, and (2) selection among and within S_1 lines.

The germplasm used in the mass selection study was a composite derived from a cross between a short early corn, from Antigua in the Caribbean and a tall Tuxpeño from Mexico.

A program of mass selection in this composite was started in Poza Rica, Veracruz in 1969, using a selecton intensity of five percent for plants with the highest grain-to-stover ratio. The population has undergone three cycles of mass selection. During the second cycle, some selection pressure was directed toward lowering ear height, selecting only those plants with the uppermost ear below 161 cm. for the grain-to-stover determinations. Badly diseased or otherwise undesirable plants were de-tasseled during the third cycle of mass selection.

Progress from the first cycle of selection was evaluated in the summer of 1969 in a performance trial with ten replicates. This trial included: the original population C_0; the first cycle population, C_1 (Me) from the grain stover program; and a first cycle population derived from selection for grain weight per plant C_1 (M).

Three plant densities (21,739; 43,478; and 65,217 plants/ha) were used in a split-plot design. Data were recorded on days-to-silking, plant and ear height, day-to-pollen shedding, number of ears-per-100 plants, stover weight, grain weight, shelling percentage, and percent of lodged plants.

Mean values and the realized gain for grain-to-stover ratio and grain yield of the populations are presented in Table 1. Relative to the original population, one cycle of selection resulted in a gain of 2.9 percent in grain-to-stover ratio at the rate of planting similar to the one used during selection. Negative values were obtained when the population was evaluated at higher plant densities. The population resulting from selection for grain yield per plant showed no gain in grain-to-stover ratio at all three plant densities.

It is worth noting that the gains in yield after one cycle of selection for grain-to-stover ratio [C_1 (Me) vs. C_0] were 2.2 percent, 2.4 percent, and 6.3 percent at 21,739; 43,478; and 62,517 plants per hectare, respectively. This seems to indicate that selection for grain-to-stover ratio resulted in considerable improvement in yield and tolerance to high plant densities.

One cycle of mass selection based on yield-per-plant [C_1 (M) vs. C_0] produced a gain of 3.2 percent in grain yield at 21,739 plants per hectare, but there was no gain at 43,478 plants/ha, and a reduction of 4.9 percent at 65,217 plants/ha.

There were changes associated with the selection for grain-to-stover ratio in other agronomic characteristics, also. In general, the population C_1 (Me) was earlier, with shorter plants and lower ears, and better standability than the original population.

The outstanding feature of the selection for grain-to-stover ratio seems to be the correlated responses which enable the resulting population to be: (1) more productive, (2) more tolerant to high plant densities, (3) earlier, and (4) shorter.

Estimation of Heritability and Correlations with Grain-to-Stover Ratio

Using fifty families showing the highest grain-to-stover ratio from a mass selection program for this character, an experiment was planted in Poza Rica, Veracruz, Mexico, to estimate the heritability of grain-to-stover ratio by parent-offspring regression and to compare simple correlations between grain-to-stover ratio and eight other characters. These characters were: plant height, ear height, day-to-pollen shedding, days-to-silking, lodged plants, number of ears, stover weight, and grain weight.

TABLE 13. Mean values and % realized gain for grain/stover ratio and grain yield of three Comp. C populations at three planting densities. Poza Rica, Veracruz, Mexico. 1969.

	Grain/stover		Grain yield (kg/ha)	
	Mean	% Gain	Mean	% Gain
21,739 pl/ha				
C_0	0.68	0.0	3391	0.0
C_1 (Me)	0.70	+ 2.9	3467	+ 2.2
C_1 (M)	0.67	— 1.5	3500	+ 3.2
43,478 pl/ha				
C_0	0.68	0.0	5022	0.0
C_1 (Me)	0.67	— 1.5	5141	+ 2.4
C_1 (M)	0.67	— 1.5	5022	0.0
65,217 pl/ha				
C_0	0.64	0.0	5369	0.0
C_1 (Me)	0.60	— 6.2	5706	+ 6.3
C_1 (M)	0.60	— 6.2	5109	— 4.9

The estimated heritability for grain-to-stover ratio was 0.16 ± 0.27, which falls within the same range as grain yield. This value indicates that selection for this character must necessary show relatively small gains per cycle.

The correlation coefficients are presented in Table 2A. Highly significant negative correlations were found between grain-to-stover

and plant height, days-to-pollen shedding, days-to-silking, and stover weight. The correlation with ear height was negative, but significant at the 5 percent level. The correlations with grain weight and ears-per-100 plants were not statistically significant.

These correlations are in agreement with the ones obtained in a random set of S_1 lines from Tuxpeño, (described later in this report) and indicate that favorable correlated responses of considerable agronomic and economic importance can be expected from selection for grain-to-stover ratio.

Through selection for grain-to-stover ratio, a reduction can be expected in plant height, ear height, and days to maturity; together with an increase in grain yield. This is in marked contrast to selection for grain yield alone. For the tropics, where extremely tall plants pose a problem, this method of selection seems to provide a reasonably useful method for shorting plant height.

TABLE 14. Correlation coefficients between grain-to-stover ratio and eight other characters.

	Grain/stover ratio
Plant height	− 0.3985 **
Ear height	− 0.3238 *
Days to pollen shedding	− 0.5110 **
Days to silking	− 0.5659 **
Lodged plants (%)	+ 0.2199
Number of ears/100 plants	+ 0.1461
Stover weight	− 0.5399 **
Grain weight	+ 0.1691

* Significant at 5% level. ** Significant at 1% level.

Precise measurements are needed for determining grain-to-stover ratios and related characters.

Experiments were conducted at Poza Rica, Veracruz, Mexico, in two seasons of 1969 to determine some of the effects of varying plant densities on the following characters: grain-to-stover ratio, plant and ear height, days-to-pollen shedding and silking, percent lodged plants, grain mosture at harvest, ears-per-100 plants, shelling percentage, and grain yield.

The varieties used were: Tuxpeño brachytic, Caribbean Composite, Eto Blanco, Antigua Gpo. 2, and the double cross hybrid H-507. Plant densities were 21,739, (level-1), 43,478 (level-2) and 65,217 (level-3) plants per hectare.

The combined analyses showed that increasing plant density had no affect on plant height and days-to-pollen shedding. However, the other characters studied were affected: the interaction variety x density was significant for day-to-pollen shedding, days-to-silking, percent-lodged plants, ears-per-100 plants, and grain yield. This indicates that the varieties did not respond equally within all three plant densities.

When yield is plotted against plant densities, it is worth noting that the hybrid H-507 and Caribbean Composite showed increases in yield from Level 1 to Level 2 of plant density, reaching a plateau at Level 3. Tuxpeño and its brachytic version yielded the most at level 2 but at Level 3 the yield dropped back to that of Level 1. Eto Blanco and Antigua Gpo. 2 showed a linear increase in yield from 21,739 to 65,217 plants per hectare.

These same two varieties also had high values for grain-to-stover ratio. As reported earlier, grain-to-stover ratio and tolerance to high plant densities appeared to be associated.

S_1 Line Selection and Grain-to-Stover Ratios

196 S_1 lines derived from a Tuxpeño source were planted in a simple lattice design. Among line selection was based primarily upon grain yield and grain-to-stover ratio as determined from five competitive plants per plot. Within line selection involved chain crossing the best three competitive plants (desirable height, disease free, insect tolerant, productive, etc.) in one row of each replication.

Individual plant data were taken on day-to-flower, plant height, ear height, grain weight, stover weight and grain-to-stover ratios on the same five competitive plants selected as the basis for the among line selection.

Based on one year's data, the correlations among the grain-to-stover ratio and the other characters studied suggest that this ratio could be a useful index for selection for high yield.

According to these limited data, selection solely for grain weight will tend to increase days-to-flower, plant height, ear height, and stover weight. For the materials used in this study and the conditions under which it was conducted, selection for high values of grain-to-stover ratio tended to decrease maturity, plant height ,ear height, and stover weight, and to increase grain yield.

Use of U.S. Corn Belt Germ Plasm in Tropical Corn Improvement

The effects of introgression of two sources of germplasm were studied, using double-cross corn hybrids selected to represent widely divergent types of corn from two different ecological areas. These sources were H-507. (T_2 x T_3) (T_{11} x T_{12}), from the Gulf coast of Mexico and the U.S. hybrid AES 801 (B10 x B14) x (wf9 x B7) from the corn belt of the United States.

The single cross (T_2 x T_3) was crossed to (Wf9 x B7) and then the F_1 backcrossed to the two parental single crosses. In similar manner, (T_{11} x T_{12}) was crossed with (B10 x B14) and the F_1 backcrossed to both parents. The backcrosses [(T_2 x T_3) (Wf9 x B7)] x (T_2 x T_3) and [(T_{11} x T_{12}) (B10 x B14)] x (T_{11} x T_{12}) were then intermated in Mexico for five generations, with mild selection for agronomic traits emphasising prolificacy and freedom from ear rots.

Reciprocal cryptic hybrids were made between the two populations using prolific plants. These hybrids were then tested for yield and agronomic performance in El Roque, Guanajuato in 1969.

Yields obtained would appear to be sufficiently promising to merit further development of the materials, since the area's climatic conditions are intermediate between those of the two regions within which the two types of germplasm originated. It appear that yields substantially better than the hybrid recommended for the area could be obtained with these materials.

The S_1 lines obtained in the formation of the cryptic hybrids were planted at Poza Rica and advanced to the S_2. They will be further evaluated to assess the possible effects of the introgression of Corn Belt germ plasm.

BREEDING METHODOLOGY

Since 1962, CIMMYT has conducted a number of selection experiments to obtain empirical comparisons of different methods. Findings have proved useful in guiding CIMMYT's breeding program, as well as in assisting breeders elsewhere. This year's report summarizes some of the results.

Stratified Mass Selection Versus Modified Ear-to-Row Selection

Stratified Mass Selection (M) was initiated in two populations (Composite Chalqueño 61 and Mexico Group 10) in 1962 near Chapingo, Mexico (2250 m.) Ear-to-row Selection (E) was initiated in the same populations in 1963. The "M" selection was conducted at approximately 23,000 plants per hectare, and the "E" selection at approximately 50,000 plants per hectare. Both schemes were continued until 1966. During 1967, 1968, and 1969, the original population and the various cycles of selection, together with two outstanding locally adapted commercial double-cross hybrids, were grown in trials with 20 replications to evaluate progress. Of these 20 replicates, ten were planted at 43,000 plants per hectare and ten with 63,000 plants.

The analysis of variance for yield indicated that the two levels of population used in these experiments had no significant effect on yield and there was no significant difference in yield between the advanced cycles of selection and the two adapted hybrids included as controls.

A summary of the values obtained for regression of yield on cycles of selection is presented in Table 15. Two conclusions seem

TABLE 15. Regression of yield on cycles of two methods of selection in two populations, tested at two planting rates. Averages of three years data (1967-1969) near Chapingo, Mexico. Ten replications per planting rate.

Population	Method of Selection	No. of cycles of Selection	Planting rates	
			43,000	63,000
Composite Chalqueño 61	Mass	5	5.08% ± 1.16	4.42% ± 1.35
	Ear-to-row	4	6.46% ± 1.55	5.95% ± 0.57
Mexico Group 10	Mass	5	4.82% ± 0.68	5.14% ± 1.08
	Ear-to-row	4	5.71% ± 1.39	6.96% ± 1.39

obvious from these data: (1) apparently ear-to-row selection was slightly more effective than was stratified mass selection in both populations at both plant population levels, and (2) for the Composite Chalqueño 61, either method of selection was more effective at the 43,000 plant rate, than at the 63,000 planting rate.

Although it is readily apparent that both of the methods of selection compared in this project were effective in increasing yield, earlier investigators have reported certain undesirable side effects when selection is based principally on the basis of yield. Data from this study, bearing on this question, are summarized in Table 16.

These data indicate that, in addition to yield, the corns have been improved in respect to ear rots (the percentage of rotted ears decreased with either method in both populations). Also, improved were the characters tillers-with ears and ears-per-plant, both of which are, in part, another measure of yield.

Both methods of selection, however, as practiced in these studies, resulted in an increase in days-to-flower, ear height and lodging. In most cases, the plant breeder would consider such changes as undesirable.

As reported here last year, studies are underway to determine whether manipulation of the environment under which the selection is practiced could reduce the magnitude of these undersirable indirect responses.

TABLE 16. Percent changes in various characters in two populations as effected by stratified mass selection and ear-to-row selection for yield.

Population	Method of Selection [1]	No. of cycles of Selection	Character in % of original population						
			Yield	Days to Flower	Tillers with ears	Ear Height	Lodging	Ears/ Plant	Rotten Ears
Composite Chalqueño 61	Mass	5	+ 22.1	+ 6	+ 3.6	+ 12	+ 14	+ 13	— 4.7
	Ear-to-row	4	+ 24.5	+ 6	+ 2.9	+ 13	+ 13	+ 14	— 6.0
Mexico Group 10	Mass	5	+ 21.5	+ 6	+ 9.7	+ 6	+ 2	+ 24	— 4.1
	Ear-to-row	4	+ 22.2	+ 4	+ 5.0	+ 4	+ 2	+ 12	— 1.6

[1] Final cycle of selection compared to hybrid controls.

TABLE 17. Yields of Dry Ear Corn and other agronomic traits comparing Stratified Mass Selection by weight (W) versus prolificacy (P) in Composite II Celaya and Puebla Group I. Three year averages (1967, 1968, 1969). 20 replications per year. El Roque, Guanajuato, Mexico.

Population	Cycle	Method	Yield tons/ha	Ears/100 Plants	Tillers/100 Plants	% Lodging	Ear Height (meters)	Days to Flower
Composite Celaya II	0	—	6.1	96	21	12	2.03	81
	1	W	6.3	97	25	10	1.99	82
		P	6.4	97	18	9	2.03	82
	2	W	7.0	111	39	16	2.09	84
		P	6.9	108	34	13	2.10	84
	3	W	7.2	110	43	15	2.13	84
		P	7.3	118	48	16	2.14	85
Puebla Gpo. I	0	—	6.2	98	26	48	2.28	87
	1	W	7.5	112	36	40	2.31	86
		P	7.1	111	40	38	2.22	86
	2	W	8.2	125	55	42	2.29	87
		P	7.8	115	39	39	2.28	87
H-366 Control	—	—	7.4	114	7	13	2.29	88

A Comparison of Two Methods of Stratified Mass Selection

Stratified Mass Selection as usually practiced by maize breeders involves the time consuming operation of physically weighing the dry grain produced on each of the selected plants. Selection for prolificacy has been suggested as an effective alternative. The study described below attempts to compare the effectiveness of these two systems.

Two populations adapted to the intermediate altitudes of Mexico (Composite II Celaya and Puebla Group I) were subjected to three cycles of Stratified Mass Selection by grain weight and by prolificacy. The resulting populations were studied in yield trial for a period of three year and the data are summarized in Table 17.

It is apparent that the two methods were substantially equal in their effectiveness in increasing yield and that the yields after two and three cycles in Composite Celaya II and Puebla Group I, respectively, were equal to or better than the best adapted hybrid for the region. It should be noted, however, that the Puebla Group I, Cycle 2 population, could not be recommended to farmers because of its lodging susceptibility even though it apparently outyields the recommended hybrids.

Another fact is worth noting. These data do not show the clearcut tendency for the accompanying undesirable side effects — increase in days to flower nor in percent lodging as was reported in the study of Stratified Mass Selection versus Ear-to-row selection in the two Chalqueño populations.

GENETICS AND CYTOLOGY

Studies on the Chromosome Morphology of Maize

Extensive data on chromosome knobs of maize have been accumulated during the last decade, beginning with the work of Dr. Barbara McClintock in 1958. These studies have been extremely useful in determining the origin, relationships and migration of the different races of maize in Latin America.

Through detailed analysis of these data, CIMMYT scientists have localized several geographical centers of origin of the present day races of maize. Each of these centers has been located on the basis of a specific combination of basic knobbed positions and sizes called "chromosome knob complexes".

These complexes include: (1) Mesa Central Complex, characterized by the absence of knobs in all the knob forming positions, center of origin of this complex is in the highlands of Mexico. (2) Eastern Mexico Complex, characterized by the presence of medium-sized knobs in many of the knob forming positions. The center of origin of this complex is in the eastern coast of Mexico. (3) Zapalote Complex, having a very special knob combination of several sizes in several of the knob forming positions. This complex originated in southwestern Mexico, in the states of Oaxaca and Chiapas. (4) Small Knob Complex, characterized by the presence of small knobs in many of the knob forming positions. Origin is in the highlands of Guatemala. (5) Southern Guatemala Complex, characterized by several large and some small knobs. Center of origin is probably in the lowlands of southern Guatemala. (6) Venezuelan Complex, possesses large knobs in several knob forming positions, primarily on the long arms of the chromosomes. Geographical center of origin is in some region of Venezuela. (7) Andean Complex, characterized by the presence of only two small knobs; one on the long arm of chromosome 7 and the other on the distal position of the long arm of chromosome 6. Center of origin of this complex is located in the highlands of South America.

Study of the Chromosome Knob Constitution of Teosinte

To study the chromosome constitution of maize and its relatives, 14 new collections of Teosinte were obtained from the States of Guanajuato, Mexico, Guerrero and Michoacan in Mexico, making a total of 39 Teosinte collections among CIMMYT's seed stocks.

In an investigation of the frequency with which different maize and teosinte races hybridize in nature, several maize races and the teosintes Chalco (T_1) and Guerrero (T_2) were planted at the Tepalcingo Experiment Station in Mexico. At flowering time, five pollinations were made on shoots of each maize variety, using a mixture of equal volumes of pollen of the variety and T_1. Mixing equal volumes of maize and teosinte pollen simulated a hypothetical situation in which such populations would grow together and coincide in their flowering periods. The same procedure was used in the case of T_2 to pollinate the maize races. No attempt was made to use teosinte populations as females.

If no selective fertilization occurred, about 50 percent maize teosinte crosses would be expected in all cases. However, 58 percent of the maize races pollinated with the maize-T_2 mixture showed that there was a definite selection in favor of maize pollen. Thirty five percent of the maize races permitted some crosses with Guerrero teosinte to occur, but there was a strong bias in favor of maize pollen. Two races of maize, Camelia Vicuña and Arrocillo Amarillo, showed no evidence of any mechanism which prevented teosinte pollen from fertilizing maize ovules, even in competition with maize pollen. As can be seen in Table 18, a similar situation was observed in the group of maize races that were pollinated with maize plus maize-T_1 mixtures.

TABLE 18. Estimated percentages of maize-teosinte crosses that may happen in nature if different races were associated and their flowering periods coincide. Tepalcingo, Mexico, 1969.

Maize Race	Observed % of crosses with Chalco Teosinte	Maize Race	Observed % of crosses with Guerrero Teosinte
Jala	31.8	Canario de 8	0
Cuba 12	8.8	Martinica 2	0
Guatemala 127	6.9	Camelia Vicuña	42.4
Arrocillo Amarillo	4.9	Arrocillo Amarillo	40.4
Cuba 54	3.8	Tuxpeño	22.4
Vandeño	3.4	Guatemala 55H	12.3
Bolita	3.3	Jala	9.1
Nal-Tel Guat.	2.9	Tabloncillo	5.9
Cónico	2.8	Cuba 54	4.2
Tabloncillo	2.4	Tehua	3.8
Honduras 19 .	2.2	Zapalote Grande	3.8
Guatemala 806	1.8	Olotillo	2.4
Cónico Norteño	1.5	Flint Guarani	1.6
Cuba 63	1.2	Chapalote	0
Chapalote	0	Reventador	0
Reventador	0	Vandeño	0
Harinoso de ocho	0	Harinoso de ocho	0
Maíz Dulce	0	Maíz Dulce	0
Guerrero 250	0	Cónico Norteño	0
Celaya	0	Bolita	0
Jalisco 78	0	Cónico	0
Palomero Toluqueño	0	Guerrero 200	0
Serrano	0	Caingang	0
Guatemala 114	0	Comiteco	0
Guatemala 145	0	Pepitilla	0
Nal Tel de 8	0	Comun Segregaciones	0
Quicheño precoz	0	Puya Segregaciones	0
Cuba 31	0	Entrelocado duro	0
Costa Rica 30	0		

The races of maize Celaya, Maiz Dulce, Bolita, Vandeño, Palomero Toluqueño, Jala, Cónico, Zapalote Grande, Zapalote Chico, Nal-Tel, Arrocillo Amarillo, Harinoso de Ocho, Dzit Bacal and the collection Martinica 2 were used as females in crosses with pure pollen of teosinte and in all cases a good seed set was obtained. Thus, in most cases, competition between the two sources of pollen seems to be the reason for the lack, or reduced number, of maize teosinte crosses.

A similar study on individual plants of the F_2 of the crosses of Camelia Vicuña and Arrocillo Amarillo, with collections that do not cross with teosinte, might provide a better understanding of the genetic mechanism (if any) involved in the selective fertilization observed in maize-teosinte associations. Similarly, a better understanding could be gained of the mechanism by which teosinte and maize populations can grow together: remaining compatible in crosses, yet maintaining their identities even when their flowering periods overlap.

Other Genetic Studies

Investigations of possible uses of genetic mutants in modifying plant height is now under way. The "square stem" character represents one such possible mutant and appears to show height reduction in the F_1 crosses, although the genetics of its use are not yet clear. Other characters, both identified and unidentified types, are under study.

The use of mutants in the development of higher quality protein is being investigated, also. This involves study of the effects of a combination of two or more protein quality endosperm mutants on grain texture. The search for marker genes as an aid in the identification of kernels homozygous for the Opaque-2 and Floury-2 genes is being continued.

PHYSIOLOGY

Leaf orientation: One thousand S_1 lines derived from Tuxpeño composite were evaluated for leaf angle and 50 lines with erect leaves and 50 with floppy leaves were selected to generate two populations. Two generations of synthesis were carried out at Poza Rica in 1969. The resulting populations will be studied to investigate the probable effects of leaf orientation on yield and other important characteristics.

With the same purpose in mind, 35 S_1 lines derived from combinations of USA Corn Belt and Mexican germplasm were used to generate the same two types of population with respect to leaf orientation. These populations went through one cycle of synthesis at El Roque, Guanajuato, Mexico in 1969.

The process of developing several lines differing in leaf orientation is underway on 47 S_2 lines of Tuxpeño.

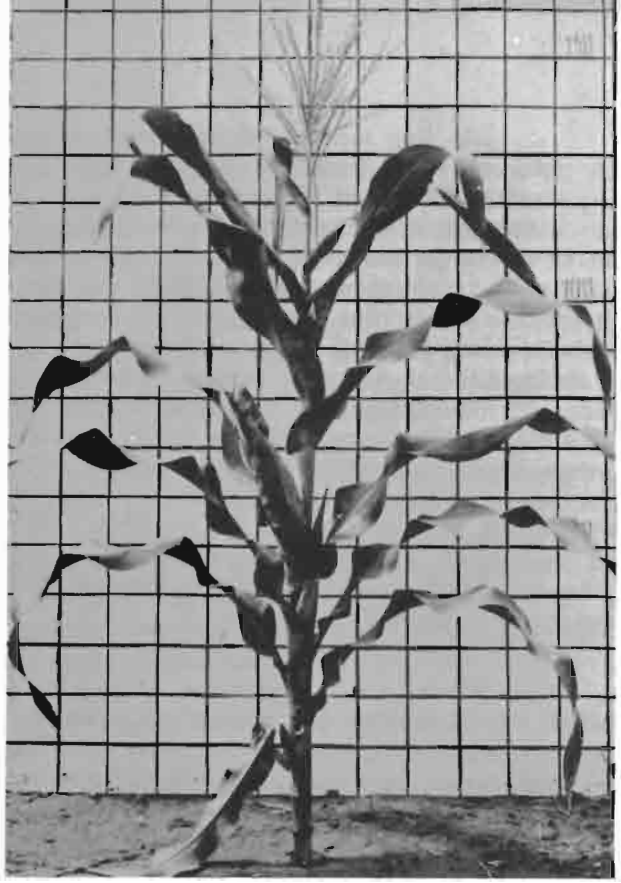
Defoliation trials: A number of defoliation trials have been carried out involving the following treatments: (1) control, (2) removal of leaves above the ear, (3) removal of leaves below the ear, (4) removal of alternate leaves, (5) splitting and removal of one-half of the leaf blade on all leaves, (6) tying-up of leaves above the ear to an angle of approximately 10°, (7) same as No. 5 above, plus tying up of leaves above the ear to an angle of 10°, (8) splitting and removal of one-half of the leaf blade above the ear and tying up of leaves above the ear.

The experimental findings indicate a trend toward a decreased per-plant grain yield due to removal of leaves above the ear. This decrease seems to be equal to, or greater than, the decrease due to removal of the leaves below the ear.

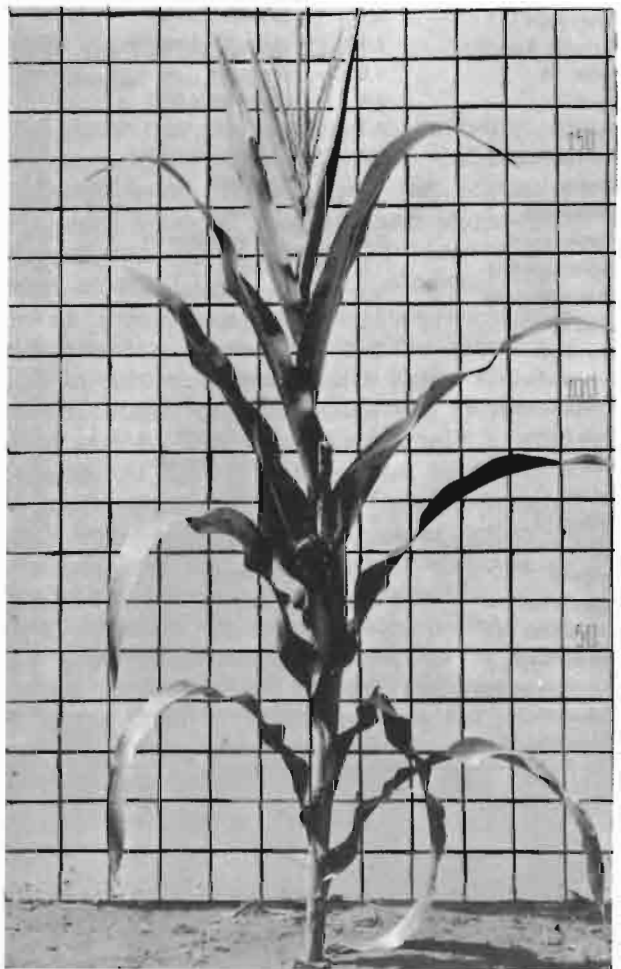
The effect on grain-per-plant, due to tying up the leaves above the ear to a more erect position, is not clear. However, there are some indications of a beneficial effect of erect leaves at high population densities (higher leaf area indices). In treatments where one-half of each leaf was removed along the midrib, a detrimental effect was observed when the leaves above the ear were tied in the erect position.

Maximum Yield Study

A study was initiated at Tlaltizapán in June, 1969, to investigate the yields obtained on a per-unit-time and per-unit-land area basis. High populations and continuous cropping were used. Initially, the varieties chosen for this experiment were two improved populations (Caribbean Composite and Tuxpeño Composite) and two unimproved collections (Guerrero 221 of the race Pepitilla, and Oaxaca 179, of the race Zapalote Chico). The Zapalote Chico is very early, and short in stature, while the other three varieties are late and tall. Each variety was planted at three populations densities and fertilizer was applied at the same rate on a per-plant basis in all densities.



Two plants from the same population (Tuxpeño brachytic-2) exhibiting marked differences in leaf habit (or angle). By breeding for erect leaves it is hoped to improve light interception particularly at high population densities.



The varieties and rates of planting were as follows:

Variety	Rates of Planting (plants/ha)			
	54,000	67,000	100,000	167,000
Caribbean composite	X	X	X	
Tuxpeño composite	X	X	X	
Guerrero 221 (Pepitilla)	X	X	X	
Oaxaca 179 (Zapalote Chico)		X	X	X
Row width (cm)	92	75	50	30

Single plant hills 20 cm apart were used at all row widths.

Data for one complete year are now available. The variety of Zapalote Chico completed three cycles of growth and flowered in its fourth planting at the end of one year. The other three varieties were in the grain-filling stage of their third cycle at the end of one year.

In general, yields seem to increase with increased plant populations, unless the percentage of ear-bearing plants decreased with increase populations, as occurred in the first cycle for Pepitilla, the Caribbean Composite and the Tuxpeño Composite.

Zapalote Chico, at 167,000 plants/ha, produced 14 tons of grain in the first three cycles. This variety completed an additional one-half of a growth cycle in the first year of the experiment, which suggests that its annual production will probably approach the maximum annual grain production reported in the tropics (see CIMMYT Annual Report 1967-68, p. 43). The Zapalote Chico used in this experiment is an unimproved collection. It is very early and short in stature.

These results underline the need for additional study of different plant types in association with the appropriate cultural practices necessary for expression of their full yield potential.

Selection For Root Strength

Root lodging is a major problem in all corn-growing areas of the world. When not caused by disease and/or insect attack, lodging can generally be traced to an inadequate root system. One approach to development of populations with a high degree of resistance to root lodging is the selection of plants showing the highest pulling resistance.

The first CIMMYT study in this direction consisted of a mass selection program for root strength, initiated in Roque, Guanajuato, Mexico in 1969. The "Late Interracial Composite" was used at population levels of 25,000 and 50,000 plants/ha. Root strength was measured by pulling the root from the soil using a tripod, a Chinese finger, and a tensiometer to indicate the force required.

Preliminary analysis of the data collected seems to indicate that there is some useful genetic variation for this character. Seed from about five percent of the plants showing highest pulling resistance will be used to form a balanced composite for the next cycle of selection.

Photoperiod Studies

The experiments reported here summarize a preliminary attempt to pinpoint some important growth responses, and environmental factors producing these responses, when experimental conditions are changed over latitude and altitude.

Two varieties of each of seven Mexican races of maize were planted in Tepalcingo, Tlaltizapán, and Roque, Mexico, at a number of dates throughout 1968 and 1969. Six of these races are adapted to altitudes between 1,000-1,800 meters. The seventh race, Zapalote Chico, is adapted to lower elevations. Two improved varieties were included each year as checks.

TABLE 19. Sites, dates of planting, observed daylength at planting dates, and mean maximum and minimum temperatures during the 30 days following planting.

Site	No. of Plantings	Planting Date	Observed[1] [2] Daylength	Mean temperatures for 30 days after planting (°C)[2]	
				Max.	Min.
Roque, Gto.	1	April 21	12h 36'	29.2	10.3
Roque, Gto.	2	May 21	12h 57'	30.0	12.6
Roque, Gto.	3	June 21	13h 12'	26.7	13.4
Tepalcingo, Mor.	4	Oct. 1	11h 31'	32.5	15.0
Tepalcingo, Mor. 1968	5	Nov. 1	11h 04'	30.4	12.2
Tlaltizapán, Mor. 1969					
Tepalcingo, Mor. 1968	6	Dec. 1	10h 43'	29.2	10.5
Tlaltizapán, Mor. 1969					
Tlaltizapán, Mor.	7	Dec. 21	10h 41'	30.1	8.8

[1] Observed daylength is period between the times when the sun's disc was half below the horizon in the morning and evening when observed from the site of planting.

[2] Observed daylengths and mean temperatures are for 1 year only on plantings numbered 4 and 7. For other planting dates the values are means of 2 years data.

Two rates of N (80 and 160 kgs/ha) were used and each variety was replicated twice at each fertility level for each planting date. Rate of planting was 44,000 plants per hectare.

Days-to-flower, ear height, and grain-to-stover ratios were measured on ten competitive plants in each plot, as indicators of the response to changes in daylength.

Ear height and grain-to-stover ratios give some indication of relative vegetative growth under varying photoperiods. The grain-to-stover ratio is a measure of plant efficiency which may be useful as an indicator of stability under changing daylengths.

In general, for the trait days-to-flower, the trend was toward a longer period as daylength (at planting) became shorter. This does not agree with the premise that maize is a short-day plant. However, the maximum difference in daylength at the different planting dates was 2 hours, 31 minutes. Also, the maximum daylength was 13 hours, 12 minutes, which is still a photoperiodically short day for maize.

It appears that at these intermediate daylengths, some other environmental factor exerted an effect strong enough to override the effect of small changes in daylength (possibly temperature). The importance of interactions between photoperiod and temperature in controlling flowering in maize have been emphasized by several investigators.

With respect to ear height there was no clear effect of photoperiod. It was not possible to pinpoint a direct relationship between photoperiod at planting or temperatures following planting, and yield of grain per plant. However, in general, the longer the time from planting to flowering, the greater the plant height and the greater the grain weight per plant.

The grain-to-stover ratio, although useful as a measure of plant efficiency, integrates many of the responses of a plant to its environment. It is obvious that this ratio was not a very meaningful indication of response to photoperiod in this particular experiment. Taller and later varieties, high in grain production, did not show high grain-to-stover ratios. On the other hand, the shorter, early varieties, lower in grain production, showed a high ratio. Different relationships could exist at higher population levels.

An experiment to follow up these earlier findings on days-to-flower, using artificial illumination to extend daylength, was planted at El Batán Experiment Station, in 1970. Twenty-nine varieties, including the 17 varieties in the previous experiment, were planted in rows perpendicular to the light source. Dissections were made of the developing tassel on single plants of each row at distances of 5 to 7 meters, 14 to 16 meters, and 44 to 46 meters from the light source. Indications were that development of the tassel was delayed in those plants under long days (close to the lights), as compared to plants under natural short-day conditions.

Photoperiod experiment using artificial lights to extend daylength. Two rows of a variety of Zapalote chico are shown. Note plastic, lower right.

Immediately after emergence, a clear plastic sheet, with holes for growth of the plants was placed on the soil surface along the length of one row of each variety as a means of increasing the minimum night soil temperature. Vegetative growth of all entries in the rows with plastic was greater than in the rows without plastic. The dissections showed that tassel development was hastened by this treatment, also.

Temperature changes are obviously involved in the effects of altitude on the days-to-flowering of a maize variety. These experiments suggest that temperature may be as important as photoperiod when latitude changes are involved. Production of a variety of maize possessing the degree of temperature insensitivy (in terms of its effect on time to flowering) necessary for wide adaptation, may be neither possible nor desirable.

PATHOLOGY

Resistance to Stunt Disease (A Cooperative Study with INIA)

To build up populations with a high degree of resistance to the stunt disease, a new cycle of recombination of previously selected materials was planted early in 1969, at Cotaxtla, Veracruz, Mexico.

A total of 238 selected families were grown in a triple lattice experiment; with one replicate in an isolated field employing the modified ear-to-row technique used for the improvement of the level of resistance and yield of this population.

Of the 238 families tested, 136 came from the composite "Republica Dominicana", and 102 from the composite Cubano x Rep. Dominicana". The new population derived from a recombination of the best 20 percent of these 238 families will be known as Composite A.

Three commercial double crosses and the original population were included as controls in the test. The results show an average reduction of 16 percent and 8 percent in stunt index for the selected families, when compared with the average for the controls and the original population, respectively. In yield, there was an average gain of 7.1 percent over the original population (no significant difference with the mean of the hybrids). In number of ears per plant, the selected families showed an average gain of 13 percent over the original population and the hybrids. Maturity was two percent later than the original population, and three percent earlier than the mean of the commercial hybrids.

In another attempt to isolate sources of resistance to the corn stunt disease, a series of S_2 lines were selected from among highly susceptible and highly tolerant S_1 lines from the composite "Cubano x Rep. Dominicana". These S_2 lines were inoculater by means of infectious leaf hoppers *Dalbulus maidis*, with three insects allowed to feed for 48 hours on each seedling. The most resistant and susceptible plants were then selfed to advance the lines to S_3. The cycle was repeated to obtain highly homozygous lines (resistant and susceptible) for future studies on the inheritance to the virus disease.

The resulting resistant and susceptible lines were inoculated in the manner described earlier. The findings indicate some breakdown in resistance in the S_3 generation; within some lines which were highly resistant in both S_1 and S_2.

The highly resistant S_3 lines are now being used in a study to determine whether the resistance could be due to a resistance to the insect vector, rather than to the virus itself.

The most resistant and susceptible S_3 lines have been advanced to the S_4 and a composite made up of 25 of the more resistant lines.

A preliminary screening of 125 S_1 lines from the Cuban Composite, artificially inoculated, indicate that some of these lines may prove to be good sources of resistance to this disease.

Ear Rot Resistance

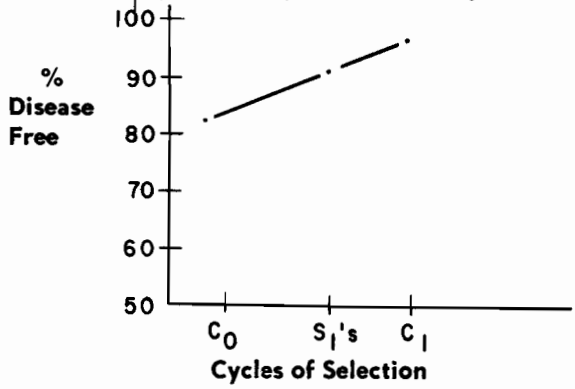
In a search for sources of resistance to the ear rot caused by *Diplodia maydis*, 140 varieties were tested at five locations in the tropics of Mexico where the disease is endemic.

At one location, several hundred plants were artificially inoculated, and selfed. Sixty five of the resistant S_1 lines were recombined (C_1) using a modification of the ear-to-row technique. The female rows were again inoculated, as were several hundred plants in the male rows which, in turn, were selfed to develop S_2 lines.

In the summer of 1969, a new cycle (C_2) was planted for recombination among the nine most highly resistant S_1 lines. The S_2 lines also were planted and artificially inoculated.

The relative gains in resistance (one year's data) are shown in Fig. 1 where the mean of the C_0 (Composite of 32 varieties), S_1's (balanced composites of resistant S_1 lines), and C_1 (first cycle of recombination of selected S_1 lines) are compared.

FIGURE 1. Gain in resistance in Composite B after 2 cycles of selection against the ear-rotting organism Diplodia maydis in the tropics.



The average gain in resistance can be estimated as 15 percent above the original population, which, as expected, showed a relatively high degree of resistance.

TABLE 20. Incidence of stunt disease and Downy mildew in 2 localities on Caribbean Collections of maize.

	Pedigree	Stunt disease mean	% Downy mildew [1] Rio Bravo
1.	Barbados Gpo. 1	2.8	37.4
2.	P. Rico 16 D	2.2	41.6
3.	,, ,, 19 D	2.0	37.4
4.	,, ,, 2 D	2.8	55.4
5.	Haiti Gpo. 7	2.4	31.7
6.	P. Rico 15 D	1.8	25.5
7.	,, ,, Gpo. 5	2.8	48.8
8.	Jal 188 x Pepitilla	4.8	37.0
9.	P. Rica 12 D	2.6	65.1
10.	,, ,, Gpo. 5 A	2.2	38.8
11.	Granada Gpo. 1 D	2.4	44.8
12.	,, 13 D	3.0	35.6
13.	Haiti Gpo. 8	1.4	41.4
14.	,, 8 J	1.8	35.8
15.	P. Rico 7 D	2.2	44.8
16.	Haiti Gpo. 4	1.7	37.9
17.	,, 23 J	2.3	35.3
18.	Tuxpantigua	2.6	34.2
19.	Haiti 14 J	1.9	38.2
20.	P. Rico 24 D	2.6	47.8
21.	P. Rico 6 D	2.5	50.0
22.	Antigua 2 D	2.5	48.8
23.	Haiti 24 J	2.0	34.4
24.	Sta. Lucia 2 D	3.3	51.9
25.	P. Rica 23 D	2.6	36.2
26.	P. Rica 8 D	3.1	39.1
27.	Sta. Lucia Gpo. 2	2.4	30.7
28.	Antigua 8 D	3.4	54.9
29.	P. Rica Gpo. 6	2.1	35.7
30.	,, ,, 4 D	2.8	31.6
31.	P. Rica Gpo. 4	3.3	40.9
32.	,, ,, Gpo. 5	1.8	47.8
33.	(B_{10} x B_{13}) x Harin. de 8	4.1	23.3
34.	P. Rica 5 D	3.6	29.4
35.	Haiti 7 J	2.1	50.3
36.	Haiti Gpo. 1 I	2.3	44.8
37.	Antigua 7 D	2.4	38.7
38.	P. Rico 14 D	3.0	41.7
39.	Tobago 14 D	2.5	41.2
40.	Rep. Dom. Gpo. 11	2.5	36.3
41.	Haiti 5 J	1.7	36.6
42.	Antigua 4 D	3.5	47.5
43.	Westigua	3.8	27.9
44.	P. Rico 1 D	2.3	32.5
45.	Haiti 21 J	1.9	22.8
46.	Rep. Dom. Gpo. 8	2.1	33.7
47.	Haiti 23 J	1.7	50.8
48.	Barbados 5 D	2.8	50.8
49.	Tobago 2 D	2.5	38.0
50.	CBC x (P_{330} x M_{330})	3.7	23.4
51.	P. Rico 22 D	2.9	38.6
52.	Rep. Dom. Gpo. 9	1.8	35.0
53.	Sta. Lucia 14 D	3.8	33.4
54.	Haiti Gpo. 6	1.6	39.4
55.	(Oh. 43 x M_{14}) x Ant. 2 D	4.8	21.7
56.	Haiti Gpo. 2 A	1.7	37.8
57.	Tuxpeño x N. Engr. Flint	5.0	32.3

[1] Average of 8 replications. Readings taken at Rio Bravo, Tamps.

The evaluation of the second cycle of selection (C_2) is underway, as is the advancement of the selected S_2 lines which will be used to study the inheritance of resistance or tolerance to *Diplodia* ear rot.

Convergent-Divergent Selection in a Caribbean Composite for Insect and Disease Resistance

A composite of most of the collections from the Caribbean available in CIMMYT's germ plasm bank was planted and mass selected at five locations in the tropics of Mexico during the summer of 1969. Plants showing insect and/or disease damage were eliminated.

Twice each year, the subpopulations, now named Cotaxtla, Chontalpa, Poza Rica, Rio Bravo, and Tlaltizapán, are selected and recombined simultaneously at each location. Agronomic characteristics such as plant height and number of ears per plant also are considered in the selection process.

Selection for resistance includes: fall armyworm, stemborers, earworm, leaf blights, stalk rots, Downy mildew, corn stunt and ear rots. At each location, a balanced composite of the populations is planted within male rows and each subpopulation within the female rows. The objective is to develop a widely adapted population with built-in resistance to major insect and disease problems of the lowland tropics.

Disease and Pest Reaction Nurseries

As a joint effort of the entomologists and pathologists, 57 varieties were evaluated at two locations in Mexico, to assess their insect and disease reactions.

The incidence of stunt disease and Downy mildew in two localities is summarized in Table 20.

Screening Maize Genotypes for Ear-Rot Resistance

Ear-rotting fungi (Diplodia spp.) are grown in jars before inoculation of maize genotypes to screen for resistance. Black masses of spores and mycelium are obtained from the jars.

Heavy spore suspension of the ear-rotting fungi are sprayed on ear-shoots about 10 days after tasseling.

In spraying the spore suspension of ear-rotting fungi on young ears. The stream is directed to the silk and base of the shoot. This is the inoculation method which is closer to the natural infection in the field.

High percentages of infection are obtained in susceptible maize genotypes.

ENTOMOLOGY

Stem Borer Resistance

An additional set of 57 varieties from Caribbean germ plasm were evaluated during 1969, under natural infestations of *Zeadiatraea grandiosella* (Dyar), *Z. lineolata* (Walker), and *Diatraea saccharalis* (Fab.). These materials were selected from among those groups in the 1968 tests which showed the lowest number of borer-injured internodes (Table 21). A few susceptible entries also were included.

TABLE 21 Reaction of Caribbean Germ Plasm to stem borer attack [Zeadiatraea grandiosella, Z. lineolata and Diatraea saccharalis (Fab.)] in Mexico.

Source	Number of Entries	Damaged [a] Internodes Per Plant	Days of Anthesis	Stalk Diameter Second Internode
		1968		
Antigua	2	2.06	56	18 mm
Martinique	1	2.08	55	17
República Dominicana	3	2.17	57	18
Puerto Rico	3	2.18	58	19
Guadalver	3	2.22	57	19
Haiti	3	2.28	62	20
San Croix	3	2.28	58	19
San Vicente	3	2.32	55	18
Barbados	2	2.35	61	19
Santa Lucia	2	2.47	66	22
Other origins	20	2.52	56	18
Cuba	3	2.66	62	20
Granada	3	2.68	65	21
Tobago	2	2.79	69	22
Jamaica	2	2.86	63	20
Trinidad	2	2.96	65	21
L.S.D.	0.05	0.39		
		1969		
Antigua	4	3.43 [b]	60	1.4 [c]
Other origins	7	3.70	57	1.5
Puerto Rico	19	3.80	62	1.6
Santa Lucia	3	3.94	77	1.9
Haiti	15	4.00	71	1.7
Granada	2	4.14	72	1.7
Barbados	2	4.54	61	1.4
Tobago	2	5.36	72	2.0
L.S.D.	0.05	0.44		

[a] Average of five locations (Rio Bravo, Poza Rica, Cotaxtla, Chontalpa and Tepalcingo).

[b] Average of four locations (Rio Bravo, Poza Rica, Cotaxtla and Chontalpa).

[c] Scale 1 to 3, where 1 = thin, 2 = intermediate and 3 = thickstem.

The nurseries were established at: Poza Rica and Cotaxtla, Veracruz; Río Bravo, Tamaulipas, and Chontalpa, Tabasco, in cooperation with regional experimental stations of the National Institute of Agricultural Research in Mexico (INIA).

In 1969 the damage records (number of injured internodes per plant), from Chontalpa were not significantly correlated with those from the other locations. This was probably due to the influence of planting date and/or the presence of a different species of stem borer. (In 1968, insect collections revealed the presence of a different species of stem borer not yet identified.)

The interaction varieties x localities was significant, indicating that a group of varieties did not react uniformly in the different environments. However, significant correlations occurred among data from the other three locations.

Again, the amount of damage was significantly influenced by relative maturity (earliness or lateness) and by the diameter of the stalk (measured at the second internode from the base). Early varieties with thin stalks, as well as late varieties with large stalks, may not be resistant, even though they showed a relatively low amount of damage.

Taking into account damage, stalk diameter, relative maturity, estimated yield, and soundness of the ear, the following varieties (together with those selected in 1969) can be considered as useful in the development of stem-borer resistant populations: Antigua 4D, Antigua 8D; Haiti 21J, Haiti 23J; Haiti 265; Haiti group 6; Puerto Rico 2D; Puerto Rico 6D; Puerto Rico 8D; Puerto Rico 14D; Puerto Rico 19D; Puerto Rico group 5; Puerto Rico group 6; Santa Lucia 2D; Santa Lucia group 2; Tuxpeño x New England Flint; Tuxpantigua and Westigua.

As was observed in previous years, the efficiency of this year's tests increased with higher levels of infestation. The estimates of heritability for the number of damaged internodes per plant at Rio Bravo, Poza Rica, Chontalpa and Cotaxtla were 2.4 percent; 4.2 percent and 3.0 percent, respectively. These estimates, as in 1968, are considered to be very low. Progress from selection per cycle would be very small, because 96 percent to 99 percent of the total variance could be attributed to environmental effects. However, these environmental effects can be minimized to a considerable degree by attaining uniform artificial infestation.

Stored Grain Pests

A test to evaluate the performance of Malathion as a grain protectant under two different environments (temperate and sub tropical) was terminated this year. (The 1968-69 annual report included the procedures and initial results.) Observations were conducted for 605 days. It should be recalled that after Malathion ceased to be effective in the test initiated at Chapingo (temperate climate), the treated wheat, hulled rice and corn samples were transferred to Tepalcingo (subtropical climate) 134 days after the first observation. Reinfestations were made at 3 to 5 week intervals. Mortality was recorded after 48 hours of exposure.

Mortality fluctuations from one reading to the next can be attributed to environmental changes in temperature. Differential degradation of Malathion was observed with respect to dosage and grain type in both environments. At Tepalcingo, rice was effectively protected for a longer period of time than maize and wheat (Table 22). At Chapingo, before transfering the samples to Tepalcingo, mortality records were higher, over a longer period of time, in maize than in wheat and rice. However, once the samples were established at Tepalcingo, the performance of Malathion was similar to that observed in the test initiated at this location.

It was not until 488 days after the tests were begun that adult insects began to emerge from the routine infestations conducted every 3 to 5 weeks (Tables 22 and 23). This indicated that, in spite of a continuously decreasing mortality, the remaining insecticide was still effective in inhibiting reproduction.

Two interesting conclusions may be derived from this study: (1) the activity of Malathion is greatly enhanced when treated grain is moved from a low temperate to a sub-tropical climate, and (2) Malathion residues seem to arrest reproduction for an extended period, in insects that survive a 48 hour exposure to treated grains.

Insect Control with Insecticides

Two field tests were established during the rainy season in 1969 to evaluate the effectiveness of seven insecticides in granular formulation. One test was conducted in the lowland tropics of Mexico at Poza Rica, Veracruz (average rainfall 1800 mm). The other test was at Tlaltizapán, Morelos (subtropical climate) which has an average rainfall of 700-800 mm.

TABLE 22. Percent mortality of Sitophilus zeamais Motschulsky in rice, maize, and wheat grain, each treated with three different dosages of Malathion. Tepalcingo, Morelos (sub-tropical climate), 1968-69-70.

Days after grain treatment	Rice			Maize			Wheat		
	Dosages ppm								
	15	10	5	15	10	5	15	10	5
	%	%	%	%	%	%	%	%	%
2	98	99	92	100	100	100	100	100	100
28	100	100	94	100	100	100	97	100	92
49	99	98	70	100	100	98	95	56	13
70	99	95	40	100	100	84	73	10	4
91	99	95	51	100	100	73	35	20	5
112	100	97	57	98	97	40	7	7	5
141	100	96	52	94	64	16	9	7	5
163	100	100	92	99	84	16	9	6	9
183	100	78	21	64	39	11	4	5	11
203	90	30	6	39	22	13	7	5	8
224	100	94	50	72	40	9	18	12	4
246	98	83	27	38	14	6	7	2	19
267	100	99	86	63	38	12	7	2	16
303	100	97	72	27	13	7	6	3	13
323	100	95	79	19	10	9	5	3	5
348	85	42	8	12	3	6	10	2	6
376	93	76	10	14	15	9	5	2	5
412	82	42	10	14	12	7	12	8	13
435	50	12	7	16	8	2	4	8	5
460	6	5	1	7	12	3	2	6	7
488	23	25	6	18	7	2	0	3	4
511	17	14	14	5	3	2	4	3	2
544	7	6	2	2	2	1	0	1	3
577	6	0	0	0	0	0	0	0	0
605	77	48	10	12	2	9	13	10	9
	Mortality on Emerging Adult Insects								
488	0	0	0	55	54	5	4	2	9
511	0	0	0	50	42	3	4	5	6
544	0	0	0	41	36	3	6	11	15
577	0	0	24	20	25	5	5	5	11
605	0	0	75	14	15	9	7	15	12

Data reported are the averages of four replications. Malathion was applied to the grain on July 18, 1968.

TABLE 23. Percent mortality of Sitophilus zeamais Motschulsky in rice, maize, and wheat grain, each treated with three different dosages of Malathion. Chapingo, Mexico (temperate climate) and Tepalcingo, Morelos (sub-tropical climate), 1968-69-70.

Days after grain treatment	Rice			Maize			Wheat		
	Dosages ppm								
	15	10	5	15	10	5	15	10	5
CHAPINGO									
	%	%	%	%	%	%	%	%	%
8	71	49	5	100	100	100	100	100	82
28	79	63	44	100	100	100	97	93	55
49	47	23	10	100	100	100	82	38	5
70	17	7	1	100	99	82	19	7	2
91	9	2	0	100	97	35	8	0	0
112	14	6	0	96	90	13	3	0	0
134	10	5	0	96	97	17	2	0	0
162				92	45	6			
183				25	17	6			
204				16	9	2			
TEPALCINGO									
141	100	100	98				90	54	9
162	100	99	96				56	23	3
183	100	95	84				10	4	1
204	100	87	51				13	5	5
224	100	99	89	100	100	81	23	7	18
244	99	71	29	98	86	31	13	5	15
265	100	100	95	100	92	45	15	5	17
303	100	96	88	69	28	19	12	3	9
323	100	99	79	56	28	14	8	4	6
348	96	47	5	19	9	8	2	6	3
376	97	74	19	24	21	11	10	5	5
412	67	25	6	8	16	5	3	1	5
435	70	39	12	15	18	16	7	9	4
460	8	0	1	6	10	3	3	1	3
488	95	49	7	43	22	8	1	3	7
511	34	19	22	5	5	1	4	5	4
544	31	7	3	2	4	4	4	8	4
577	54	47	6	10	4	10	0	0	0
605	93	71	21	11	16	17	35	22	17
Mortality on Emerging Adult Insects									
488	0	0	0	87	35	48	15	9	3
511	0	0	0	58	18	11	5	1	7
544	0	0	0	56	27	17	26	19	15
577	0	0	0	26	26	15	42	20	21
605	0	0	0	25	21	16	36	31	28

Rice and wheat were transferred from Chapingo to Tepalcingo 145 days after the experiment began, and corn after 187 days. Infestation and readings proceeded as before.

Data reported are the averages of four replications. Malathion was applied to the grain on July 18, 1968.

Two applications were made: at two weeks after plant emergence, and at eight weeks after emergence. Birlane, Cytrolane, Gardona, Bidrin and Azodrin, where the compounds tested for the first time. Sevin and Telodrin were included for comparison. Considering the overall performance on fall armyworm (Table 24), the data indicate that Telodrin, Birlane and Cytrolane were the most effective at Tlaltizapán. Cytrolane, Telodrin and Gardona provided the best protection at Poza Rica.

In spite of the low stem borer population at Tlaltizapán, it was possible to detect differences among the insecticides tested, with Telodrin, Gardona, and Birlane showing the greatest effectiveness. At Poza Rica, the same compounds provided the most protection (Table 24).

TABLE 24. Relative effectiveness of several insecticides formulated in granules on the fall armyworm and stem borers at Tlaltizapan, Morelos and Poza Rica, Veracruz, Mexico, 1969.

Granular Insecticide and Concentration	Kg/ha	% Fall Armyworm Damage Plants after one Application			Stem Borer
		2 weeks	3 weeks	4 weeks	Injured Internode per Plant
TLALTIZAPAN, MORELOS					
Telodrin 1.5%	8.0	1	16	15	0.2
Birlane 2.0%	8.0	1	22	17	0.5
Sevin 2.5%	10.0	4	25	21	0.6
Cytrolane 10.0%	2.5	4	15	18	0.6
Gardona 2.0%	8.0	6	22	21	0.4
Bidrin 2.0%	8.0	10	31	19	0.6
Azodrin 2.0%	8.0	17	32	17	0.7
Check (Untreated)		40	25	14	0.9
LSD 0.05		7	11	NS	0.3
POZA RICA, VERACRUZ					
Telodrin 1.5%	8.0	5	29	18	1.8
Cytrolane 10.0%	2.5	6	21	23	3.7
Birlane 2.0%	8.0	17	36	23	2.1
Gardona 2.0%	8.0	21	25	14	2.3
Bidrin 2.0%	8.0	28	52	28	3.5
Azodrin 2.0%	8.0	28	51	38	3.5
LSD 0.05		15	14	15	0.8

Planting date: July 22, 1969. Test conducted during the rainy season.

Data are averages of 5 replications, plots 5 rows, 5 meters long.

Planting date: July 29, 1969. Test conducted during the rainy season.

Data are averages of 5 replications. Plots 4 rows, 4 meters long.

Stem borer = Tlaltizapán: Zeadiatraea grandiosella,
Poza Rica: Z. lineolata and Diatraea saccharalis.

Fall armyworm = Spodoptera frugiperda.

Additional information was obtained concerning the timing of application of granular insecticides (Table 25).

As in previous tests, the first application made 2 to 4 weeks after plant emergence provided the most effective protection against the fall armyworm. The lowest stem borer damage was registered when the second application was made 7 to 9 weeks after plant emergence.

TABLE 25. Effect of timing of applying Telodrin 1.5% in granular formulation, 8 kg/ha per application on fall armyworm and stem borer at Tlaltizapan, Morelos and Poza Rica, Veracruz, Mexico, 1969.

Time of treatment weeks after plant emergence	11 Feb., 69*	27 Jun., 69	17 Feb., 69	29 Jul., 69
	Tlaltizapan		Poza Rica	
	Av. % plants damaged by fall armyworm**			
2 weeks and 6 weeks after	0.3	26	7	22
3 weeks and 7 weeks after	1.4	25	11	23
4 weeks and 8 weeks after	2.5	23	12	36
5 weeks and 9 weeks after	14.8	45	16	44
Check	46.7	74	25	41
LSD 0.05	—	34	10	14
	Av. Number of borer damaged internodes/plant***			
2 weeks and 6 weeks after	0.08	0	1.9	2.3
3 weeks and 7 weeks after	0.05	0	1.2	1.8
4 weeks and 8 weeks after	0.06	0	1.0	1.3
5 weeks and 9 weeks after	0.04	0	1.2	1.0
Check	0.64	0	1.5	4.0
LSD 0.05	—	—	0.4	0.6
	Average yield as percent of check			
2 weeks and 6 weeks after	106	115	183	105
3 weeks and 7 weeks after	100	120	119	109
4 weeks and 8 weeks after	102	115	174	110
5 weeks and 9 weeks after	104	118	152	100
Check	100	100	100	100
LSD 0.05	—	—	44	—

* Planting dates for each test.

** Fall armyworm (Spodoptera frugiperda) records are the average throughout the season.

*** At Tlaltizapan Zeadiatraea grandiosella and at Poza Rica Z. lineolata and Diatraea saccharalis.

Although yield increments over the check were not substantial (except in the test established at Poza Rica on February 17) in most cases the treated plots yielded more than the check.

Another test was conducted at Poza Rica to determine the number of applications and proper timing of the applications during the rainy season. The findings (Table 26) revealed that two applications (15 and 30 days after plant emergence) were necessary to suppress fall armyworm. An additional application, made 45 days after plant emergence, significantly reduced stem borer damage to the stalks and ears.

TABLE 26. Reduction of fall armyworm and stem borer infestations by a variable number of applications of granular Telodrin 1.5% 8 kg/ha per application. Poza Rica, Veracruz, Mexico, 1969.

Time of treatment days after plant emergence	% Fall armyworm damaged plants After 2 weeks	3 weeks	4 weeks	5 weeks	6 weeks	7 weeks	Stemborer Injured Internodes per plant	% Injured Ears	Yield % of check
Check	67	60	50	45	24	25	3.9	44	100
15 days after	63	1	10	29	26	19	3.6	29	106
15 and 30 days after	67	1	6	0	2	2	1.6	20	113
15, 30 and 45 days after	56	0	8	0	2	1	1.3	17	107
15, 30, 45 and 60 days after	60	2	5	1	1	0	0.8	18	113
LSD 0.05	NS*	11	16	8	8	8	0.5	12	—

Data are average of 5 replications. Plots were 4 rows, 4 meters long.

Fall armyworm = Spodoptera frugiperda.

Stem borer = Zeadiatraea lineolata and Diatraea saccharalis.

Planting date: July 29, 1969. Test conducted during the rainy season.

* Count made just before the first application.

Optimum Sample Size for Determining Stem Borer Incidence

An arbitrary sample, which may be inaccurate and inefficient, is used frequently in chemical studies to estimate stem borer infestations. In the experiments reported here, attempts were made to estimate optimum sample size, utilizing the data secured from three tests conducted at Poza Rica, Veracruz.

There were a total of 68 plants in each plot. Experiment 1 obtained estimates on the effectiveness of several granular insecticide. Experiment 2 obtained estimates for timing applications of granular insecticides; while experiment 3 obtained estimates of the number of granular applications needed for effective control of borers, as well as fall armyworm. Damage records (number of injured internodes per plant) were obtained from all plants within each plot. For the statistical analysis, random samples of four plants were combined in a stepwise manner to form the plot sizes, studied.

Table 27 summarizes the results of the analyses. The data show that the experimental error mean square increased as the sample size increased. Also, the sampling error mean square (except in experiment 2) increased slightly as the sample size increased.

The stability of the sampling error indicates the homogeniety of the samples taken in each experimental plot. The reduction of the estimated variance of the mean permits estimation of the optimum sample size for experiments of this kind.

It can be observed (Table 27), that the variance of the mean is considerably larger for a sample of 4 plants than for a sample of 48 plants. However, it also becomes obvious from the three tests, that the variance of the mean becomes stabilized for samples of 24 plants or more. Thus, it may be considered that any increment of a sample size above 24 plants will not result in a substantial reduction in the variance of the mean. The variance of the mean is important because it generates the standard error of mean.

The estimation of treatment means is one of the basic objectives of the experiments, hence as the standard error of the mean becomes smaller, a greater precision is obtained in the comparisons of treatments. Finally, this information suggests that for experiments such as those mentioned above, 24 plants per plot (taken at random) is the most efficient sample size.

TABLE 27. Statistics for estimating optimum sample size for stem borer incidence in chemical control field trials. Poza Rica, Veracruz, Mexico, 1970.

No. of Plants Inspected	Experiment No. 1			Experiment No. 2			Experiment No. 3		
	EMS_E	EMS_s	$S^2_{\bar{X}}$	EMS_E	EMS_s	$S^2_{\bar{X}}$	EMS_E	EMS_s	$S^2_{\bar{X}}$
48	7.49	3.70	0.031	9.17	2.99	0.038	3.86	2.59	0.016
44	7.58	3.71	0.034	10.23	2.94	0.046	4.03	2.58	0.018
40	7.35	3.69	0.037	9.06	2.93	0.045	3.48	2.57	0.022
36	5.67	3.59	0.031	8.14	2.99	0.045	2.87	2.61	0.016
32	4.30	3.65	0.027	8.04	3.00	0.050	2.98	2.55	0.019
28	4.59	3.45	0.033	5.77	2.96	0.041	2.79	2.51	0.020
24	4.24	3.47	0.035	6.29	3.00	0.052	2.19	2.53	0.018
20	4.36	3.44	0.044	6.57	3.05	0.066	2.56	2.49	0.026
16	5.33	3.59	0.067	5.12	3.18	0.064	2.48	2.64	0.031
12	3.55	3.33	0.059	4.19	3.02	0.070	1.54	2.35	0.026
8	2.59	3.25	0.065	3.60	2.66	0.090	1.17	2.16	0.029
4	3.15	3.36	0.157	2.11	3.00	0.106	1.34	2.05	0.067

EMS_E = Experimental error mean square.

EMS_s = Sampling error mean square.

$S^2_{\bar{X}}$ = Variance of the mean.

Experiment No. 1: 6 treatments, 5 replications.
Experiment No. 2: 5 treatments, 5 replications.
Experiment No. 3: 6 treatments, 5 replications.

NOTE: The number of injured internodes per plant was the criterium used in determining the efficiency of the different sample sizes.

ASIA

The Inter-Asian Corn Program (IACP) is centered in Thailand and cooperates effectively in a majority of Asian countries, ranging from Pakistan in the North and West, to Indonesia on the Southern perimeter, to Korea and Japan in the East.

Most of the Research and Training is conducted at Farm Suwan in cooperation with Kasetsart University, the Ministry of Agriculture of Thailand, and the Uttar-Pradesh Agricultural University in India. Efforts are focused on developing varieties and breedings materials, fostering international testing; training; technical leadership; and consultation and travel within individual countries.

INDIA

India's large scale, intensive breeding program has triggered recent yield increases through use of new hybrids and synthetics. However, the larger acreages of new materials have accented potential disease problems, also.

Source Population Improvement

Recent work has been directed toward improvement of source populations, so that resistances to the important disease become population characters. Major emphasis was placed initially on improvement of the released composites Sona, Kisan, and Jawahar, using the S_1 line testing method followed by mass selection for three generations. Data from four stations in 1969 indicated 8 to 25 percent yield increases; with maturity 4 to 5 days earlier; plus greater resistance to brown stripe, downy mildew, *Helminthosporium* leaf blights and to *Cephalosporium* stalk rot. Twelve other composites or varieties are under a similar improvement program.

Stalk Rot Studies

The stalk rots continue to be the most important disease problem in India. *Cephalosporium maydis,* the late wilt pathogen as described in the UAR, was first found in the country during the winter of 1968-69. It has since been found to be widely distributed. It is more virulent than the highly prevalent *C. acremonium.* However, present indications are that materials appear to react in the same order of magnitude regardless of the *Cephalosporium* species involved.

Results of a doctorate thesis study indicate that inoculation of the first elongated internode in eight-week-old plants with *C. acremonium* resulted in greatest disease infection. Variations in plant population did not significantly affect infection percentage; nor severity. Multiple inoculations of *C. acremonium* together with *Fusarium moniliforme* or *F. graminearum* resulted in neither measurable synergism nor antagonism.

The problems of bacterial and *Pythium* stalk rots remain and several phases of research are currently under investigation. Evaluation of reaction of a wide spectrum of material, suggests that the variety with best resistance to bacterial stalk rot seems to be Rudrapur Local (Uttar Pradesh).

Insect Resistance

In the All India Maize Improvement Project, research is being continued to develop high yielding maize hybrids and composite varieties with resistance to the stem borers, *Chilo partellus (zonellus)* (Swinhoe) and *Sesamia inferens* (Walk.). During the 1969 monsoon season, further selection for *C. zonellus* resistance was conducted at Delhi. The work was done on progenies of biparental crosses in the composite A1 x Antigua Gr. I, in manually infested plots.

Agronomically promising experimental hybrids and composites also are being evaluated for resistance to these borers at several other locations.

Downy Mildew Workshop

The downy mildew diseases have been a major deterrent to increased production of maize in areas of Southeast Asia throughout the present century. They also are injurious to sorghum and pearl millet, or bajra, in India and many African countries. Little research has been done on these diseases since W. H. Weston's work in Southeast Asia during the early part of the century.

With this background in mind, a "Workshop on the Downy Mildew Diseases of Maize (Corn) and Sorghum" was organized to assemble the most knowledgeable scientists currently working with these diseases. Main objectives of

the workshop were to: review work done to date; exchange information, experiences, ideas and methodologies; discuss problems encountered and research in progress; and pave the way for organized cooperative activities in the future.

This workshop was sponsored jointly by the Indian Council of Agricultural Research CIMMYT, and by Uttar Pradesh Agricultural University (UPAU), which served as host, September 21-25, 1969. Fifty-seven participants were present from ten countries: India, USA, Taiwan, Philippines, Indonesia, Israel, Mexico, Nigeria, Uganda and Thailand. Twenty-four papers and two special addresses were presented, and three round table discussions were held. The last session was devoted to planning future organized activities, and decisions were made to:

(1) issue a "Downy Mildew Newsletter" to enable this group and other interested individuals to maintain contact and exchange information. (2) prepare a complete bibliography of the Downy Mildew Diseases of Gramineae. (3) seek finances for a duplication and reprinting service when the bibliography is complete. (4) establish a list of common names for each of the pathogen species. (5) form a taxonomical committee to help researchers identify the causal species of the Downy Mildew Diseases encountered in various geographical areas. (6) establish a uniform disease rating system. (7) continue to enlarge the international mildew resistant nursery of maize and sorghum. (plantings, of either one or both nurseries, were planned at 24 locations around the world during 1970.) (8) conduct an international cooperative fungicide trial at eight locations during 1970 in which candidate chemicals would be selected for application to the seed, soil and foliage. (9) meet again after two to three years at a formal symposium on the downy mildew diseases of Gramineae. (See: Indian Phytopathology, Vol. XIII 2, 1970.

Inter-Asian Corn Improvement Program Workshop

The Inter-Asian Corn Improvement group held its Sixth Annual Workshop at Nainital, India, September 26-29, 1969. The Uttar-Pradesh Agricultural University hosted the Workshop, immediately after the Downy Mildew Workshop. Delegates from 14 countries participiated in a wide ranging program dealing with maize improvement and production.

The 1968 Workshop in Thailand had initiated a uniform yield trial to be conducted in 1969. Twenty-eight varieties and hybrids from eight countries were tested in 13 countries. Because of differences in type of entries, three separate yield trials were developed: Early Varieties and Hybrids (seven entries, plus a local check variety); Medium-to-Late-Maturing Varieties (15 entries), and Medium-to-Late-Maturing Hybrids (six entries plus a local check variety).

Grain yield and other agronomic data have been received from only nine locations in six countries. Hybrid Ko. No. 7 developed in Japan was the highest average yielding early entry at 3848 kg/ha over five locations.

The highest yielding medium-to-late- variety was Bogor Composite 2, at 3962 kg/ha averaged over 9 locations and six countries. This entry was developed in Indonesia.

The highest yielding hybrid in the medium-to-late maturity trial was Ganga 5, at 4223 kg/ha averaged over 8 locations and six countries. This hybrid was developed in India.

THAILAND

With its rapid increases in acreage and production, Thailand has placed new emphasis on training of extension personnel and degree training of research personnel. Also, special efforts are being made to develop better maize varieties for the two, rather distinct, growing periods of the year. Research activities in breeding are centered in variety testing, population improvement, and special studies. Disease resistance has been given special attention in all population improvement studies.

A test with eight hybrids from private corn companies, seven composites from CIMMYT, and 13 populations from the local program further demonstrated that tropical hybrids and varieties out-perform those from the temperate zone in the monsoon season. Yields ranged from 1394 kg/ha to 7232 kg/ha. In this test Nicarillo x La Posta Sel. Blanco was the top performance.

In an effort to determine yield potentials for the tropical germ plasm, six varieties were entered in a "maximum yield trial" in two seasons of 1969. Attempts were made to provide soil moisture and fertility conditions favorable for high production. The data demonstrates the lower yield potential in the monsoon climate, as compared to the dryer April-July season; with average yield for the six varieties at 4531 and 7334 kg/ha, respectively, for the two seasons. Two factors that probably play a major role in limiting yield during the monsoon season are (1) increased disease incidence and (2) reduced light intensity and total light accumulation.

Population Improvement

Evaluation trials in 1969 indicated that full-sib and modified ear-to-row selections were quite effective for increasing yield in several populations. Early maturing populations that have retained some of the disease susceptbility of the early parent.

Training and demonstration of new production technology is a major emphasis in Inter-Asian Corn Program. At left, a three-eared plant is examined. Workshops (below) allow participants to observe, exchange information, and discuss common research and production concerns.

A project was initiated in 1968 to evaluate the value of mass selection for prolificacy as a means of population improvement in tropical germ plasm grown under local conditions. A second objective was to determine if a genotype x plant density interaction could be detected in the original and selected populations.

Three sources of germplasm were chosen, one being somewhat prolific (V_3- Cuba 11J x Georgia cow corn) and two non-prolific (V_1- Cuba 11J x V_2-Doeto and Veracruz 181 x Antigua Gr. 1). Two cycles of selection were carried out in both 1968 and 1969. Plantings of 26,000 plants per hectare were made and individual plants with strong prolific tendency at flowering were selected. Pollen from selected plants was bulked and used to pollinate most plants in the block.

At maturity, prolific plants were harvested and seed bulked to form the next cycle. About 1000 plants were used each cycle, from which 10 to 12 percent were selected for the next cycle.

In 1969, the four cycles of selection were compared with the original varieties for ear-number and grain yield at a plant density of 40,000 plants/ha. The last cycles ($P/_4$) were also compared with the original varieties ($P/_0$) at three plant densities (26,000; 40,000 and 53,000 plants/ha.

The findings suggest that selection resulted in a small increase in ear number, but was ineffective in altering grain yield. There were changes in both grain yields and ear number due to selection, although the former character was not consistent in its performance over varieties or densities. However, there were no significant first-order interactions in the second trial.

Results from the 1969 evaluation tests suggest that the prolific character did not respond rapidly to selection. These results were not expected, as previous reports had indicated relatively high heritability for this trait. Even though ear number was increased, the magnitude of the response was not encouraging on a per-cycle basis. At best, the average increase over all varieties was only 3.5 percent per cycle for ear number and 2.3 percent per cycle for yield. Results are not conclusive that yield was improved by selection for increased ear number.

Several factors may be involved in the lack of rapid response to selection based on the prolific character. Further tests should reveal if the present results are valid. If the 1969 tests do represent a true evaluation of selection progress, other factors must be considered. One or more of the following could be important factors in selection response: (1) A season x genotype interaction may exist that reduces effectiveness of selection in an "off-season". (2) Selection procedures were such that true prolific plants were not identified at pollination. (3) The character, ears per plant, is not as highly heritable as suggested in other studies.

Maturity and Yield Relationships

Another study was initiated in 1968 to investigate the relationship of maturity and yield within three genetic populations. The procedure was designed to separate each variety into early, medium, and late-maturing groups by a modified mass selection scheme.

Significant changes in maturity occurred in both directions as a result of selection, when maturity is measured by silking date. Similar changes were noted in moisture content at harvest. The average changes were rather small for early maturity (1.3 days per cycle) and for late maturity (approx. 1 day per cycle). However, this was expected under such mild selection intensity. The greatest change was shown by Antigua 2D x Okuzuruwase (population 1), for earliness. This change was probably related to more vigorous selection in the first cycle.

Grain yields tended to be maintained in the early groups, but increased in two populations for the medium and late groups. However, rigid selection for grain yield *per se,* was not practiced. Plant height was positively related to maturity. The strongest association was observed in the Antigua 2D x Okuzuruwase variety, where 15 and 9 centimeter height differences were recorded between early-medium and medium-late maturing groups, respectively.

Results of this experiment suggest the possibility of maintaining, or even increasing, the grain yield of the source population, with rather mild selection for earliness. The study may suggest that this procedure, when carried out on a larger scale, could be effective in producting high yielding, early-maturing varieties.

Soil Fertility Experiments

Two experiments were conducted at Farm Suwan in 1969 in an attempt to establish response curves of maize varieties to changes in soil fertility. The first experiment was de-

signed to study the response of the "local" variety Guatemala, over a wide range of nitrogen and phosphorus levels. There was a general lack of response of grain yield, with yields ranging from 3,239 kg/ha to 4,282 kg/ha. These results were quite unexpected, as good responses to phosphorus had been noted in the past. Investigations are being made to determine the nutrient(s) and/or soil conditions which may limit grain yield in this particular soil type.

The second experiment contained a cross-section of the treatments used above, with four additional varieties. The objective was to determine if a variety x fertility interaction could be detected. However the lack of response of all varieties precluded this analysis. Varietal differences were detected, however, as Puerto Rico Gr. 1 outyielded the Guatemala variety by 18 percent. The yields for the five varieties ranged from 2710 kg/ha to 4483 kg/ha.

Plant density studies: Two trials were planted at Farm Suwan in 1969 in order to study the response of different varieties to variations in plant densities. Density treatments in the trials ranged from about 30,000 to 85,000 plants per hectare.

There were no important variety x density interactions and most varieties reached a maximum yield near 40,000 plants per hectare.

Weed control studies: Studies using chemicals to control weeds in maize have been conducted for several years. Atrazine at the rate of 1.5-2.0 (active) kg/ha has given generally satisfactory control on farm tests. At present prices the cost of material is about $15-$20 (U.S.) per hectare which compares favorably to costs of hand weeding.

Tests using 2,4-D in maize have provided interesting results. Rates of 2-2.5 kg/ha have given satisfactory control in some areas, at a cost lower than control with Atrazine. Some problems, such as time of application, require further study.

The length of time during which crops need protection from weeds has been investigated, also. General conclusions from preliminary trials are that protection is adequate for up to 40 days after planting. It has been shown also, that weed competition at a very early stage of crop growth can be detrimental to grain yield.

Downy mildew studies: Downy mildew incited by *Sclerospora* sp. is a new disease of maize in Thailand. In July and August, 1968, an outbreak was reported in an important maize producing area (Nakorn Sawan Province). A similar, but larger, area was infected in 1969. Late plantings of maize have been avoided in these areas because of the seasonal pattern of infection.

A trial was planted near Nakorn Sawan in 1969 to obtain information on varietal resistance and time of infection. Twelve maize entries and one sorghum entry were planted on different dates beginning May 17 and ending July 17. Entries that are considered resistant to downy mildew in Taiwan and the Philippines seemed to exhibit tolerance to the disease in Thailand. No infection was recorded for the first replication, but progressively higher ratings were recorded for the following replications.

The species causing downy mildew in Thailand has not been identified positively. However, from a morphological standpoint, the causal organism appears to be *Sclerospora sorghi.* The fact that sorghum has not been infected, either naturally or by artificial innoculatons, suggests that a new variant of *S. sorghi* may be present in Thailand. Plans have been made to test other germ plasm from Taiwan, Philippines and Indonesia for sources of resistance, and to further investigate the species in Thailand.

PAKISTAN

Training Programs

An intensified research production and training program has been mounted in Pakistan. Two training meetings are held each year for agircultural extension agents in the Northern and Central regions. In 1970 the five-day meetings were held in areas where maize is the most important summer crop. Follow-up included the strategic location of 300 one-acre demonstrations throughout the region. Each agent was provided with sufficient seed of the latest cycle of Synthetic-66 white maize, and arrangements made for fertilizer and pesticide needs. Through use of 'farmer field days" at the demonstration sites, they are seeking utilization of 50% of the field production for seed.

This same extension procedure was used in the Central Zone, where yellow maize is grown. The J-1 composite has been established as the *de facto* local open-pollinated variety during recent years. Although there is appreciable farmer demand for experiment

station produced seed of synthetics not involving tropical germ plasm, farmer-to-farmer sales of such synthetic seed have been disappointing. This sort of interaction is vitally needed to supplement present seed production and distribution facilities.

Seed Production

A new generation of double topcrosses, involving temperate zone single crosses and materials containing 50% temperate zone and 50% tropical germ plasm, have been tested for three seasons at the Central Maize Research Station. They were grown in one-acre demonstration plots during the summer of 1970. It is expected that up to 50% of the yield from the better plots can be used for seed.

Two local firms have begun hybrid maize seed production in an exploratory manner, and several firms with established fertilizer and pesticide distributorships are indicating an interest in producing and distributing improved seeds.

With agro-industry and government groups working together, it is expected that per acre yields of maize can be raised from the present 1000-1200 kg/ha to 2000 kg/ha in the next three years. Maximum yields recorded in one-eight-acre-demonstration plots have been 9000 kg/ha, which is nine times the national average.

Winter Nursery

At the breeding stations situated in the Indus Valley at 30° N, and 32°N, two crops have been grown each year for the past four years. To accelerate the rate of progress in breeding, a winter nursery was planted in late October, 1969, at 25° N. The five new composites grown yielded 5000-7000 kg/ha, indicating that the winter season may be appropriate for commercial planting of maize in the southern part of the country.

Over the past 3 seasons, preliminary tests with micro-elements added to the soil indicate that maganese, copper, sulfur, and boron are not limiting at the Central Maize Research Station, while zinc may be slightly limiting.

The maximum cropping intensity trial conducted during the past two years, involving short wheat during the winter and two crops of short season maize during the summer, yielded 13.5 and 14.2 metric tons per hectare in 1967-68 and 1968-69, respectively.

Two training sessions are held each year for agricultural extension agents in the Northern and Central regions of Pakistan. Follow up includes demonstrations at "farmer field days" throughout the regions.

AFRICA

In East Africa, the EAAFRO and neighboring countries have charted new operations. Dr. Lowell Penny, USDA, is on location and has followed through with work on evaluating breeding methods and conducting regional performance trials. CIMMYT's representative Mr. Michael Harrison, formerly involved in this work, has moved to the International Institute of Tropical Agriculture. As an IITA staff member, he will function as CIMMYT's West African representative, developing varieties and conducting other CIMMYT activities.

KENYA

Harrison conducted a program to introduce certain simply inherited characteristics into some of the Kenya composite varieties. The gene *brachytic 2,* which reduces the length of internodes below the ear, is being introduced into KCB and KCE. Genes *opaque-2* and *floury-2* which affect the amino acid distribution in the grain, are being introduced into all Kenya composite varieties to improve protein quality. The Ht gene for resistance to the leaf blight caused by *Helminthosporium turcicum* was introduced into several varieties. Cytoplasmic male sterility also was being introduced as a possible aid in commercial seed production.

Eastern Africa Maize Variety Trial

The 1968-69 Eastern African Maize Variety Trial consisted of 25 entries grown at several locations in most countries of Eastern Africa.

H 611 (R) C1 was outstanding in yield at all locations in Kenya and especially at the higher altitudes. The yield of the composite cross KCB x KCE also was encouraging, being exceeded only by H 611 (R) C1 and H-613B as an average of the four high altitude locations. This composite cross in the basis for the present Kenya applied breeding program for the high altitudes of Western Kenya. As selection continues in the two parental composite varieties, the cross is expected soon to become superior to H 611 B, H 613 B, and H-632; and commercial production will begin.

UNITED ARAB REPUBLIC

Realizing the potential for increasing yields in the UAR, the Ministry of Agriculture started an accelerated research project on maize production in UAR in late 1965. The CIMMYT specialist arrived in Cairo in October, 1968, so the project has been in effective operation for less than two years.

UAR research on maize has two central projects:

Project 1: Identification, evaluation and utilization of superior maize germ plasm complexes for the improvement of maize in the UAR.

Research was direct to: (1) evaluate the vast range of germ plasm available in the tropics and semi-tropics as a new source of genes for yield, disease resistance, insect tolerance and nutritive quality; (2) develop new basic breeding materials at higher yield levels through blending of elite exotic and local germ plasm complexes; (3) utilize these new materials for the production of higher yielding, disease resistant, insect tolerant and more nutritive varieties and hybrids for commercial maize production.

Introduction and evaluation of maize germ plasm: A wide spectrum of maize germ plasm representing the elite races and varieties was introduced through CIMMYT and grown and evaluated in the 1969 crop season at the Sids experiment station. Outstanding germ plasm have been identified and will be used in the breeding program. The elite materials from the Middle American region were Mexican June, Jellicorse, Yellow Tuxpan, Sonora Groups 2, 7, and 51; Chihuahua Groups 13 and 41; Chapalote; Llera III, and V-520. Blanco Comun from Colombia was the best from the South American region.

The Caribbean materials, Compuesto Cubano and Antigua showed good combining ability with Mexican and US germ plasm, and the compact plant type needed for the region. Combinatons of US with Central American and Caribbean germ plasm appeared particularly outstanding. The better ones were Iowatigua, Carotigua, double top crosses between single crosses of US inbred lines, and single crosses of Mexican tropical hybrids, Compuesto Cubano and V-520C.

Local varieties Nab-El-Gamal and American Early Dent (a selection from Boone County White) also combined well with Central American and US germplasm. Thirty-eight white composite populations developed in India also were grown for seed increase. A white selection from J1 appeared well adapted, comparable to its performance in India, Pakistan and Nepal. This project will continue with new collections obtained through CIMMYT.

Screening germ plasm for resistance to the major diseases: A total of 250 elite local and exotic varieties were grown at Sids, Fayuum and Tahrir experiment stations. At these locations natural epiphytotic of the three major diseases occur, namely, rust *(Puccinia sorgi),* stalk rot *(Cephalosporium maydis),* and leaf blight *(Helminthosporium turcicum, H. maydis).* Sources of resistance to rust and leaf blight have been identified. Llera III, Blanco Común, and Antigua varieties are the most promising. None of the materials showed resistance to the stalk rot.

Developing new composite populations for UAR: Three local varieties have been top

crossed to 250 elite varietal collections; moreover three diallel sets of varietal crosses have been developed among the best available materials from the Central and South American and Caribbean regions. These comprehensive, newly developed populations will be tested for their yield potential in trials at the Sids and Gemiza experiment stations.

Development of two experiment stations for maize research: The Ministry of Agriculture has allocated about 50 acres of experimental land at each of the stations, Sids and Gemiza. These locations will form the main centers for maize research and land and laboratory facilities are being developed.

Winter nursery: A very successful winter nursery was grown for the first time in UAR in November, 1968, and a second nursery was planted in November 1969. These plantings have demonstrated that it is possible to obtain two generations of maize per year: one during normal planting in June and the second, as an off-season winter planting in early November which will greatly speed up the breeding work.

Seed stores: Insect, rat proof an air-conditioned seed stores have been developed at Sids, Gemiza and Giza stations. Seed increases of different maize germ plasms will be indexed, catalogued and stored for future use in the breeding and other projects.

Project 2: Soil and water management for maximum maize production

Field studies were made to determine the chemical fertilization, water management, land preparation and planting practices most useful for the production of high yields, following the winter crops of wheat, beans and Egyptian clover. With the available soil and water resources and practically unlimited supply of solar energy, yields of about 8 to 10 tons per hectare should be obtained, once superior varieties are available.

Reshaping and levelling of maize land: In order to successfully implement the soil fertility and management experiments, the operation of the experimental land had to be mechanized so as to give precise control over the different agronomic practices. Agricultural machinery such as tractors, plows, harrows, land leveller, ditcher, ridger, etc., now have been obtained. Levelling and grading of the drainage system is in progress at Sids. The land and the development of on irrigation and experimental area was reshaped at Sids and Gemiza previous to the current crop season.

Maximum Productivity Demonstrations

The Maize Committee of the Ministry of Agriculture, which the CIMMYT specialist assists, drew up a package of recommended practices from available research data for implementation on about 50 thousand acres in Sharkia province. The results were spectacular; overall maize production was 50 percent greater than neighboring areas in which the project was not implemented. More demonstrations are planned for next year on a smaller scale at more sites and at experiment stations across the maize growing areas.

CENTRAL AMERICA AND THE CARIBBEAN

The Central American Cooperative Food Crops Program (PCCMCA), began its work in corn production in 1954 in Central America, it now works with sorghums, beans and rice, as well, and has expanded to include the Caribbean area. Each year the cooperating workers meet to discuss the year's work and plan for future joint efforts. Basically, the aim of the meeting is to interchange ideas, information and materials.

Uniform variety trials are conducted by PCCMCA in two regular series: (1) commercial varieties and hybrids and (2) experimental materials. In addition, studies on plant populations, fertilizer treatments, insect control, and other phases of corn production, are encouraged in the several countries. Efforts to extend the use of improved seed and cultural practices are emphasized, and results are reported at the annual meetings.

Even though accurate, up-to-date statistics are not available, production of both maize and sorghum is being accelerated in spite of the many deterrent factors. Most of the recommended varieties of corn and sorghum forming the main basis for this growth have evolved from the PCCMCA program. These varieties now are distributed commercially in the area by both private and governmental agencies.

It is generally agreed that the level of technology in Central America is probably better than available statistics would indicate. Poor communications, high fertilizer prices, unstable

grain prices, unavailability of the necessary inputs, lack of credit, lack of sufficient applied research, and inadequate extension funds and personnel, are among the factors which have been cited as deterrents to production in Central America. CIMMYT is hopeful that team efforts by groups of farmers (such as the cooperative program of small farmers which has spread rapidly in El Salvador in the past two or three years) may be a practical system for a gradual elimination of these barriers. Ideas and information are being exchanged with the farmer cooperative groups in El Salvador and the Puebla Project in Mexico.

A significant addition to the PCCMCA program during the past year involved a concerted effort to initiate commercial production of opaque-2 corns. Varieties which had been developed by various Central American countries, and by CIMMYT, and private companies, were simultaneously tested in all countries.

In addition, a semi-commercial production block of the CIMMYT tropical 1 (Opaque-2) composite variety was grown in each country. The grain produced was put to trial use in making tortillas and in preparing various other foods for human comsumption, as well as in animal feeding trials. Each Central American country also initiated a program to convert one or more local corn varieties to Opaque-2 for use by small farmers who consume most of their own production.

SOUTH AMERICA

During the past year, CIMMYT staff members visited extensively in South America to review and assist programs already underway, and to add new dimensions to others.

For example, Drs. Wellhausen, Jiménez and Laird visited Colombia, Ecuador, Peru and Bolivia to initiate plans for the establishment of the Accelerated Maize Production Training Programs. These programs will be funded, in part by the UNDP-CIMMYT (Global 1) project. Details are reported in the "Production Research and Practices" section of this report.

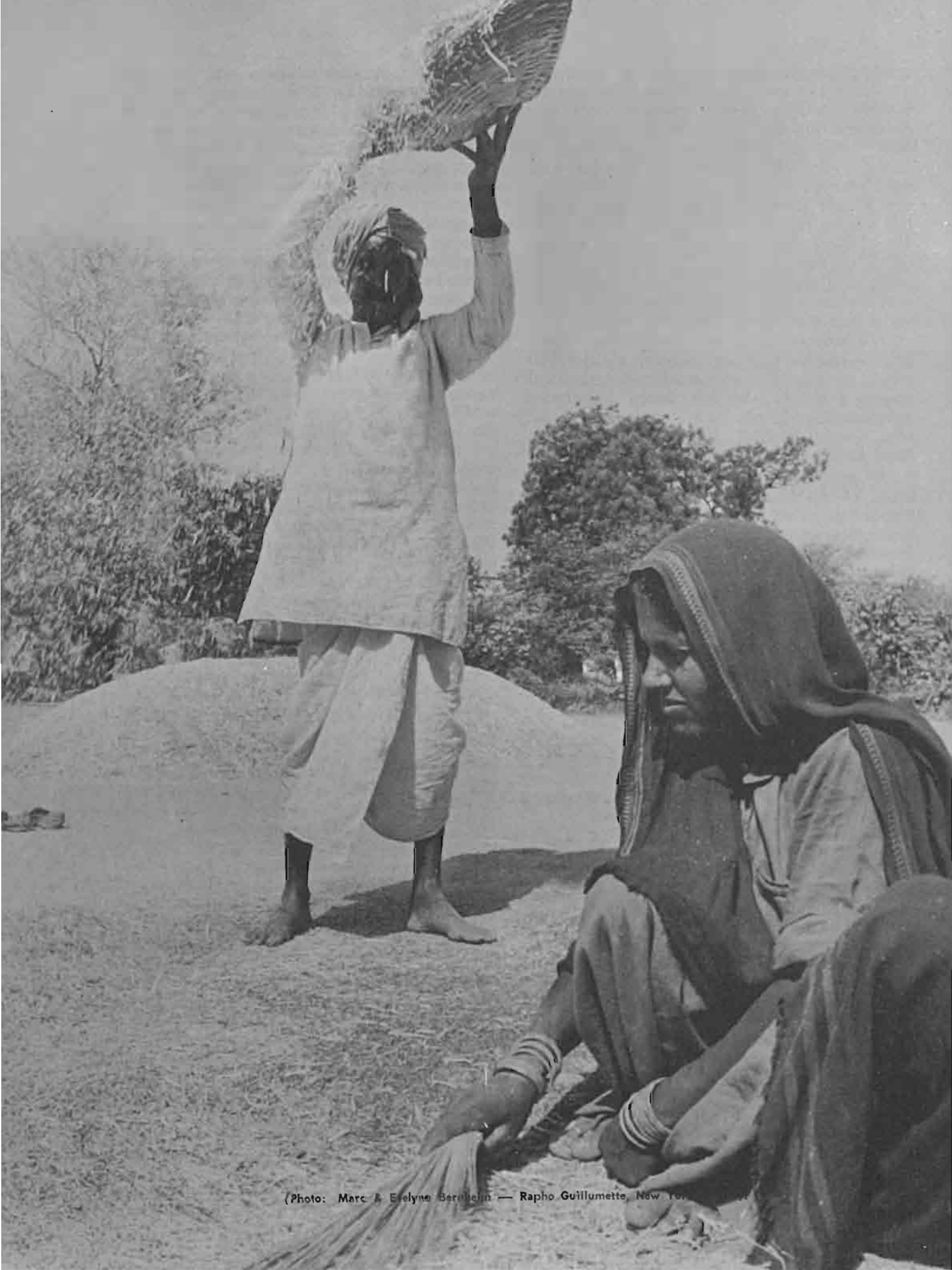
Drs. Sprague and Johnson visited the same countries to further intensify cooperative arrangements for accelerating maize production. They were particularly interested in promoting a more rapid development of high lysine varieties adapted to various maize growing regions. As a result of these visits if was agreed that:

(1) CIMMYT will chemically analyze samples of promising materials for each of the countries' breeding programs aimed at conversion of local varieties to opaque-2 or floury-2 types. These materials have been planted in Mexico to obtain a generation in the conversion of locally adapted varieties to high lysine types.

(2) CIMMYT will work with CIAT to continue the Andean Zone project established several years ago. Due to changes of personnel, this project was only partially operative during the past year. A new staff member will work with CIMMYT and provide regional coordination. This program will serve as the regional maize improvement program in the Andean region, including the countries of Venezuela, Colombia, Ecuador, Peru and Bolivia.

(3) CIMMYT will continue to help with training at the in-service level, and will assist in the support of training at the Masters and Ph.D. level for selected national program personnel who can contribute substantially to bringing about a more efficient production of nutritive corn in the area of South America.

During a meeting involving maize scientists from Brazil, Chile, Paraguay, Uruguay and Argentina (held in Argentina, March 9-13, 1970) plans were made for the continuation of the CIMMYT coordinated project entitled "Convergent-Divergent-Convergent Improvement". The attending scientists agreed that the Southern South America regional program will be subdivided into two subregions: Subregion I will include La Estanzuela (Uruguay), La Platina (Chile), and Paraná and Pergamino (Argentina). Subregion II will include Pelotas and Piracicaba (Brazil), Caacupe (Paraguay) and Corrientes and Saenz Peña (Argentina).



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INTRODUCTION

The green revolution in cereal production in south and west Asia is now an accepted accomplishment. It resulted initially from the introduction and widespread intensive cultivation of the so-called "dwarf Mexican wheats". It was not the introduction of the Mexican dwarf varieties alone that triggered this revolution, but equally important was the simultaneous introduction along with the new seed of a package of intensive improved agronomic management practices which permitted the new seeds to express their high genetic yield potential. Grain yield and production have risen sharply where the new technology has been properly employed. The spectacular impact of the green revolution of Pakistan and Indian wheat production is shown in Table W1. A number of countries, where much of the wheat is grown under rainfed conditions, such as Afghanistan, Iran, Turkey, and Tunisia, are also now making good progress in revolutionizing their production.

Continued progress has been best in those countries where the national production campaigns are backed by strong national research programs, for example, India, Pakistan and Tunisia.

The first wave of the green revolution became clearly evident during the 1968 harvest when production in Pakistan and India, soared by 45.7 and 34.1 percent, respectively, over that of the previous all-time high of 1965. Many observers attributed the increased production primarily to favorable weather conditions. Those who had been close to the wheat research and production programs, however, were all convinced it was primarily the result of change in production technology. The 1969 harvest, despite very unfavorable weather conditions characterized by virtually no winter rains and higher than normal temperatures during the time the grain was filling, was nonthe-less larger in both countries than the bumper crop in 1968. The production rose by 7.5 and 13.3 percent in Pakistan and India, respectively, over that of the excellent 1968 crop; however, most of this increase was attributable to extending the new technology to a larger area in each of the countries, rather than from a further increase in yield per acre on farms already employing the new technology. Consequently, 1969 was a critical year. Many farmers, who had harvested very high yields in 1968 and had cherished and anticipated even higher yields in 1969, were disappointed. Adverse weather conditions in East and West Punjab, the main wheat belt, reduced anticipated yields on some farms, and although still good by pre-green revolution standards, caused some concern. In Pakistan, the farmers disenchantment was further aggravated by a reduction of 12½ percent in the price for wheat grain after the harvest had already been begun. As a result, rumors were circulated, especially in Pakistan, to discredit the veracity of the green revolution. One widespread rumor stated that the lower yields were the result of "genetic degeneration" of the Mexican varieties. Those who were close to the wheat research and production program knew these rumors were not based on facts.

In spite of these apprehensions the outstanding performance of the 1969 crop, pro-

TABLE W1. Wheat production in Pakistan and India from the All-time Record 1964-65 Crop Year through 1969-70 Showing Percentage Cumulative Change and Annual Percentage of Change. (Production in Millions of Metric Tons.)

	1964-65[1]	1965-66[2]	1966-67[2]	1967-68	1968-69	1969-70
PAKISTAN						
1. Production	4.6[1]	3.7[2]	4.3[2]	6.7[3]	7.2[3]	8.4[4]
2. Cumulative % Changeover 1964-65	—	— 19.6	— 6.5	45.7	56.5	82.6
3. Percentage Annual Change	—	— 19.6	16.2	55.8	7.5	16.7
INDIA						
1. Production	12.3[1]	10.4[2]	11.4[2]	16.5	18.7	20.0[4]
2. Cumulative % Changeover 1964-65	—	— 15.4	— 7.3	34.1	52.0	62.6
3. Percentage Annual Change	—	— 15.4	9.6	44.7	13.3	7.0

[1] Very favorable weather, the 1964-65 crop was an all-time record production in pre-green-revolution era.

[2] Drought year.

[3] Data from Annual Reports of Accelerated Wheat Improvement Program in West Pakistan.

[4] 1969-70 is estimated production; production data for other years from official government sources.

duced under very unfavorable weather conditions clearly established the creditability of the green revolution.

The current 1970 crop, produced under moderately favorable weather conditions in both India and Pakistan was the third consecutive record breaker. Production climbed to an estimated more than 20 million and 8.4 million tons in India and Pakistan, respectively.

Green revolution rolls onward in both Pakistan and India.

During the past three wheat harvests, 1968-70, a total of US$1,850,000,000 and US$850,000,-000 has been added to the gross agricultural product of India and Pakistan respectively, above the value of the record 1965 wheat crop.

The injection of this vast new income into the economies of the two countries has greatly expanded business activity. Farm incomes have soared and farmers demands for a wide variety of goods have expanded rapidly. They are buying inputs such as improved seeds, fertilizers, pesticides, pumps, tractors, plows, threshers and grain drills as never before. Farmers are also rapidly expanding their purchase of consumer goods such as transistor radios, bicycles, sewing machines, refrigerators, and many other items. The widespread sales of radios offer the possibility of improving the educational level of farmers. These and other aspects of the green revolution are discussed in more detail in the section covering the Indian wheat program.

The Research Base Supporting the Green Revolution

The breeding, pathologic and agronomic research program on wheat in India is now almost certainly the largest and most diversified of any in the world. The magnitude and scope of the Pakistan wheat research program is also one of the largest and most dynamic. When the research being done by CIMMYT is added to supplement that of these two strong national programs, the research underpinning of these national program is very great. This feat of strengthening research has been achieved without adequate financial support from the governments of India and Pakistan, largely through the reorientation and reorganization of the existing programs and through the efforts of members of the research and extension teams. For example, although the scheme for the All-India Coordinated Wheat Improvement Programs dates back to 1961, and the budget and staffing pattern were drawn up and submitted in 1965, it was not finally approved until late 1969, and funded in early 1970. In essence then the research developments on wheat in India were accomplished without formalized expanded financial support for research. The finances available were drawn from previously fragmented schemes brought together under the coordinated program. These funds were modestly supplemented by additional state or university sources. Shortage of funding also constituted a major constraint at certain stages on the expansion of several state and university programs. Nevertheless, success has been achieved, and largely because of the teamwork approach.

It must be pointed out that wheat research work is nonetheless either still weak, or fragmented in many other countries of the Near and Middle East and North Africa. Steps are being taken in all countries where CIMMYT is directly or indirectly involved in production programs to attempt to correct this defect. This takes time, money and staff. The following examples illustrate the needs for more research. Some of the highest yielding Mexican varieties, i.e., Siete Cerros and Inia 66 are susceptible to either *Septoria,* Mildew or stripe rust in the heavy rainfall areas of the Mediterranean. Other varieties such as Tobari 66 and Penjamo 62 are somewhat more resistant to such diseases under these conditions. It is necessary to develop research programs in the Mediterranean climate areas to identify, develop and recommend those varieties most appropriate for this climate. During the past year, the national research programs in Tunisia and Morocco with direct technical assistance from CIMMYT have been strengthened so as to achieve this goal. They have already made a potentially valuable contribution to improving wheat production in North Africa, and perhaps also in the entire spring wheat area of the Mediterranean by identifying several experimental high-yielding dwarf CIMMYT Mexican lines with better resistance to these diseases. Both countries are now struggling to expand their breeding programs so as to handle these diseases as well as several insect problems which are especially severe in North Africa.

There is now a welcomed strengthening of research on the horizon, from an unexpected source. Developing countries are beginning to help other developing countries. The government of India, which has profited enormously from the green revolution, is now in the preliminary stages of formally setting up a foreign

agricultural assistance program to be staffed with Indian scientists, to assist Afghanistan with its wheat research and production program. The government of Pakistan has for the past three years made substantial gifts of commercial quantities of seed of some of the introduced dwarf varieties, i.e., Mexipak 65, to its neighboring countries, and during the past two years in the Pakistan Accelerated Wheat Improvement Program has made available to many developing countries an abundance of advanced lines and segregating wheat lines from its very large breeding programs.

Considering the vigor, diversity, magnitude and excellence of the wheat breeding program in India, Pakistan and Mexico, it would not be surprising to see these so-called developing countries making important direct contributions to wheat improvement in developed countries. This has already begun in the case of Mexico, since considerable areas of Mexican varieties or reselections from Mexican materials, are already being grown in the U.S.A. and several other developed countries.

Nevertheless, despite the aforementioned encouraging developments, complacency must be avoided and more must be done to strengthen wheat research at both the national and regional level in the developing countries. During the past year, CIMMYT in collaboration with the Near East Arid Lands Program of the Ford Foundation, established a large spring wheat breeding nursery at Beirut, Lebanon. It is hoped this will evolve into a regional hub

Wheat trainees also gain experience in the milling and baking quality laboratory.

for research on spring wheat improvement for the Near East area. Tentative arrangements also have been made for the Rockefeller Foundation and CIMMYT to collaborate with the Government of Turkey in expanding research on both winter and spring wheats.

CIMMYT's Continuing Role in Wheat Research, Training and Assistance to National Production Programs

The CIMMYT wheat program attempts to carry on a balanced program between applied and fundamental research in all disciplines affecting wheat production and utilization. It gives primary emphasis to the applied. The research is production oriented (rather than discipline oriented), and efforts are made to concentrate on the factors in each discipline that most affect yield, crop losses and utilization. The major research effort is confined to the disciplines of breeding, agronomy and soils, plant pathology, entomology and biochemistry, from both industrialization and nutritional viewpoint.

CIMMYT's research program is executed in two different ways. A large part of the research work is conducted in Mexico at CIMMYT-INIA stations or laboratories. Other parts are carried on in other countries where CIMMYT staff members collaborate with research workers or national programs. These various aspects are discussed in other parts of this report.

Training is one of the most important functions of the CIMMYT program. The CIMMYT training program is of a practical nature and is designed primarily for young scientists. It is oriented largely toward "learning by participating in research". In the past year, however, since the CIMMYT core staff has been expanded to include a training officer, more time is also devoted to seminars. Production training also has been added during the past six months.

During the past eight years 140 young wheat scientists have been trained at CIMMYT. Many who have received training in CIMMYT are now active members of either wheat reserch or production teams in their respective countries. The successful implementation of the production program in Pakistan for example, in a large part, was due to contributions made by young scientists who had trained in CIMMYT-Mexico.

Within the past two years another facet has been added to the CIMMYT training program. Currently a number of Post-doctorate fellows are receiving training. Moreover, in the same period a number of foreign scientists have spent part of their sabbatical leave at CIMMYT; their breadth of interest and experiences have been drawn on to increase the effectiveness and scope of our practical training program for foreign scientists.

MEXICO

THE JOINT CIMMYT-INIA PROGRAM

Commercial Production

Although final figures are not yet available for the 1970 crop, it is almost certain that Mexico has again established a new record for both total production and yield per hectare. The weather during the past season was very favorable for wheat production throughout the entire country.

Diseases were not a factor of any significance in affecting either yield or total production. It was difficult to find any appreciable amount of stem rust (*Puccinia graminis tritici)* in any part of the republic. A few late sown fields of Super X and Siete Cerros, which are known to be susceptible to some Mexican races, showed some infection but all escaped injury:

Although stripe rust *(P. glumarum)* is rarely found and never causes damage on the coastal belt of Sonora and Sinaloa, it often occurs and occasionally causes damage to wheat sown at elevations of 1500 meters or above in the Central plateau. This past season, however, stripe rust infection was extremely rare even at higher elevations.

Leaf rust *(P. triticina)* was widespread throughout the coastal areas of Sinaloa and Sonora. The variety Inia 66, which constituted the largest area sown to wheat throughout the country, was heavily infected in most areas. Nevertheless, Inia produced excellent yields generally ranging from 4 to 5 tons per hectare with grain test weights that generally ranged from 82 to 84 kilos per hectoliter. Generally throughout the region, November and December sown fields of the varieties Azteca 66, Ciano 66, Noroeste 66, Norteño 67, and Tobari 66, although free from all rusts and other diseases were outyielded by Inia 66 even though

the latter frequently had 70 to 90 percent of leaf rust. Apparently the only fields sown to Inia that were significantly affected yieldwise by leaf rust were those sown in January. Under these conditions Tobari 66 and Noroeste 66 sometimes outyielded Inia and Siete Cerros.

The second group of most extensively grown varieties were the white grain variety Siete Cerros (equivalent to Mexipak 65 and Kalyansona in Pakistan and India respectively) and its red grain sister Super X (equivalent to Indus and PV 18). This year both of these varieties performed superbly as far as grain yield was concerned. In general, both were favored by absence of rust and by the longer than normal low temperatures at time of grain filling. When heavily fertilized (120-40-0 or 140-40-0) and given five irrigations most commercial fields of these varieties generally outyielded Inia 66 by 500 to 700 kilos per hectare, i.e., 4500 kilos versus 5000 kilos per hectare. Wherever only four irrigations were given, Inia 66 because of its earliness generally outyielded Siete Cerros by 300 to 500 kilos per hectare.

The commercial variety situation in Mexico now calls for the rapid multiplication and distribution of several new varieties. The varieties Ciano 66, Azteca 66, Noroeste 66, Norteño 67 and Tobari 66, all possess excellent milling and baking quality and remain highly resistant to the prevalent races of the rust. All, however, are being rapidly driven out of production by the higher yielding varieties Inia 66, Siete Cerros and Super X. For this reason, the National Institute of Agricultural Research has now named four new varieties, as indicated in the following section, to replace the aforementioned varieties and diversify the varieties sown and thereby provide better protection against diseases.

Losses from insects were minimal during the past season. There were local infestations of both army worm and greenbug in Sonora during early January, but both were successfully controlled by timely application of insecticides.

Weeds contributed more to yield reductions than all of the combined reductions from diseases and insects. There are many farms in Sonora and Sinaloa where near perfect weed control is obtained through the proper rotations employing winter and summer row crops combined with winter cereals. Most of the farmers who employ proper crop rotation practices to obtain good weed control also employ supplementing chemical weed control when necessary. Frequently one can observe poorly managed farms, adjacent to ones on which near perfect weed control is obtained, where 30 to 50 percent reductions in wheat yields are resulting from weeds.

The two most serious weeds limiting wheat yields in Mexico are wild oats *(Avena fatua)* and the so-called "Alpiste" or giant fox tail *(Philaris* sp.). A very large research effort designed to reduce losses from weeds employing both cultural practices and chemicals is being conducted by Ing. Isidro Martínez of the CIANO staff.

Varietal Development of Bread Wheats

The task of varietal improvement is a never ending job. It must strive to develop new varieties that increase the genetic potential for grain yield, improve the agronomic type so that it will be better suited to more intensive agriculture, improve both the spectrum and depth of disease and insect resistance and improve both the industrial and nutritional quality of the grain.

The breadth of adaptation of the so-called "Mexican-dwarf wheat varieties" and their high yield over a wide range of conditions has provoked new thinking concerning the validity of the old concepts of the superiority of narrowly adapted varieties, based on the idea of the strict relationship of variety-environment interaction.

CIMMYT being an international research institute that is both directly and indirectly collaborating with many national wheat breeding programs operating under widely different climatic conditions in different parts of the world has a unique challenge. It should be possible through the international cooperative network of research organizations to further greatly improve on the varieties now available. Best overall progress will be made by close cooperation between the CIMMYT Mexican program and national programs in different parts of the world.

New Mexican Commercial Bread Wheat Varieties

Last month four new varieties were named by C.I.A.N.O. and I.N.I.A. for commercial release in Mexico. Three of these varieties, Nuri 70, Yecora 70 and Saric 70, are derivatives of the promising cross II-23584 whose parents are (Ciano "s" x Sonora 64-Klein Rendidor) x Siete Cerros. Last year a number of these lines were found to be unusually high yielding in prelim-

inary yield tests and were given the "generic" name "Bluebird" by CIMMYT. A fourth new variety, Potam 70, was derived from the cross Inia "s" x Napo 63 II-22402. The pedigrees, former "generic" designation and yield, disease reaction and quality performance of the new Mexican varieties during the past two years is summarized in Table W2.

TABLE W2. Performance of new Mexican varieties and most promising lines from advanced yield tests conducted in Sonora, Mexico, during 1968-69 and 1969-1970.

Varietal Name		Progenitors and Pedigree	Maturity Class*	Degreed Dwarfing**	Grain Yield			
					1969		1970	
Mexican Commercial Name (May 1970)	CIMMYT Provisional Name (July '69)				kg/ha	% of Highest Check	kg/ha	% of Highest Check
Nuri 70	Bluebird # 1	CIANO x Son 64-Klein Rend[1]/8156 23584-15Y-6M-0Y	I	S	8890	123	7065	95
Yécora 70	Bluebird # 2 (B)	(CIANO "s" x Klein Rend) x 8156 23584-26Y-2M-1Y-0M	I	T	9313	120	7381	101
Saric 70	Bluebird # 3	(CIANO "s" x Klein Rend) x 8156 23584-26Y-2M-2Y-0M	I	T	8708	112	7151	96
Potam 70	——	INIA "s" x Napo 22402-6M-4Y-1M-1Y-0M	E	S	7020	110	7039	95
——	Bluebird # 4	(CIANO "s" x Klein Rend) x 8156 23584-26Y-2M-3Y-2M-0Y	I	T			7652	104
——	Bluebird # 4 (A)	(CIANO "s" x Klein Rend) x 8156 23584-26Y-2M-3Y-1M-0Y	I	T			8555	109

TABLE W2. (Cont.)

Varietal Name		Rust Reaction					Grain		Quality				
		1969			1970				Alveogram				
									1969		1970		
Mexican Commercial Name (May 1970)	CIMMYT Provisional Name (July '69)	Stem	Leaf	Stripe	Stem	Leaf	Test kg/ha	Color***	P/6	W	P/6	W	Sedimentation 1970
Nuri 70	Bluebird # 1	TrMR	TrMR	5MR	5MS	TrR	82	W	2.8	197	315	350	57
Yécora 70	Bluebird # 2 (B)	TrR	TrMS	0	0	10S	81	W	5.5	400	4.0	380	64
Saric 70	Bluebird # 3	0	TrMR	TrR	0	5S	81	R	4.2	333	4.5	400	64
Potam 70	——	0	60S	0	0	80S	79	W	2.1	161	2.7	183	36(1)
——	Bluebird # 4	0	10S	0	0	10S	80	R	4.8	340	4.0	303	55(1)
——	Bluebird # 4 (A)	0	TrMS	0	0	TrR	80	R	4.4	285	4.5	530	68

* E = Early (Like INIA).
I = Intermediate.
L = Late (Like Siete Cerros).

** S = Single.
D = Double.
T = Triple.

*** R = Red grain.
W = White grain.

(1) Sedimentation from 1969.

[1] Son 64 = Sonora 64.
Klein Rend = Klein Rendidor.

It is believed that the varieties Nuri 70, Yecora 70 and Saric 70 possess a combination of yield potential and superiority of agronomic type which will permit them to replace Super X and Siete Cerros. All three of the aforementioned new varieties are superior to Super X and Siete Cerros in quality. They are intermediate in maturity and have superior resistance to lodging.

During the past two years the area sown to Lerma Rojo 64A has dropped precipitously as this variety has been replaced by Siete Cerros and Inia thereby provoking a shortage of soft wheats for pastry flours and also for blending purposes. Potam 70 is a high yielding soft wheat which will replace Lerma Rojo 64.

Between 3 and 5 tons of seed of each of these new varieties were harvested in CIANO in May of 1970.

Promising New Bread Wheat Lines

The CIMMYT-INIA breeding program evaluated approximately 800 lines in preliminary yield tests in CIANO (Ciudad Obregón) during the past season. The vast majority of these lines yielded less than the two commercial check varieties Inia or Siete Cerros, or than the four newly named Mexican varieties which also were used as checks.

The most promising new materials based on yield, disease resistance, and quality performance are indicated in Table W3. The two most outstanding new lines were Inia 66 x Bluebird, cross 26477-35Y-1M-1Y-7M-0Y, and Bluebird x Inia 66, cross 26591-1T-7M-0Y. Both lines, however, are still segregating for color of glumes and are consequently now being purified in head rows.

Another very promising experimental bread wheat with potential for commercial use in Mexico is a new variety from Pakistan, called CHENAB 70. This line was included in the Sixth International Spring Wheat Yield Nursery which was grown in Sonora during 1969-1970. It outyielded all other varieties in this test including Siete Cerros and Inia 66. This very promising soft wheat variety is derived from a cross involving C-271 - Willet$_E$** Sonora 64, PK 146-12a-4a-1a. It has been outstanding in yield performance in both experiment station plots and microplot variety trials on farms in Pakistan during the past two years. It is also showing promise in Saudi Arabia, Lebanon and Yemen.

** Enano or dwarf.

TABLE W3. Most promising new crosses based on performance in preliminary yield, disease resistance and quality tests in Mexico during the 1969-1970 crop cycle.

Progenitors	Cross Number	Number of Promising Lines
Bluebird-Inia x Calidad	II 27237	1
Bluebird x Norteño 67	II 27100	2
HD 832-5-5 x Norteño 67	II 27037	1
Ciano x Bluebird	II 26939	1
Bluebird x Ciano 66	II 26592	2
Bluebird x Ciano 66	II 26572	4
Bluebird x Inia 66	II 26591	3
Inia x Bluebird	II 26478	5
Inia x Bluebird	II 26477	1
Sonora-Klein Rendidor x Bluebird	II 26502	1
Ciano-Siete Cerros x Bluebird	II 26218	1
(Ciano-Siete Cerros) (Son. 64 x Y50$_E$-Gto./Tob.)	II 25918	5
Ciano-Siete Cerros x Ciano-Pénjamo	II 25917	3
Ciano x Inia	II 25717	2

Broadening the CIMMYT Bread Wheat Gene Pool

Within the past five years CIMMYT-INIA Mexican wheats have been tested in many parts of the world. They are now being grown commercially in eleven Asian, eight African, two European, two South American, and four Central and North American countries. The Mexican varieties have performed surprisingly well under this very wide range of conditions when the proper choice of varieties is based on effective locally conducted adaptive yield tests. In a few areas inappropriate choice of varieties, for example Siete Cerros or Inia 66 instead of Tobari 66, for use in the higher rainfall areas bordering the Mediterranean or Caspean, has resulted in severe damage from *Septoria.*

It is the aim of CIMMYT now that it has established close collaborative programs with Morocco, Tunisia, Lebanon, Turkey and Portugal to incorporate a greater degree of *Septoria* resistance into the Mexican gene pool. This is being attempted at the present time by incorporating the *Septoria* resistance present in French, Italian and Chilean winter wheats and from the Argentinean, Brazilian and East and South African spring wheat varieties. The screening of large number of CIMMYT lines in the Mediterranean climate areas and also in the high rainfall areas of East and South Africa, Brazil and Argentina, already has resulted in identifying lines that carry considerable resistance to *Septoria.*

Similarily an attempt is being made to incorporate a broader base of resistance to scab *(Giberella* sp.) into the gene pool. The

best climate and locations for identifying new combinations with unusual resistance to scab are certain locations in southern Brazil and the maize belt of Argentina. It is also being attempted to incorporate mildew *(Erysiphe* sp.) resistance into the gene pool.

At the present time an attempt is being initiated to identify the best sources of resistance to Hessian fly *(Phytophagus destructor),* Sawfly, *(Cephus* spp.), cereal leaf beetle *(Oulema* spp.), Zuni pest *(Eurogaster* spp.), and wheat stem maggot *(Meromyza* sp.), all of which can cause serious losses in the Mediterranean region or Near East in certain years.

A continuing effort is being made in the crossing program to broaden and deepen the spectrum of resistance to the three rusts.

Major difficulties are involved in attempting to simultaneously incorporate all of the aforementioned improvements into the gene pool. For this reason a large portion of the CIMMYT program is currently devoted to utilizing *top crosses* (crosses made between a superior F_1 population and another superior commercial variety distinct from either parent used in making the single cross), and especially double crosses. The double crosses involve crossing two superior F_1 plant populations. Attempts are made to produce a minimum of 150 and preferably 200 crossed F_1 seeds when top crosses and double crosses are made. The resulting F_1 populations of top crosses and double crosses are space planted and rogued vigorously for agronomic phenotype and diseases reaction. The seed from the superior F_1 plants (after roguing heavily) is bulked and sent to collaborators in different parts of the world for selection.

Currently a cooperative effort is underway between scientists in the Indian, Pakistan, Lebanon, Tunisian, Moroccan and Mexican programs to further improve the 8156 derivatives, i.e., Kalyansona, Mexipak, Siete Cerros, etc. These varieties or related selections are currently being grown on more than 8 million hectares in the Middle East, Near East, Africa, Mexico and U.S.A. They have unusually broad adaptation and have outyielded all other commercial spring wheat varieties throughout this vast area when diseases are not a limiting factor. They have good resistance to loose smut, considerable resistance to bunt, and carry genes which cover many races of stem, leaf and stripe rust. They also carry considerable resistance to mildew and sawfly. They are, however, extremely susceptible to *Septoria* and scab *(Giberella).*

They need to be improved in rust, scab and *Septoria* resistance, gluten quality, and dwarfing.

Although a large amount of breeding effort has already been done in several national programs to attempt to correct the aforementioned defects, while maintaining the highly desirable phenotypes of the 8156 derivatives, the results have not been good. Lines have been developed in Mexico that are similar in phenotype and possess much better rust resistance than Siete Cerros and Super X, but all of these yield 10 to 20 percent less than the parent 8156 varieties. The most promising lines with 8156 phenotype which are available for further improvement were derived from the following crosses:

1) Mengavi x 8156, cross II-233064.
2) Tobari x 8156, cross II-23439.
3) Jaral[2] x Mengavi-8156, cross II-26784.
4) $Y50_E$*-8156 x Kalyansona, cross II-28895-3004-304M-0Y.
5) Zambesi, a new Rhodesian variety developed by Dr. Olesen, from a cross of 8156 x Lee - ND74 is also phenotypically similar to 8156, but about 15% lower in yield under Mexican conditions.

Currently, several hundreds F_1 single crosses have been made in India, Pakistan, Lebanon and Mexico. These will be grown by CIMMYT in Mexico and combined into a large number of double crosses and top crosses as well as backcrosses employing the techniques outlined above. The F_2 of this vast crossing program will be sent to all participating national programs for selection, and potential use as both conventional and multilineal varieties.

Testing

Development of Screening Nurseries. During May 1969 the First CIMMYT Bread Wheat Screening Nursery was established. Since then, two other subsequent Screening Nurseries have been prepared, the Second from the lines and varieties harvested in Toluca in October 1969 and the Third from the most promising lines and varieties harvested at CIANO in May 1970.

The purpose of the CIMMYT Screening Nursery is: 1) To make available to legitimate research organizations (government, educational or private) genetic materials that may be useful for development of commercial varieties, and 2) To provide information for CIMMYT on the yielding ability and adaptation of the experimental materials included in the nursery under a wide range of conditions. It is hoped

* E = dwarf.

that this nursery will help to identify those lines that have yield stability, (high yield over a wide range of conditions) i.e. like Inia 66, Siete Cerros, Nainari 66, Pitic 62 and Penjamo 62, and thereby avoid the multiplication of such yield unstable varieties as Ciano 66, Azteca 66, Tobari 66, and Norteño 67.

The materials included in the screening nursery are mostly F_4, F_5, F_6 generation lines that have shown good performance in preliminary tests from the standpoint of grain yield, disease resistance and milling and gluten quality. These materials are the cream of the newer materials being selected in the CIMMYT program.

The Screening Nursery currently includes about 300 entrees, of which 10 percent are check varieties. Each envelope contains sufficient seed of a given line to permit sowing of 2, two meter rows. Data on grain yields, disease and insect reactions are requested for all rows from collaborators who receive this nursery.

Currently, fifty sets of this nursery are prepared for distribution to any collaborator who agrees to return the aforementioned information.

The CIMMYT Elite Line Yield Nursery is a more advanced test designed to explore more thoroughly the breadth of adaptation and yield stability of advanced lines. It was prepared for the first time in November 1969. Twenty sets were prepared for sowing in Mexico, Argentina, Brazil, India, Pakistan, Lebanon, Tunisia and Morocco.

This is a replicated yield test with six-row plots, two meters long, replicated four times. The yield results from this first nursery for Sonora, México, Rabat, Morocco and Tunis, Tunisia, is summarized in Table W4. Lines such as Inia "s" x Napo 63, cross II-22406-6M-4Y-6M-1Y-0M (Potam 70) and perhaps Bluebird # 2 (Yecora 70), # 3 (Saric 70) and almost certainly Bluebird # 4 appear to have both high yield and good yield stability based on these limited results.

Varietal Development of Durum Wheats

Durum wheat is very important to the economy of both the North African and Near East countries. It is preferred to prepare a number of native dishes, i.e.. couscous. Substantial quantities also are exported, especially to Italy and France, and these exports are one of the principal sources of foreign exchange. The recent introduction of high yielding Mexican dwarf bread wheats into these areas threaten to drive out of production the tall strawed low yielding durum varieties. Consequently there is an urgent need for higher yielding durum varieties, so as to prevent this unfavorable shift in wheat types.

Plant type plays a major role in the potential grain yield and adaptation of a wheat

TABLE W4. Grain yield and yield rank of the lines in the CIMMYT Elite Line Yield Test when grown at Ciudad Obregón, Sonora, Mexico, Merchouch, Morocco, and Tunis, Tunisia during the 1969-1970 Season.

			Sonora, Mexico	Morocco		Tunisia	
Yield Rank	Variety	Variety No.	Yield kg/ha	Yield Rank	Yield kg/ha	Yield Rank	Yield kg/ha
1	Bluebird # 4; 23584-26Y-2M-3Y-2M-0Y	(1205)	8075	11	2266	2	3640
2	Saric 70 = Bluebird # 3; 23584-26Y-2M-2Y-0M	(1204)	7492	10	2300	4	3560
3	Siete Cerros	(1206)	7465	2	3100	16	3010
4	Yécora 70 = Bluebird # 2; 23584-26Y-2M-1Y-0M	(1203)	7424	9	2333	2	3640
5	Potam 70-Inia-Napo; 22402-6M-4Y-1M-1Y-0M	(1212)	7346	3	3033	1	3740
6	Penjamo 62	(1201)	7237	8	2366	15	3016
7	INIA 66	(1209)	7231	10	2300	5	3540
8	Bluebird x Ciano 26572-61Y-3M-0Y	(1223)	6940	1	3600	12	3103
9	Sonora 64	(1225)	6778	6	2466	14	3052
10	Tobari x Ciano 24908-30M-3Y-3M-0Y	(1114)	6773	4	2733	6	3306
11	Nuri 70-Bluebird # 1; 23584-15Y-6M-0Y	(1202)	6721	7	2433	8	3234
12	Tobari 66 x Ciano "s"; 25000-26M-1Y-1M-0Y	(1221)	6690	5	2666	23	2758
13	Bluebird # 5; 23584-37Y-2M-2Y-0M	(1207)	6622	17	1566	7	3240
14	Ciano 67	(1220)	6538	4	2733	21	2779
15	Norteño 66 "s" x Ciano "s"; 24941-23M-5Y-2M-0Y	(1219)	6523	4	2733	11	3105
16	Klein Rend-Sonora 64^2 x Inia "s"/Ciano "s"; 24970-29M-3Y-2M-0Y	(1218)	6460	18	1533	17	2987
17	23584 x Ciano "s"; 26592-1T-17M-0Y	(1222)	6398	8	2400	25	2170
18	Tobari 66 x Ciano "s"; 25000-6M-2Y-0M	(1215)	6320	15	1900	18	2828
19	Tobari 66 x Ciano "s"; 25000-68M-2Y-2M-0Y	(1216)	6304	19	1433	19	2826
20	Bluebird # 7; 23584-18M-10Y-3M-3Y	(1208)	6210	16	1866	13	3075
21	Tobari 66	(1213)	6205	12	2200	9	3170
22	Tobari 66 x Ciano "s"; 25000-13M-3Y-2M-0Y	(1217)	6179	14	1933	22	2578
23	Ciano "s" x Inia "s"^{2}; 23959-52T-1M-3Y-0M	(1211)	6106	15	1900	10	3160
24	Sonora 64-Klein Rend/Ciano "s" x LR 64^2-Sonora 64; 27139-57M-0Y	(1224)	5924	13	2133	24	2746
25	Ciano "s" x Inia "s"; 23959-13T-1M-5Y-0M	(1210)	5700	19	1200	20	2798

TABLE W5. Grain yields of ten of the most promising durum lines compared to the most important commercial varieties of bread and durum wheats in replicated yields tests, under 1969-1970 Sonora, Mexico conditions.

Variety No.	Cross	Pedigree	Yield kg/ha	Grain test Weight kg/hl
015	(Ra_E-Tc^4) Stw. 63 x AA "s"	27617-18M-6Y-0M	9.722	82.4
045	[T. dic Varum (TM_E-Tc^2/Z-B x W)]	26636-1M-6R	9.665	83.2
057	CRANE "s"	23055-56M-5Y-1M-0Y	9.472	81.2
09	(BY_E-TAC_E x Tc^4) (BY^2_E-Tc x Stw. 63) AA "s"	27591-3M-3Y-0M	9.242	81.4
02515	BY_E-Tc^5	21276-3Y-1Y-1Y	9.378	82.3
023	B. Bal. (BY^2_E-Tc) x Cr "s"	27676-1M-1Y-0M	9.444	83.2
068	(BY_E-Tc^5) x AA "S"	27512-16M-5Y-0M	9.117	82.7
01	ALBATROSS = JORI 69		9.060	81.2
030	(Z-B x LK) 60-120/TM_E-Tc^2/Z-B x W)	26813-43Y-1M-0M	9.044	83.6
029	(T. dur. tipo, sph-Mogel. Karak x AA "s") (BY^2_E-TAC_E-Tc^3)	27680-2M-1Y-0M	9.029	82.4
	Siete Cerros (bread wheat)		9.036	80.1
	Inia 66 (bread wheat)		8.065	83.2
	Ciano 67 (bread wheat)		7.044	81.6
	Oviachic 65 (dwarf durum)		7.563	80.1
	Tehuacan 60 (durum variety)		4.822	81.2

variety. Factors such as tillering, straw height and strength, the number of spikelets per spike, number of seeds per spikelet, the size, weight and density of the grain and the growth habit and light sensitivity, all strongly influence yield. The dwarfing genes from Norin 10 were transferred to the durum wheats more than 14 years ago in Mexico. Two dwarf varieties Oviachic 65 and Jori 69 have been developed. Oviachic 65 has not been highly successful, despite the excellent agronomic plant type. Both of the dwarf durum varieties have had poor yield stability. Under certain favorable conditions they have yielded more than the best dwarf bread wheat varieties. Nevertheless under other conditions which seem nearly identical, yields have frequently been disappointing. An analysis of the cause of unstable yield in the dwarf durum varieties and lines has established that it is primarily related to sterility of many florets when they are grown under certain ill-defined conditions. It appears that the instability of fertility is in some way related to sensitivity to day length and perhaps also to temperatures. These defects have been probably indavertently exaggerated in the past in the CIMMYT dwarf durum breeding program because of the narrowness of the genetic base. The relatively small durum breeding program until recently was largely a backcross program, which consequently reduced even more the possibilities of overcoming the aforementioned defects.

Three years ago an intensive crossing program, employing many durums from the USDA World Durum Collection, was initiated to correct these and other defects. During the season of 1969-70 at CIANO, out of 140 new lines evaluated in yield tests, 109 outyielded Inia 66, and 36 outyielded Siete Cerros. Eighteen of the best lines yielded more than 9 metric tons per hectare. The performance of 10 of the best lines is shown in Table W5, together with the bread and durum check varieties. In addition to the very promising advanced generation lines included in yield tests a number of outstanding new crosses were identified in less advanced generations.

The CIMMYT dwarf durum varieties have been selected strongly for resistance to stem, stripe and leaf rust in Mexico and excellent resistance has been obtained. During the past two years when they have been evaluated in Tunisia many were found to be susceptible to either stem or leaf rust, indicating different races in the two regions. Fortunately some high yielding lines were found which are resistant in both areas. Nevertheless, it has become apparent that it is necessary to increase the spectrum of rust resistance in the CIMMYT materials as rapidly as possible. Moreover, wheats that are to be grown in the Mediterranean region need a high degree of resistance to both *Septoria* and mildew. Many of the lines from North Dakota carry good resistance to mildew, perhaps derived from Khapli. There is, however, a need to evaluate all genetic stocks from the World Collection for *Septoria* resistance in an area where severe *Septoria* epidemics develop.

The phenotype of the best of the CIMMYT dwarf lines, if they can be corrected for partial sterility and strengthened in disease resistance, give promise of outyielding the highest dwarf bread wheats. This is the aim of the expanded CIMMYT durum breeding program.

The Development of Intermediate Growth Habit Bread Wheat Varieties

The entire experience of CIMMYT and its staff in wheat breeding, with the single exception of limited experience in southern Chile, has been with spring habit wheats. There are, however, some areas where CIMMYT is now collaborating in wheat improvement such as in Afghanistan, Iran and Turkey, where varieties with intermediate growth habit are needed to produce best results. For this reason CIMMYT staff member, Dr. J. A. Rupert, was transferred to Davis, California, two years ago. He is collaborating with the University in the development of a breeding program to produce high yielding lines and varieties that will be adapted to the winter rainfall climate of the Anatolian and Iranian Plateaus, and to other similar ecological conditions. The objective of this project is to combine the desirable characteristics of the high-yielding Chilean semi-winter varieties with those of the CIMMYT spring wheats. The performance of other winter wheats in the International Winter Wheat Yield Nursery and similar yield nurseries is also used to choose additional parents for inclusion in the crossing program. For example, the outstading performance of the Russian variety Bezostaya # 1 in the last two International Winter Wheat Yield Nurseries indicates it has high yield potential combined with broad adaptation and yield stability. Consequently it is now being widely used as a parent.

It should be pointed out that at Davis, California, in contrast to Sonora, Mexico, the climate is appropriate for handling both winter and spring habit varieties without artificially vernalizing the winter types. The F_2 bulk seed as well as advanced lines of the crosses made in California are sent to collaborators in other parts of the world for selection.

Hybrid Wheat Research

Hybrid wheat research during the past year has progressed far enough to draw several conclusions. Firstly, the degree of restoration that has been isolated in certain lines developed from single crosses is adequate to provide an acceptable level of restoration for the production of commercial hybrids for use under Sonora conditions. Secondly, improved restoration capacity, beyond that which is considered acceptable in the restorer developed from single crosses referred to above, is being isolated from the intercrossing of the best restorers obtained from the first cycle of crossing. Thirdly, all of the best restorer lines now available are inadequate, because of agronomic shortcomings, for producing commercially acceptable hybrids. Although all of this restorers contain a dwarfing gene from Norin 10, when they are crossed with tall varieties the hybrids are tall and lodge badly. Therefore hybrids derived from these restorers cannot complete with the best semi-dwarf and double dwarf conventional varieties.

Cytoplasmic Sterility in Triticale

During the past year *Triticum timopheevi* cytoplasmic has been incorporated into Triticale. The resultant crosses are completely sterile but upon backcrossing to Triticale a few seeds are produced and the line can be maintained. It has been observed, in two preliminary test crosses, that a cytoplasmic sterile Triticale pollinated with one of the better restorer hexaploid wheat lines gave a surprising degree of fertility. The validity and repeatability of these preliminary observations is now being explored in depth. If verified it would have great implications.

Triticale, unlike wheat, has large anthers which produce great quantities of pollen; in addition, the anthers are generally well exerted before dehiscing. These characteristics greatly expedite cross pollination and if an acceptable level of restoration can be found, it might become possible to produce a commercial Triticale hybrid.

Pathology Research

With the expansion of funding for CIMMYT during the past year it has been possible to expand the staff and strengthen the research on diseases of wheat and Triticale. A staff member Dr. Santiago Fuentes, and post-doctorates S. Rajaram and Enrique Rodríguez are now engaged in pathological studies.

The relatively broad spectrum of rust resistance has been one reason for the successful transplant of the Mexican wheats to many countries in Asia, Africa and the Americas. Nevertheless, there is a continuous need to both broaden the spectrum and to increase in depth the genes for resistance to rusts and other diseases in the CIMMYT gene pool. It is CIMMYT's aim to continue producing superior agronomic wheat phenotypes, but it also further aims at improving the disease resistance in these superior phenotypes to a point where it will comprise more global resistance to rusts and several other diseases. This can be accomplished by locating as much variability as possible in both the general and specific types of resistance and subsequently, through a

sound scientific approach, incorporate and utilize it in the breeding program.

Each season several hundred crosses are made between superior CIMMYT dwarf phenotypes and materials from the International Spring Wheat Rust Nurseries (ISWRN) which have been found to be not only resistant in Mexico but also in several other parts of the world. Mexico, and especially the summer nursery site in Toluca, is ideal for screening for stem rust and stripe rust and to a lesser degree for leaf rust resistance. Although leaf and glume blotch *Septoria tritici* and *Septoria nodorum* occur in Mexico, especially in the summer Toluca nursery, it seldom reaches epiphitotic proportions. Consequently, it is impossible to select effectively for resistance under Mexican conditions. Other diseases, such as scab(*Fusarium* or *Giberella* head-blight) and powdery mildew *(Erisyphe graminis* var. *tritici)* are rare and never epidemic. In these cases too it is necessary to bring heavy selection pressure to bear on populations segregating for resistance if resistant varieties are to be developed. However, CIMMYT being an international research institute, and directly or indirectly cooperating with many countries, is in a strong position to assist in the development of lines or varieties combining resistance to all of the aforementioned diseases. Materials reported as being resistant to *Septoria,* scab and mildew in national programs in other parts of the world are crossed widely with CIMMYT dwarfs in Mexico. The F_2 bulk materials derived from these crosses are sent for screening to cooperating countries in other parts of the world. Seed of any outstanding lines identified through these procedures again are sent back to CIMMYT for further crossing and up-grading of the gene pool.

Within the past year a CIMMYT Rust Research Laboratory, under the direction of Dr. S. Rajaram, has been established at Chapingo. Research at this laboratory is done to identify the genes for resistance in basic and advanced generation lines of bread and durum wheats and in triticales. The data supplement those from the field. The summarized data from the past year appear below.

Identification of Races: Three hundred (300) collections of stem rust were made from Sonora, Toluca, Chapingo, Roque and Huamantla areas during 1969 and these were identified on the set of International Differentials. The most prevalent major races found were 11, 12, 15, 113 and 151. These races are further defined in terms of their pathogenecity genes on genetic stocks.

In 1969, 112 genetic wheat stocks were received from Dr. I. A. Watson (Australia) for use in analyzing the Mexican stem rust flora as a part of the International Virulence Gene Survey. The results have given a good idea about the effectiveness of the various stem rust genes. On the basis of these tests 7 lines with different genes are now used as supplemental rust differentials. These genes are internationally used in various breeding programs, and listed as follows:

1) Sr 6 (Mc Marachy); 2) Sr 11 (Yalta); 3) Sr 9b (Gamenya); 4) Sr Tt. (Mengavi); 5) Sr 8 (Mentana); 6) Sr 17 (Selkirk), and 7) Yuma.

The definition of the pathogenecity of the standard races, in terms of precise genes has permitted a more conclusive and realistic analysis of the CIMMYT breeding materials. It has also made possible the detection of new genes in the program.

Based on the analysis of stem rust races from last summer's collection in Toluca, Chapingo, Roque and Huamantla it is clear that no single gene would give very effective protection. The summarized results are given in Table W6.

Six strains of stem rust having different combinations of genes for pathogenecity were

TABLE W6. Analysis of the total stem rust collection made from Toluca and Chapingo, Mexico, during the summer of 1969, showing virulence in relation to different tester genes, Mexican cultivars and other resistant genotypes.

Genotype		Percentages of Isolates Showing Virulence (on seedlings)
Mc Murachy	Sr6	57
Yalta	Sr11	51
Gamenya	Sr9b	66
Mengavi	SrTt	33
Mentana	Sr8	81
Siete Cerros	(Sr6 + Sr11)	32
Pitic 62	(Sr8 + Sr9b +)	71
Sonora 64	(Sr11 +)	22
Tobari 66	(Sr11 +)	1
Noroeste 66		0
Norteño 67		0
Selkirk	(Sr6 + Sr17)	0
Yuma		1
Waldron		0
Chris		44
Crim		22

utilized to evaluate the 550 lines of the 1969 A CIMMYT Screening Nursery. Their pathogenecity is described below in Table W7.

With the help of these strains all the lines of the Screening Nursery were grouped into 5 categories:

1) Resistant to all races. Thirty seven lines of this group are given in Table W8. It is suggested that these lines carry either an additional gene or a combinaion of genes or both. They are a good source of resistance to stem rust; 2) Lines with the genes Sr 6 and Sr 11 with or without minor genes; 3) Lines with the gene Sr 11 with or without minor genes; 4) Lines with the resistance similar to that found in Sonora 64, and 5) Lines susceptible to at least 5 strains of stem rust.

All the 550 lines were raised to adult stage and inoculated with two strains 15-2, 4, 7 (# 13-1), and 151- 1,2, 3, 5 (# 64) separately by spraying. All the lines which were resistant to these races in the seedling stage were also found to be resistant in the adult stage. However, 21 lines which were classified as susceptible in seedling to both the races, turned up resistant to both in adult stage, and the results are presented in Table W9.

Twenty eight (28) lines included in multiplication plots in 1969-1970 were screened for resistance to 5 stem rust strains (15-2, 4, 7; 151-1, 2, 3, 5; 15B; 12-1, 3, 5, 6; and 12-1, 3, 4, 5) and the results are given in Table W10, together with adult plant reaction to 15-2, 4, 7 and 151-1, 2, 3, 5. The lines which are susceptible in the seedling stage to the later mentioned races are resistant in adult plant stage to the same races, and were found also resistant to the most prevalent races in Sonora 1969-1970 in field condition.

Resistance in the Durum Breeding Program

Apparently the materials in the Crossing Block and Durum Screening Nursery are highly resistant to stem rust. This may be more apparent than real. Since most of the "wild" inoculum of stem rust is produced on bread wheat varieties, it is likely that these races will generally not be pathogenic on the durums. Consequently, races virulent on durum constitute only a small percentage of the total wild rust population. They are consequently exerting very little selection pressure in the durum breeding nurseries in Mexico. Therefore, unless adequate and proper testing techniques are used now whereby the various sources of resistance are identified and recombined, the new durum wheat varieties are likely to meet the same fate as has too often happened to the bread wheat varieties in the past once they are in large scale commercial production.

Recently an analysis has been made using aces *15*-2, 3, 4, 7 (*221*-1); *12*-1, 3, 5, 6; (*15*B);

High yielding triple dwarf wheats, 26-30 inches in height, have been developed and will soon be in large scale commercial production among farmers.

TABLE W7. Mexican Strains of Stem Rust Used to Evaluate the Resistance of the Wheat Lines Included in the Second 1969 A CIMMYT Bread Wheat Screening Nursery.

Strain	Race	1 Sr6	2 Sr11	3 Sr9b	4 SrTt	5 Sr8	6 Selkirk	7 Yuma
# 13-1	12-1,3,4,5,6	R	R	R	R	R	R	R
# 13-1	15-2,4,7	R	S	R	S	R	R	R
# 64	151-1,2,3,5	S	S	S	R	S	R	R
# 221	15B	R	S	R	S	R	R	S
# 158	12-1,3,4,5,6	S	R	S	S	S	S	R
# 7	12-1,3,4,5	S	R	S	S	S	R	R
# 122	12-1,2,3,5	S	S	S	R	S	R	R

TABLE W8. Lines from the Bread Wheat Screening Nursery showing a wide spectrum of resistance to stem rust in both the seedling and the adult plant stages, and potentially valuable as parents.

Third Screen Nursery "A"	Pedigree	Seedling Infection Types						Adult Plant Reaction		
		# 13-1 15-2,4,7	# 64 151-1,2,3,5	# 221 15 B	# 122 12-1,2,4,5	# 158 12-1,3,4,5,6	# 7 12-1,3,4,5	# 13-1 15-2,4,7	# 64 151-1,2,3,5	Y69-70 (Field)
656	(Son. 64 x $Y50_E$-Gto./Crespo) (cfn. Pj. 62) 25949-9Y-1M-1Y-0M	1,2—	1,2—	1,2—	2+	2=	3=	20 MR	20 MR-MS	TrR
677	Bluebird-Ciano 26573-33Y-3M-3Y-0M	2	1,2	3—	0	0	3=	0	TrMR	0
680	Noroeste 66 x Tiba 63 26870-1Y-6M-1Y-0M	;1	1,2—	1	0	0	;	0	5 MR	0
689	Ciano x Inia "s" 25329-1T-18M-1Y-0M	;1	1+	—	0	1+	3—	5 MR	0	0
703	Bluebird x Ciano 67 26592-1T-17M-5Y-0M	;1	1	;1	2	0	3—	5 MR	0	TrR
755	Bluebird # 7 23584-18M-10Y-3M-3Y	;1	2	0;	2	0	2—	0	0	TrR
759	Tobari 66 x Ciano "s" 25000-26M-1Y-1M-1Y-0M	2	2	3—	2	2=	2=	0	40 MR-MS	0
773	Ciano "s" x 8156 (B) 25332-6M-3R-11M-4Y-0M	;1	X	0;	X	3=	2—	0	0	0
787	LR 64-Son. 64 x Napo/Az. 67 28017-19M-5Y-0M	2=	1,2	;	2+	0	;	0	0	0
803	Bluebird x Inia 66 26591-3T-1M-1Y-0M	;1	2	;	2—	2	2	0	5 MR	0
845	Bluebird x Ciano 67 26592-1Y-8M-3Y-0M	;1	1,2	;1	2	—	2—	0	0	0
847	(Ciano-Siete Cerros) (Son. 64 x $Y50_E$-Gto.) 25918-20Y-2M-3Y-0M	;	;1	;1	;1	3=	0;	0	5 MR	0
852	Bluebird x Ciano 26592-1T-17M-2Y-0M	;1	2	1	2	0	3=	0	0	0
864	Bluebird x Ciano 26592-1R-7M-2Y-0M	1+	2	;	2	1	3—	0	0	0
873	Ciano "s"/Son. 64-$Y50_E$ x Gto. 25342-7M-1R-3M-1Y-0M	;1	1+	0	1	2—	;1	0	0	0
882	Bluebird-Inia x Cal 27237-68M-1Y-0M	2	2	2+	2	0	2—	0	5 MR	0
889	Ciano "s" x Crespo 25341-4M-1T-11M-1Y-0M	;	;	;	2	0	0	0	0	0
898	Chris x Bluebird 26448-1Y-1M-2Y-0M	1	1,2	;1	2	;	;	0	0	0
906	(Ciano-Siete Cerros) (Son. 64-$Y50_E$ x Gto./Tob. 66) 25918-20Y-1M-4Y-0M	;1	0	1—	0	0	0;	0	5 MR	0
918	Bluebird x Ciano 67 26592-1T-9M-1Y-0M	;1	2	;1	2	2	2	0	5 MR	0
956	Tob.-Pj. 62 x No.-Ciano 26004-5Y-1M-4Y-0M	;1	1	0;	1	0	2—	0	0	0
988	Bluebird x Ciano "s" 26572-42Y-1M-4Y-0M	2+	1	1	1	0	0	0	0	0
994	Calidad x Tobari 66 27456-6R-5M-2Y-0M	1	;1	0	;1	0	0	5 MR	TrMR	0
1008	Son. 64-Klein Rend./Ciano "s" x LR 64^2-Son. 64 27139-30M-0Y	X	;1	;1	;1	1+	0;	0	0	0
1009	Son. 64-Klein Rend./Ciano "s" XLR 64^2 Son. 64 27139-64M-0Y	;1	1	0;	1	1	3—	0	0	0
1010	Inia-Ciano x Calidad 27220-44M-0Y	1	1,2—	0;	2	0	0	0	0	0
1023	Bj. x Calidad 27455-3R-7M-0Y	0;	X-	0	X	—	0	0	20 MR-MS	0
1033	Bluebird 23584-18M-10Y-2M-1Y-1M-0Y	;1	1+	1,2—	1	1	0	0	TrMR	0
1060	Son. 64-Klein Rend./Ciano "s" x LR 64^2 Son. 64 27139-75M-0Y	;1	12	;1	1	0	;	0	0	0
1068	Tob.-Cfn. x Bluebird 25973-13Y-1M-0Y	X=	1	;1	1	;	;	0	0	0
1071	Bluebird x Calidad 27104-49M-0Y	;1	1+	2—	1	1	1	0	0	0
1083	Ciano "s" (W_E^3-Nar. 59 x Sta. E./Jar. "s" 27829-21Y-0M	;1,2	1	;	2	0	3—	0	TrR	0
1090	Nar. 67 x CIANO 67-Pj. 62 27866-5Y-0M	—	1	3n	2	;	;	0	0	0
1112	(LR 64-Son. 64/Son. 64-$Y50_E$ x Gto) x Cal. 28227-108Y-0M	;	1	0	3—	—	0	20 MR	TrMR	0
1120	Bj. 67 x INIA "s"-Napo 63 30601-39Y-0M	1,2—	0	1	2	2=	;1	5 MR	10 MR	0
1210	Ciano "s" x Inia "s" [2] 23959-13T-1M-5Y-0M	1	1+	;1,2	2	2—	2—	5 MR	—	0
1214	Tobari 66 x Ciano "s" 24908-30M-3Y-3M-0Y	2	2	2	—	2=	1	0	5 MR	0

TABLE W9. Lines from the Bread Wheat Screening Nursery susceptible in the seedling stage to stem rust races 15-2,4,7 and 151-1,2,3,5 but resistance in the adult plant stage to the same races. Some of these may carry general resistance.

S. N. "B"	Pedigree	Race 15-2,4,7 (Strain # 13-1)		Race 151-1,2,3,5 (Strain # 64)		Adult Plant reaction in Field Y-69-70
		Seedling	Adult	Seedling	Adult	
647	CIANO-7 Cerros x Tobari-CIANO 25863-39Y-7M-1Y-0M	3 +	5-MR	2 + 3	Tr-MR	0
661	INIA x CIANO 26475-43Y-4M-2Y-0M	3	5-MR	3 —	0	0
666	Son. 64-Kl. Rend. x Bluebird 26502-8Y-2M-2Y-0M	3 +	5-MR	3 +	Tr-MR	0
681	Tob. 66-Np. 832 26896-12Y-2M-1Y-0M	3 +	5-MR	3	0	0
698	Tob. 66 x CIANO "S" 24908-17M-1Y-1M-1Y-0M	3 +	5-MR	3	0	0
711	CIANO "S" x Tob. 66 24989-2M-2Y-2M-1Y-0M	3 +	5-MR	3	0	0
712	CIANO "S" x Tob. 66 24995-2M-1Y-1M-3Y-0M	3	5-MR	3	0	0
719	CIANO²-Chris 25101-6M-2Y-2M-1Y-0M	3 +	5-MR	3 +	Tr-MR	0
728	CIANO "S" x Tob. 66 24989-2M-2Y-2M-4Y-0M	3 +	5-MR	3	0	0
745	CIANO "S"² x Jar "S" 25124-1M-1R-2M-1Y-0M	3 +	0	3 +	Tr-MR	
779	Bluebird x Nor. 67 27100-60M-1Y-0M	3	Tr-MR	3	Tr-MR	0
781	CIANO "S" x Calidad 27129-1M-1Y-0M	2 + 3	20-MR	3 +	0	0
786	CIANO-INIA x Calidad 27224-17M-1Y-0M	3	5-MR	3 +	20-MR	Tr-R
832	Pi 62 x T.T.-Son. 64/CIANO² 26745-66Y-1M-0M	3	0	3 +	5-MR	0
885	CIANO² x Chris 27341-15M-3Y-0M	3	3	4	0	0
949	Kl. Rend.-Son. 64² x INIA/CIANO 24970-17M-1T-3M-1Y-0M	4	0	4	0	0
987	CIANO-Chris x Bluebird 26558-69Y-6M-3Y-0M	3	0	3 +	0	0
999	CIANO²-Crespo 24998-18M-4R-4M-2Y-0M	3	5-MR	3	Tr MS	0
1022	CIANO x INIA 25329-1T-7M-0Y	4	5-MR	3 +	0	0
1073	CIANO "S" x INIA "S" 23959-52T-1M-3Y-0M	3 +	5-MR	3	Tr-MR	0
1077	CIANO "S" x Son. 64 x Kl. Rend. 27824-0Y-0M	3 +	0	3 +	20-MR	0

113-1, 3, 5, 6 *(12-1)* and *151*-1, 2, 3, 5 (64) on the principal lines currently included in the Crossing Block and Durum Screening Nursery. From these experiments the dangers inherent in the current situation become very apparent. Many lines that are apparently resistant in the field are highly susceptible in the seedling stage to one or more of the races, especially to race *15*-2, 3, 4, 7. On the other hand, some of the lines from the Crossing Block and Screening Nursery combine resistance in both the seedling and adult stages.

Attempts are now underway to identify durum lines and varieties which are completely susceptible in the seedling stage, but carry genes that condition resistance in the adult stage. To date, in preliminary tests, five different lines originating from two different crosses, have been identified as carrying this type of resistance (Table W11).

TABLE W10. Seedling and adult plant stem rust reactions of lines in Multiplication Plots and Elite Yield Test in the Valle del Yaqui, Sonora, Mexico, in 1969-70. Due to the adult plant resistance these lines are valuable as potential parents.

Multiplication Plot No. (PM) Y69-70	Pedigree	Seedling Infection Type					Adult Plant Greenhouse		
		# 13-1 15-2,4,7	# 64 151-1,2,3,5	# 221 15 B	# 158 12-1,3,5,6	# 7 12-1,3,4,5	# 13-1 15-2,4,7	# 64 151-1,2,3,5	Field Reaction in Sonora 69-70
1	Son. 64-Kl. Rend./CIANO "S" x LR 64[2] Son. 64 27139-57M-0Y	;	X	0;	3—	;	0	5-R	0
2	Son. 64-Kl. Rend./CIANO "S" x LR 64[2] 27139-64M-0Y	;1	1	0;	1	3—	0	0	0
3	Bluebird x INIA 67 26591-1T-7M-0Y	2 + 3	3	1,2	0	;1	0	0	0
4	Tob. 66 x CIANO "S" 25000-6M-2Y-0M	2 + 3	3	;1	0	3 +	0	0	0
5	INIA "S" x Napo 63 (Potam 70) 22402-6M-4Y-1M-1Y-0M	;1	3—	;	0	3	5-MR	20-MR	0
6	Bluebird # 2 Red Grain 23584-26Y-2M-1Y-0M	3	3,3[n]	2—	2—	3 =	5-MR	0	0
7	CIANO "S" x INIA "S"[2] 23959-13T-1M-5Y-0M	1	1	;1,2 =	2—	2 =	0	0	0
8	CIANO "S" x INIA "S"[2] 23959-52T-1M-3Y-0M	3 +	2,3 =	3 +	2—	2 =	0	0	0
9	Bluebird # 7 23584-18M-10Y-3M-3Y	;1	2,3	0;	;	;	0	0	Tr-R
10	Bluebird # 1 (Nuri 70)	2 + 3	4	0;	3	3	0	5-MR	0
11	Bluebird # 5 23584-37Y-2M-2Y-0M	3	2 + 3—	3	;2—	12	0	Tr-MR	0
12	Bluebird # 4 23584-26Y-2M-3Y-2M-0Y	3	2,3 +	3	2—	2—	20-MR	0	0
13	Bluebird # 3 (Saric 70)	3	2—	3	2	3—	Tr-MR	0	0
14	Bluebird # 2 (Yécora 70)	3	3[n]	0;	0	2	0	0	0
16	Calidad x Tobari 66 27167-25M-0Y	12	Seg. X,3 +	3—	0	2	5-MR	0	0
17	INIA x Bluebird 26478-32Y-7M-0Y	3	3[n]	;1	0	2	5-MR	10-MR	0
19	INIA x Bluebird 26478-7Y-8M-0Y	3—	3—	1 +	1	3—	0	0	0
20	CIANO[2]-Chris 26520-35Y-1M-0Y	2 + 3	3 +	3 =	3 +	3 +	0	Tr-MR	0
23	Bluebird "S" 23959-52T-1M-3Y-0M	3 +	2,3 =	1,2 =	1	0	0	Tr-MR	0
24	Bluebird x CIANO "S" 26592-1T-17M-0Y	2—	3—	;1	0.	3—	0	5-MR	0
25	CIANO x NOROESTE 66 25111-15M-12Y-4M-0Y	1 +	33—	;1	3	3—	0	0	0
26	Tobari 66 x CIANO "S" 25000-68M-2Y-2M-0Y	;1	3	;	;	1	0	Tr-MR	0
27	CIANO x NOROESTE 66 25111-6M-7Y-3M-0Y	2,2 +	—	;1	—	1 +	5-MR	0	0
28	Bluebird x CIANO "S" 26572-61Y-3M-0Y	3 +	1 +	1,2	0	—	0	Tr-R	0
29	Tobari 66 x CIANO "S" 24908-53M-2Y-1M-0Y	—	1 +	1	0	;1	0	0	0
30	NOROESTE 66 x CIANO "S" 24941-23M-5Y-2M-0Y	3,3[n]	3 = [n]	2,3	0	2	5-MR	10-MR	Tr-R
31	Son. 64 x Y50[t] x Gto./CIANO[2] 25952-3R-1M-0Y	3	3 +	1,2	0	4	5-MS	0	0
32	CIANO "S" x INIA "S"[2] 23959-27T-4M-5Y-0M	1 +	Seg. 1,4	1	2—	2	0	Tr-MR	0

TABLE W11. Durum lines with possible source of adult plant resistance (post-seedling type) to Puccinia graminis tritici.

Pedigree	Seedling Reaction				Adult Plant Reaction			
	Cult. # 284 Race 113-1,3,4,5	Cult. # 221-1 Race 15-2,4,7	Cult. # 7 Race 113-5	Cult. # 100 Race 113-1,2,3,4,5	Cult. # 64 Race 151-1,2,3,5	Cult. # 64 Race 151-1,2,3,5,	MV-69 Field	Y69-70 Field
(By_E-Tc^5) D-21276-3Y-1Y-1Y-0Y	3	3 cn	3	——	3 +	Tr-MR	0	Tr-MS
(By_E-Tc^5) D-21276-3Y-6Y-1Y-0Y	3 +	2 ++	3	2 ++	3 +	Tr-MR	0	Tr-MR
(By_E^2-Tc^2)^2 (Z-B x W) D-22232-3M-1Y-1M-0Y	4	4	4	4	3 +	Tr-MR	0	Tr-MR
(By_E^2-Tc^2)^2 (Z-B x W) D-22232-3M-3Y-1M-0Y	4	4	4	4	3 +	Tr-MR	0	Tr-R
(By_E^2-Tc^2)^2 (Z-B x W) D-22232-9M-2Y-1M-0Y	4	4	4	4	3 +	Tr-MR	0	0
(TM_E-Tc^2) (OVI-65) D-22235-23M-3Y-2M-100Y-100M	3 +	2 +	3	3 +	3 +	Tr-MR	0	30-MR

Rust Resistance in Triticales

Four hundred and sixty eight of the most promising advanced lines from the Triticale breeding program have been inoculated with wheat stem rust races 15-2, 4, 7, and 151-1, 2, 3, 5, both of which represent wide spectrums of virulence. All the lines were highly resistant to both races. The infection types ranged from (0), (0;), (;) to (2). This indicates that stem rust resistance in Triticale is dependent on several genes.

Wheat leaf rust race 144 was also employed to screen the same Triticale lines for resistance to this pathogen. Of the total 468 lines tested, 391 were susceptible in the seedling stage. The remainder of the lines showed resistance in the seedling stage. Four different types of resistance were discernable.

Entomology Research

Insect problems, with the exception of the English grain aphid *(Macrosiphum* spp.) and army worm, *(Pseudaletia* spp.) have seldom been of importance in the main areas where CIMMYT has concentrated its wheat research effort in the past. This situation has changed during the past two years since CIMMYT has become directly involved in wheat improvement in North Africa and the Near East. In this vast area insects frequently affect production seriously. The relative importance of the losses due to insects varies from year to year and also from place in the same year. The insects that are of sufficient importance to warrant control considerations include: 1) The Hessian fly, *Phytophagus destructor,* which is widespread and often destructive. It is perhaps the most important insect pest of wheat in the Mediterranean area; 2) Sawfly, *Cephus pugmacus* and/or *C. cinctus.* This insect is probably second in importance to the Hessian fly, and in some areas is more destructive than Hessian fly; 3) Cereal Leaf Beetle, *Oulema* spp. Apparently at least two species of this pest are present in the Mediterranean area, and 4) Zuni Pest, *Eurogaster* spp. This pest sometimes becomes important in local areas of the Near East.

During April and May 1970 Dr. Alejandro Ortega, a CIMMYT entomologist, made a survey of the insect problems on wheat in North Africa.

It is apparent that attempts should be made to incorporate both resistance to Hessian fly and to sawfly into the breeding program. This will be a complex struggle that will require a long-time approach. It is known that the Hessian fly in the U.S.A. is made up of a number of races. Greater genetic variability in the Hessian fly population in all probability is present in North Africa than in the U.S.A. Control through manipulating dates of planting in North Africa based on preliminary observations does not appear to be effective.

Nematode Damage on Wheat

For the past several years certain spots in fields or even entire commercial fields of wheat in the Valle del Yaqui, Sonora, have been observed to develop poorly despite proper sowing, adequate fertilization and irrigation. Generally, the plants in such fields tiller weakly, are chlorotic, and produce small heads. They give the impression of suffering from extreme nitrogen deficiency.

Two years ago Dr. S. D. Van Gundy* of the University of California at Riverside, and Ing. José Gustavo Pérez B. and Dr. Eugenio Martínez of CIANO began a study of this problem. A general initial survey established that plant roots from fields manifesting this diseased condition were heavily infested with the nematode *Pratylenchus thornei.*

During the past year a detailed study involving the effect of date of planting, variety, fertilization and soil fumigation was conducted by the same scientists at CIANO to determine the importance of this disease.

Soil fumigation with the nematocide D-D at 187 liter/ha and 373 liter/ha gave 71 - 95% control of *Pratylenchus thornei* at planting time, and from 15 to 25% increase in grain yield in the absence of any nitrogen applications. No significant grain yield response to soil fumigation was achieved when applications of urea were made at planting time (100 kg N/ha) or one month after planting (80 kg N/ha). This was attributed in part to the relatively low numbers of nematodes in the test plots compared with known field infestations. Methyl bromide and Mocap applications reduced the numbers of nematodes but did not significantly improve grain yield. Increase in plant growth following fumigation with methyl bromide was highly significant; however, most of it was straw rather than grain. Mocap apparently induced a severe nitrogen deficiency in the plants early in the growing season offsetting the beneficial effects of nematode control.

The six wheat varieties — Inia 66, Tobari 66, Azteca 67, Norteño 67, Lerma Rojo 64A and Siete Cerros— reacted similarly to soil fumigation indicating that all of them are equally susceptible to the nematode.

The greatest increase in grain yield due to soil fumigation for all varieties (26%) corresponded to the earliest planting date. The smallest increase due to fumigation corresponded to the last planting date and increases for other planting dates were intermediate. Daily mean soil temperatures at a 10.5 cm depth were 24°C at the first two planting dates and decreased to 13°C at the last planting date.

In all probability the severity of this problem, which may be more general than first thought, is intensified by lack of adequate crop rotations and aggravated further by early plantings when soil temperatures are still sufficiently high to favor very rapid development of the nematode. Although soil fumigation is effective in reducing damage, it is still prohibitive cost-wise for a field crop such as wheat.

In the event that future studies, now being planned, clearly indicate that the nematode problem is a regional problem of economic or potential importance, then it will be necessary to explore the feasibility of obtaining economic control through: 1) better crop rotations; 2) proper dates of sowing; 3) most appropriate levels and kinds of fertilization; 4) modification in irrigation practices, and 5) through the development of nematode resistant or tolerant varieties through breeding.

Wheat Physiology Research

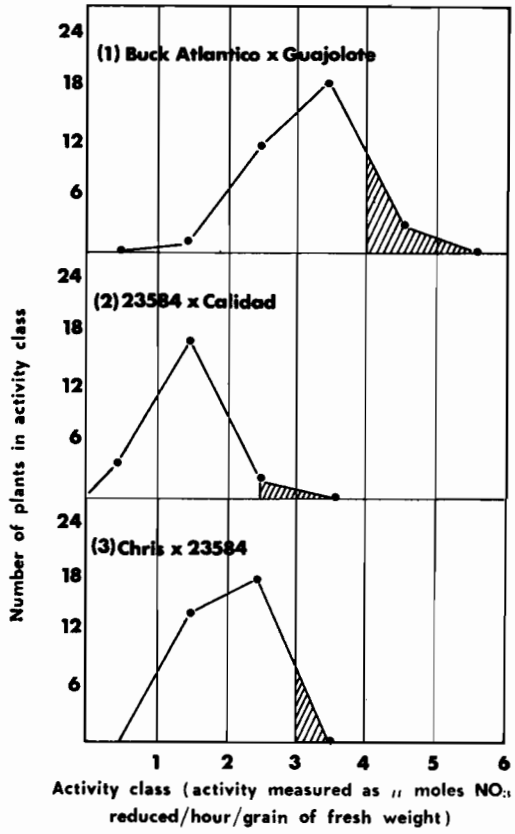
In November 1969, CIMMYT established a Plant Nutrition Laboratory at Chapingo under the leadership of Dr. Lowell Klepper. This laboratory is sufficiently staffed and equipped to perform a wide range of enzymatic analyses and routine determinations on plant tissue. Its purpose is to furnish information on the different plant metabolic pathways (which plants contain high levels of key enzimes) to aid the breeders in their selection of superior plants.

Since nitrate reduction has been shown to be a limiting step in grain protein production, as an initial project, individual F_2 wheat seedlings were screened for their genetic ability to reduce nitrate. At this time over 5000 individual plants representing 123 different F_2 populations have been analyzed. These plants were classified into categories of high, medium and low nitrate reducing activities with only the "highs" saved for F_3 seed production.

This nitrate reduction was measured by a new *in vivo* technique using intact leaf sections rather than the *in vitro* method which requires an aqueous extraction of the enzyme from the leaf tissue. As shown in Figure 1, different F_2 populations show different distributions both in shape and in placement upon the activity scale. The "high" portions of the distribution are denoted by the shaded areas and represent the plants saved and transplanted to the field for F_3 seed production. Presently,

* Supported in part by a grant from the Rockefeller Foundation.

FIGURE W1. Typical frequency distribution of the nitrogen reducing ability of dfferent F_2 wheat seedlings.



more than 300 F_3 lines selected from approximately 10,000 plants representing 65 tested F_2 populations have been planted and will again be analyzed on an individual plant basis. Plants will be selected from these populations that have the necessary agronomic characteristics such as good plant type and resistance to diseases but also will possess the genetic potential for high levels of nitrate reduction. These plants will be incorporated into the wheat breeding programs to be used as progenitors for future wheat varieties.

Another approach is presently being tested to obtain wheat genotypes with high nitrate reducing potential. The bread wheat crossing block (436 genotypes) has been analyzed in the seedling stage under field conditions and classified into activity categories (Table W12). This data coupled with the F_2 distributions provides some information on which progenitors transmit high activity plants into the segregating F_2 populations. It has been found, for example, that "highs" such as Tobari 66, Buck Atlantico, Sonora 64, or Inia when used in crosses consistently transmit "highs" into the F_2 population. Other progenitors such as Chris fail to produce "highs". This study is presently being expanded to study the segregating populations of "high" x "high" crosses.

TABLE W 12. Nitrate reduction ability of several of the bread wheat progenitors.

Progenitor	Low	Medium	High	Very High
Nadadores 63				X
Sonora 64-Yaqui 50_E x Gaboto				X
Sonora 64-Yaqui 50_E x Gaboto/Inia				X
Inia			X	
Tobari 66			X	
Sonora 64			X	
Penjamo			X	
Buck Atlantico			X	
Chris			X	
Siete Cerros		X		
Bonanza		X		
Nor 67		X		
Gaboto		X		
Sonalika		X		
Klein Rendidor	X			
Yaqui 50	X			
Pato (Rojo)	X			

Also in progress is a study of ten different wheat varieties of different yield potentials, protein content, maturity dates, plant types and levels of nitrate reducing ability. These varieties are being analyzed weekly throughout their entire growing season for nitrate reduction and several other measurements. This study was designed to determine what plant characteristics are valuable in grain protein production.

Agronomic and Soils Research on Wheat Production

The soils and agronomic research being done on wheat by CIMMYT in Mexico is presented elsewhere in this report. Shortage of staff has restricted studies in this field in recent years. Currently a new staff member, Dr. Anthony Fischer, is being added to expand and strengthen the research in these disciplines.

The advent of the triple dwarf era —which is now beginning in Mexico with the release of the new dwarfs Yecora 70 and Saric 70— will require new research to find how to effectively utilize the yield potential of these varieties. Limited preliminary work in this field

has been done by Dr. Mario Vela of the CIANO staff, and by Dr. Reggie Laird and colleagues.

Up to the present time the most detailed research work to develop adequate and effective cultural practices for growing triple dwarf wheats has been done by the All-India Coordinate Wheat Improvement Program. They are now much more advanced in this agronomic research than is the CIMMYT-Mexican program.

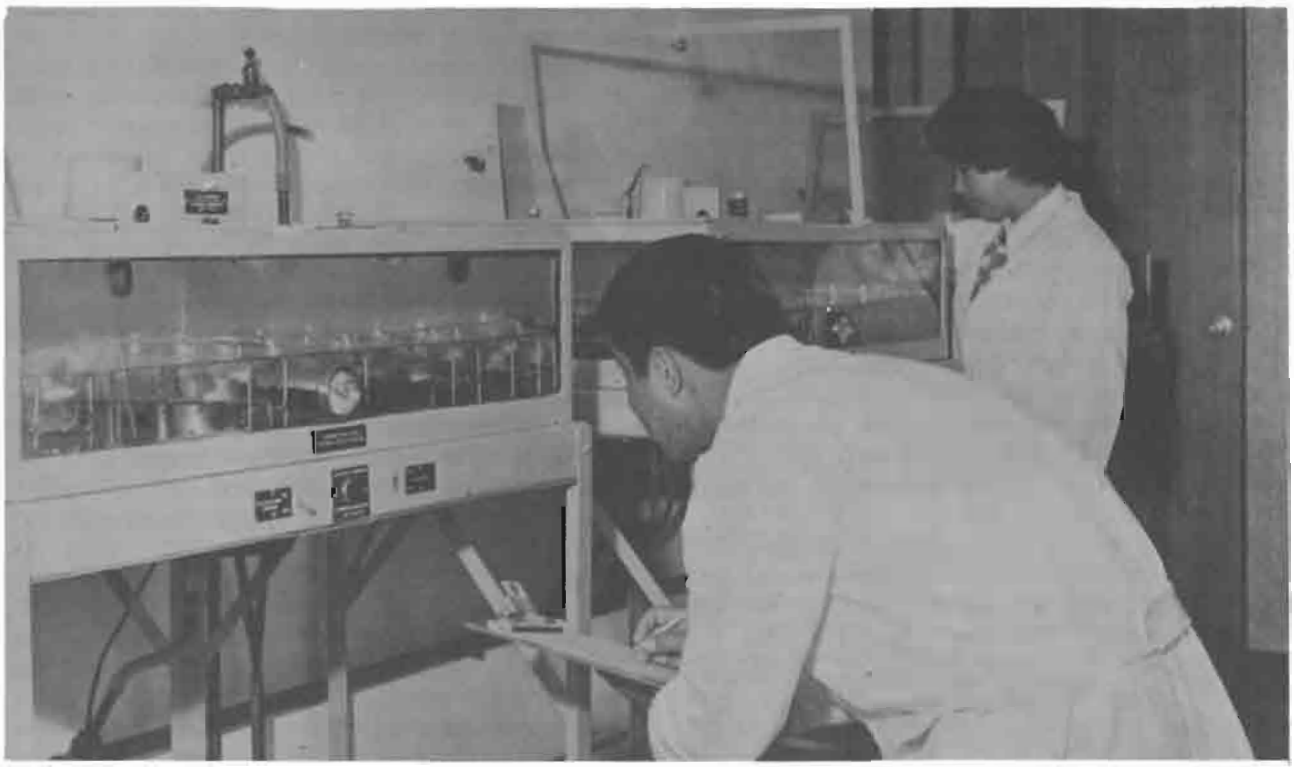
IMPROVEMENT OF WHEAT QUALITY

1. Improvement of Industrial Quality

Ten years ago the commercial Mexican wheat varieties were, with few exceptions, poor in milling and baking quality. Prior to 1958 no adequate cereal technology laboratory existed to guide the breeding program and advanced lines which had shown promise from a yield and agronomic standpoint were sent to laboratories in the U.S.A. for quality determinations. When the first Cereal Technology Laboratory was established in Chapingo in 1958 conventional methods used in laboratories in the U.S.A. and Canada were adapted. It soon became evident that these methods were inadequate for the diverse needs of Mexico; they provided no direct ties between the quality problems confronting cereal breeders and the cereal technologists. By 1962 it became obvious that micro-methods were needed, especially for the evaluation of early generation segregates from the breeding program, as well as for progenitors. Over a period of four years a series of micro-tests were developed by Drs. Evangelina Villegas, Arnoldo Amaya and Ing. Federico Castilla Chacón. These micro-methods combined in more advanced generations (when larger grain samples are available) with the conventional milling, dough-handling and baking tests have completely changed the quality characteristics of the Mexican wheats. Almost all of the more recent Mexican varieties have good milling and baking properties. The micro-methods now used in the CIMMYT-INIA laboratories to evaluate individual selections and lines in early segregating generations have been adapted in recent years for use in laboratories of government and private companies engaged in breeding wheat varieties in a number of different countries.

In the past year 17,000 lines from the F_3 and F_4 generations were evaluated for grain type. Approximately 50% of these lines were discarded for undesirable grain characteristics.

Micro-tests in the milling and baking quality laboratory are used to assist the breeding program in their selection of elite materials.



The remaining lines were evaluated by the micro-Pelshenke test (gluten strength) on an individual plant basis and approximately 30% of these were also discarded. Protein sedimentation, mixogram and alveogram tests were performed on the promising lines to identify those with potentially desirable baking quality. In this way a number of lines with good baking quality characteristics have been identified and are in multiplication for release as commercial varieties.

An important point that must be emphasized is that by using the micro-tests it has been possible to identify in early generations high quality lines in the breeding program. Such lines are then incorporated into the crossing block to be used as progenitors in subsequent crosses.

It is very important to know the quality characteristics, *good* or *bad,* of all of the progenitors, in order to plan for adequate combination of characters in new crosses. In this way progenitors with outstanding agronomic characteristics but with poor quality may be crossed with good quality lines in order to correct their undesirable traits.

Dr. F. J. Zillinsky shows an example of the highly fertile triticales recently developed from Armadillo strains.

IMPROVEMENT OF NUTRITIONAL QUALITY IN WHEAT AND TRITICALE

About three years ago, CIMMYT in collaboration with the University of Nebraska, began a modest program to increase the nutritional value of wheat. The program consisted of a two-pronged attack; firstly to increase the total grain protein content and secondly to improve the essential amino acid balance.

A preliminary evaluation of hexaploid wheat material was initiated in 1967 by CIMMYT's Protein Quality Laboratory to determine the content and variation of tryptophan and lysine in the protein of CIMMYT's wheat material.

The protein content ranged from 11.8 to 20.4 percent. Average tryptophan was 1.09 percent (range 0.66-1.60%). The lysine present in the protein was from 2.40 to 3.18 percent with an average of 2.64 percent. No correlation was found between lysine and tryptophan content in the protein of the evaluated material.

During the past two years a considerable number of single crosses have been made and studied, involving the lines found to be high in lysine content at Nebraska. To date the vast majority of segregates from these first crosses have been poor in phenotype, and many have had chlorophyll defects. Up to the present time, little if any progress has been achieved toward developing a high-yielding wheat with improved essential aminoacid balance. This research is, however, being continued on a very modest scale.

More promising for the immediate future, is the possibility of developing varieties with high levels of total protein. A number of lines, especially in durums, have been identified in the past two years with high levels of grain protein. These have been included in the crossing block and used to make many new crosses with the hope of improving the protein levels in the gene pool.

Triticales evaluated during the past two years have shown themselves to be a great potential source of protein and lysine. One hundred and ninety-one lines from the small plots (PC's) of the Y69-70 season were selected and evaluated in the laboratory. Their protein ranged from 12.8 to 17.9% and the percentage of lysine in the protein from 2.51 to 3.84%. Best lines in lysine level had a protein average of 14.8%.

One hundred advanced lines of Triticales from the yield tests were also evaluated for lysine and protein content, and great variation was observed in the protein content of these lines as well as in the lysine level in the pro-

tein. The protein ranged from 10.4% to 16.0% and the lysine in the protein ranged from 2.14% to 3.59%. In general the values for the material from the small plots were higher in protein and lysine level, than in the values obtained from the yield trials.

During the past year some strains of triticales grown in different seasons and levels of nitrogen fertilization have been evaluated by Dr. F. Elliott of Michigan State University using bio-assays employing the meadow vole. Several triticale lines have shown outstanding nutritional value in these tests.

Another development of interest was the recent discovery of a number of promising lines of Agro-triticum wheat-like derivatives. These are apparently derived from a translocation and characterized by large plump kernels of high grain test weight. Some of these lines also have high levels of grain protein.

Triticale Research

The triticale research program continues to be one of the most challenging and fascinating projects in progress at CIMMYT. Much progress has been made during the past year toward developing a triticale variety that will be able to compete successfully with the highest yielding wheat, oat and barley varieties. Triticales are also extremely interesting from a nutritional point of view, because of their high protein level, high level of lysine and high nutritive value in preliminary bio-assays. A summary of research progress achieved on Triticales during the past year is reported below.

YIELD IMPROVEMENT IN TRITICALES

Before Triticale can become established as a cereal crop competitive with other small grain cereals, it must produce as much or more grain per unit area as any of these cereals. Although average yields among triticale lines under test have increased substantially during the past two years they are not yet competitive with the best Mexican wheat varieties. The present lines of triticales have several shortcomings that must be corrected before yields can be raised to the level of the best wheats. Among these are susceptibility to lodging, low tillering capacity, endosperm shrivelling during maturity, and lack of broad adaptation. Some sterility is still present, but the reduction in yield from sterility among the better strains is now much less than from other causes.

Grain Yield in Replicated Trials

Grain yield in Mexico among triticale strains in the early trials (up to 1968) were only slightly more than half of the best wheat varieties. A major improvement in yield occurred with the selection of the more fertile types from the Cross X308, now referred to as *"Armadillo"* lines.

The Armadillo lines were included in replicated yield trials for the first time in the summer of 1969 at El Batan and Toluca. The average yields were well above those previously obtained at either Toluca or CIANO. The International Triticale Yield Nursery grown at CIANO during the winter of 1969-70 contained the best lines selected during 1968 from the Armadillo cross. The Navojoa winter 1969-70 tests contained the latest reselections from the same cross made in El Batan and Toluca in 1969. Performance of both groups improved relative to that of the wheat checks (Table W13). It is not expected that a similar degree of improvement will continue as a result of reselections from the original 308 cross. The F_3 and F_4 progenies of crosses involving Armadillo and other triticales are now growing in the Toluca nursery. It is believed that strains selected from these populations will provide the additional increment of yield necessary to equal that of the best bread wheats.

Susceptibility to Lodging and its Effect on Yield

All of the highly fertile "Armadillo" selections which provide the basis for the major

TABLE W13. Average yields of the best Triticale strains compared with yields of the best wheat varieties as checks in six tests.

Location and Year	Triticales			Wheat Checks		
	N° of strains	Ave. yield kg/ha	Yld. of top str. kg/ha	N° of checks	Ave. yield kg/ha	var. kg/ha
CIANO, Winter 1967-1968	22	2663	3196	3	4213	5207
Toluca, Summer 1968	23	2691	3190	—	—	—
El Batán[1] & Toluca[2], Summer 1969	10	3229	3972	3	3554	3645
CIANO[3], Winter 1969-1970	10	4492	4990	3	5417	6202
Navojoa[4], Winter 1969-1970	18	5066	6282	4	5321	6491

[1] Injury from residual effect of Atrazine reduced yields on both wheat and triticale.

[2] Identical tests were grown at Toluca and El Batán in 1969. The data from the two tests were averaged for this table.

[3] The International Triticale Yield Nursery 1969-1970.

[4] New triticale strains reselected from the original X308 selections.

improvements in yield, seed type and fertility, in the triticale program have weak straw. This is currently one of the more serious limiting factors to higher yields. Because of a tendency to lodge, lower nitrogen application than commonly used on wheat has had to be used in the replicated Triticale yield trials. An application of 60 kg/ha of actual N has been used in tests in Sonora and Toluca. At these nitrogen levels, the yields of the best triticales approached those of the bread wheat checks. However, under conditions of maximum productivity the best triticale yield obtained have barely reached 7 tons per hectare, while yields of the best bread wheats exceeded 9 tons. Little progress in maximum yields can be expected until a substantial improvement in resistance to lodging is obtained.

Breeding for improved lodging resistance is being approached in two ways: a) By reducing the plant height, i.e., the creation of dwarf triticales; and b) By increasing the straw strength at the E_1* height level. The following three sources of dwarfing are currently being used to produce the dwarfs: 1) UM940 which possesses one of the Norin 10 dwarfing genes from the Mexican bread wheat $P4160_{E1}$*; 2) Double and triple dwarf wheats that possess Norin 10 and other sources of dwarf genes; and 3) Dwarf rye (Snoopy), a selection from an outcrossing population of Gator rye.

Improvement in straw strength without resorting to additional dwarfing was undertaken because of the difficulty in maintaining high fertility and good test weight in the dwarf selections arising from crosses involving UM940.

The origin of the parental triticale stock now being used for improving lodging resistance was a bulk outcrossing population. The original selection was found to be highly heterozygous, but appears to have a heritable source of resistance to lodging which is not incompatible with fertility possessed by the Armadillo strains. The first strains from this program are expected to enter the yield tests within two years. Dwarf selections possessing genes from dwarf, rye or triple dwarf wheats will require at least an additional year.

Other Factors Influencing Yield

Tillering: Another characteristic which significantly limits yield is low tillering capacity. There is a tendency, particularly among Armadillo strains, to produce few tillers. This is particularly evident among the early maturing selections. There is an apparent association between light insensitivity and reduced tillering in at least one strain of Armadillo (X308-27Y-2M-4Y-3M-0Y-0B). Light sensitive segregates require an additional two weeks to head in Sonora, but produce at least twice as many tillers under spaced seeding. In Toluca, during the summer months, both types produce heads at more or less the same time and do not appear to differ greatly in the production of tillers in this environment.

A dwarf highly fertile and lodging resistant F_2 plant of triticale from the cross Beavor x Armadillo growing at Toluca.

Adaptation: The current strains of triticales appear to be very restricted in adaptation. Changes in latitude, daylength, elevation, and probably many other factors influence their performance. Since triticale is a man-made species of recent origin with a narrow genetic base, it has not been subjected to selection for survival in competition with other species under numerous environmental conditions. To compensate for this lack of a natural evolution, it will be necessary to establish populations of triticales as genetically diverse as possible, and have these grown and selected in various environments around the world. The best selections from all possible sources can then be brought back together and again hybridized to establish a second cycle of more diverse material. Such a program requires the cooperation of many interested scientists around the world.

* E_1 = a one gene or semi-dwarf level.

Cultural Practices: Special attention to production practices and agronomy will enable us to obtain better yields from the present strains of triticales in the future. Studies on the behavior of triticales under different seeding rates, row spacings, fertilizer levels and seeding dates have been undertaken by Dr. R. Laird. Observations on the use of herbicides for weed control indicate that there are wide differences among triticales in their reaction to herbicides. Generally they are more sensitive than either bread wheat or durum wheat to both pre-emergence type herbicides and to 2, 4-D.

Sprouting: Difficulties in establishing a uniform vigorous stand have been experienced on several occasions. Moist weather at maturity provokes germination in the spike. Frequently, the germination occurs before the seeds actually mature. Seeds which have started to germinate in the spike and then dry off either fail to germinate or produce very weak seedlings. Furthermore, there is a tendency for the seeds which are harvested in a damp condition to germinate poorly, even though not sprouted. Apparently, this is related to undescribed microflora adversely affecting germination.

Grain Type: Seed shrivelling is one of the major problems still unsolved in triticales improvement. After fertilization, endosperm development tends to be more or less abnormal in all triticales. The most serious abnormalities occur in the original crosses of durum and rye. It is highly possible that the failure to produce viable seeds from this cross is a direct result of abnormal development of the endosperm. Crosses between bread wheat and rye also result in badly shrivelled seeds, but an occasional seed develops sufficiently to germinate, without employing embryo culture.

When the first amphiploids are formed following treatment of the F_1 polyhaploids with colchicine, endosperm development is more normal than in the original cross, but more irregular than in the parental species. The early generations of the amphiploids produce poorly developed seeds. Usually these seeds germinate poorly and the seedlings are low in vigor. Improvement in seed can be obtained by crossing to other triticales having the same chromosome number, particularly to strains of Armadillo, and then growing advanced generations and selecting strongly for better seed type.

From the time the program started in Mexico in 1965, the triticales have been screened continually for better grain type. The most significant improvement for plumper grain was obtained with the isolation of the highly fertile strains from cross X 308 (Armadillo) in 1968. The original Armadillo selections were about 3 kilograms per hectoliter heavier in test weight than the best entries in the 1968 tests. The following information on test weights was reported in the 1968 triticale report. "Twenty-three of the most productive strains in the Y67-68 yield tests averaged 65.9 kilograms per hectoliter with the top strain at 71.1 kg/hl. Twenty-nine of the new Armadillo strains averaged 68.5 kg/hl, and the top strain weighed 74.0 kg/hl".

The most advanced crosses involving the Armadillo lines as parents are now in the F_4 generations in the Toluca nursery. They have not been bulked to determine if improvement in test weight is continuing. The test weights among reselections from the original strains of Armadillo cross X 308 continue to improve. The average test weight of the triticale strains in Navojoa 1969-70 tests was 70.4 kg/hl with the top strain at 73.7 kg/hl. It is of interest to note that although the increase in average test weight amounted to about 2 kg/hl, the top strain in the 1969-70 tests (73.7) was not as good as the best in the 1967-68 tests (74.0). Strain 308-Y-23M having the best test weight in the 1968 tests was discarded because of its extreme susceptibility to lodging.

A special effort was made during the 1969-70 season to select for better seed type. A special nursery containing representative lines from all crosses still maintained in the breeding program was established at Navojoa during the 1969-70 season. This nursery contained over 5,000 head rows and was used primarily to screen for good seed types. Another nursery of bulk material maintained as an outcrossing population was also used to screen for seed type. About 4,000 single plants were harvested and the grain examined during threshing. A third group included all populations of the segregating generations (F_3 to F_6). These were also screened for seed type. About 500 plants or lines were saved from these three sources. All samples were re-examined in the laboratory from which about 125 were retained as the best seed types to serve as a nucleus for seed improvement. They will be used in crosses to other triticales and to establish an outcrossing population within the best seeded selections.

DISEASE PROBLEMS IN TRITICALES

Although triticales appear to suffer from the same diseases as wheat and rye, diseases have not appeared to be a serious limiting factor in triticale development up to now. It is very likely that as triticale production begins on a commercial scale those diseases which find triticale a favorable host will tend to increase to epidemic proportions. It is necessary to keep a close watch on diseases which attack this crop and breed for resistant strains in the eventuality that they become important under commercial production.

The Rusts

Stem rust, *Puccinia graminis tritici,* presents very little problem in the present triticales. Practically all strains and segregating populations in the triticale nursery are resistant. Dr. Rajaram (1969-70) inoculated 468 advanced lines and strains with two virulent strains of stem rust. Strains 15-2, 4, 7, which render the resistance possessed by Garza durum (Sr 11), the *T. timopheevi* gene (Sr Tt) and that of Yuma durum ineffective, and 151-1, 2, 3, 5, a strain highly virulent on bread wheat varieties were used because these races render ineffective many of the resistance genes now carried in both the durum and bread wheat programs. All of the lines tested were resistant. The current varieties of bread wheat and durums used in the crosses do not possess a degree of resistance equal to the resistances displayed by the triticales which were derived from these wheats. Therefore, it apears that some of the genes for resistance to stem rust must have been derived from varieties of rye.

Leaf rust, *Puccinia recondita,* appears to be much more serious than stem rust on triticales. Dr. Rajaram observed that the majority of the triticale lines tested in the greenhouse were susceptible to race 144-1, 4, 7. This race attacks Inia 66, Siete Cerros and Sonora 64. The varieties Tobari 66, Preska and Agatha are highly resistant. About half of the strains in the triticale nursery at CIANO 1969-70 were observed to have as MS to S reaction under field conditions to naturally occurring inoculum capable of infecting Inia 66 and Lerma Rojo 64. However, in yield tests and increase plots, neither the yield nor grain quality appeared to be seriously affected.

Some of the infected strains in the Navojoa nursery 1969-70 produced telia soon after the uredospores appeared. It is not known whether the environment —pathogen— race combination was particularly favorable to force this early teliospore production or whether certain triticale strains are genetically constituted to do this readily.

Stripe rust, *Puccinia glumarum,* occurs more frequently in the higher elevations near Mexico City and Toluca, than in Sonora at near sea level. Varieties of durum wheat and rye from which the triticales were originally obtained are highly susceptible to stripe rust. In 1965, when the triticale program was first started at CIMMYT, the triticale nursery was almost wiped out by stripe rust at Toluca. Since then, by the incorporation of resistant genes from bread wheats, durum wheats and resistant ryes, and continued screening of the segregating populations, most of the current breeding material has become resistant to the races of stripe rust occurring naturally in Mexico.

Bacterial Diseases

A bacterial blight, or more characteristically a bacterial stripe, caused serious damage to many of the triticales in the nursery at Navojoa 1969-70. It had been observed on rye and triticales in 1968 and 1969, but caused very little if any damage to the infected plants. Damage from the 1969-70 infection at Navojoa indicates that the disease is capable of completely destroying a susceptible variety under conditions favorable to bacterial development.

Several strains of triticales were under increase in Navojoa during the winter of 1969-70. Some of the strains became infected in mid-January. By mid-February the most susceptible strains were completely defoliated. All highly susceptible plots were sister lines from a fertile dwarf triticale strain X308-27Y. Strains from other crosses and from other sister lines of X308 were found to be resistant in neighboring plots of the same nursery. Late maturing varieties were not infected until the plants approached heading. Environmental conditions became less favorable as the season progressed and tended to reduce the damage on late maturing and later seeded plots.

Ergot (Claviceps purpurea)

Ergot is a serious disease of rye which also attacks triticales and other cereal crops particularly when environmental conditions tend to induce sterility. The disease is common in most temperate zone areas where rye is grown. It does not occur to any extent in Mexico. Since the ergot bodies contain a poisonous substance called ergotin, their presence in the

grain is highly undesirable and prohibitive as a source of human food.

Dr. E. Larter (University of Manitoba) reported that the wheat variety Kenya Farmer was resistant to the ergot disease. Crosses between Kenya Farmer and triticale varieties were made at CIANO in March 1970 in an attempt to transfer the resistance to ergot disease from Kenya Farmer to triticales. Crosses were also made between Kenya Farmer and several varieties of rye to produce new octaploid triticales. Since the disease does not occur in Mexico, it will be necessary to do the screening for resistance in an environment more favorable for ergot development.

Other Diseases

Under different environments other diseases are expected to present serious production problems. Mildew occurs commonly on wheats in Europe and many wheat growing areas of the world. *Septoria* is also a very serious disease particularly in the Mediterranean area. Root rots take a toll of cereal crops in many grain producing areas. Many of these diseases do not occur regularly enough in Mexico to permit screening for resistance. It will be necessary to set up artificial environments to permit screening in Mexico and also to send the strains to areas where the diseases occur naturally. Cooperation is essential. Yellow dwarf, leaf blotch, necrotic spots and leaf firing occur to a limited extent on triticales at both Sonora and Toluca nurseries. These have not yet built up to damaging proportions, but should be watched as a possible source of disease problems such as occurred with bacterial stripe.

Distribution of Experimental Bread and Durum Wheat, and Triticale Seeds

One of CIMMYT's most important contributions to wheat and triticale research is to provide a continuous flow of experimental lines and varieties to collaborating scientists in different parts of the world. There is a growing demand for these materials. The materials being distributed represent a very diverse gene pool from the Mexican bread wheat, durum wheat and triticale breeding programs. The Mexican gene pool for each of these crops is constantly being modified and up-graded. Each year many hundreds or more commonly thousands of new crosses are made, involving the most promising Mexican materials and introduced varieties or lines showing outstanding characteristics for some special characters. The best of these new materials are subsequently sent to collaborators in other countries for selection.

Many different kinds of materials are sent to collaborators depending upon their facilities and scientific personnel.

During the past year the following types of materials were prepared by CIMMYT for shipment to collaborators:

1. The Sixth International Spring Wheat (Bread) Yield Nursery ("ISWYN") 80 sets.

2. The First International Durum Yield Nursery ("IDYN") 45 sets.

3. The First International Triticale Yield Nursery (ITYN) 47 sets.

4. Third International Wheat Screening Nursery (Bread) (ISN) 1969 Y* Series "A" (262 entries) 34 sets.

5. Third International Wheat Screening Nursery (Bread) (ISN) 1969 M** Series "B" (499 entries) 30 sets.

6. Fourth International Wheat Screening (Bread) (ISN) 1970 Y* Series "A" (270 entries) 38 sets.

7. Durum Screening Nursery (DSN) 1969 Y* 18 sets.

8. Durum Screening Nursery (DSN) 1970 Y* (232 entries) 34 sets.

8A. Elite Selection Bread Wheat Yield Trial (ESYT) 1969 Y* (50 entries) 20 sets.

9. Triticale Screening Nursery (TSN) 1970 Y* 20 sets.

10. F_2 Bulk Bread Wheat 1969 Y*, 45 sets.

11. F_2 Bulk Bread Wheats 1969 M**, 20 sets.

12. F_2 Bulk Durum Wheat 1969 Y*, 20 sets.

13. F_2 Bulk Triticale 1969 M**, 22 sets.

During the past year experimental bread wheats, durums and Triticales were sent to collaborators in 50 countries.

* Y = lines harvested in Sonora.
** M = lines harvested in Toluca.

COUNTRY PROGRAMS: INDIA

The Green Revolution has provoked numerous articles and publications concerning both the positive and negative aspects of the revolutionary changes underway in food production. Many of these articles concern various aspects of the biological, technological, economic and sociological aspects of the Green Revolution and have unfortunately been based on limited information.

For this reason the changes taking place in India resulting from the revolution in wheat production are used as a case study to illustrate and provide considerable background on the many aspects of change now under way in that country.

INDIA — A CASE STUDY IN THE GREEN REVOLUTION AND ITS IMPACT ON THE ECONOMY AND SOCIETY

This is the third year of the green revolution in wheat. Favorable weather and increased acreage sown to high-yielding varieties, were combined to increase total production for a third major advance. Acreage in high-yielding varieties (HYV) rose from 4.4 million hectare in 1968-69 to an estimated 5.6 million in 1969-70, and production from 18.7 million metric tons to an estimated more than 20 million. Figure W2 shows not only the continuing upward trend in acreage under HYV and production, but in average yield per hectare. The total acreage sown to wheat is not considered to have risen appreciably.

The green revolution has stimulated the development of tube wells for irrigation in India; 40,000 of these wells were sunk in 1967-70 in the state of Uttar Pradesh alone. Increased purchasing power has allowed the farmers to purchase a variety of production and consumer goods (Photo: Marc & Evelyne Bernheim — Rapho Guillumette, New York, U.S.A.).

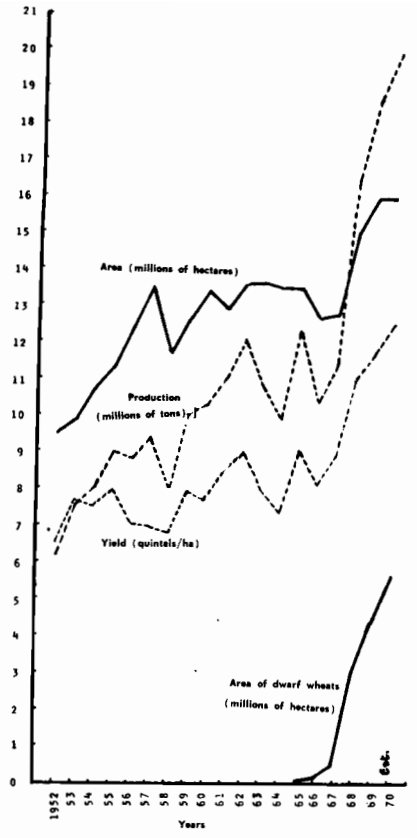


FIGURE W2. Total area, production, and yield of wheat in India, 1952-1970.

Punjab now estimates that two-thirds of its acreage is under dwarfs and production has risen from 4.35 mililon tons in 1968-69 to 5.0 million tons in 1969-79; Haryana estimates one-third under HYV —production 1.75 million tons; Bihar one quarter— production 1.6 million. Although acreage figures are not available for Uttar Pradesh (U.P.), the largest wheat producing state, a 40 percent increase in use of fertilizers reflects in part the increase in HYV. It is now estimated that its production will reach 6.1 million tons as contrasted with last year's 5.9 with little change in the 5.3 million hectares under all wheat. West Bengal which in 1964-65 was considered a non-wheat state growing only 40,000 hectares, now grows more than 200,000 hectares and the chances of expansion to as much as 800,000 hectares in the next five years are considered good..

Heavy rains over much of North India in January-February undoubtedly raised production in rainfed areas. However, in certain areas such as Eastern Uttar Pradesh the temporarily waterlogged conditions following heavy rains caused extensive leaf yellowing on the variety Kalyansona cutting yields to some degree. The early onset of the current monsoon in late May and early June, has caused some losses to unthreshed grain and grain lying unprotected from the weather.

The green revolution continues to stimulate the development of irrigation. During the year, minor irrigation continued its dramatic increase and such major projects as the Kosi and Rajasthan Canals were further extended. It is estimated that 40,000 private tube wells were sunk in U. P. alone in 1969-70. For the country the estimate is more than 70,000 which is considered to add about 1.4 million hectares. About 290,000 pumpsets were energised in this period bringing the total through March to 1.32 million. Although figures are not available other statistics indicate that as many as 500,000 additional units may be operated by diesel engine. This compares with the 0.51 million total at the end of 1966. It can be seen from Table W14 that a continued irrigation expansion is anticipated for the fourth plan.

There is still a large irrigation potential to be exploited. As seen from Table W14 the present level is 36 million has. The potential estimated is 82 million. In other words, less than one-half of the potential has been developed.

Maintenance of Market Prices

The Central and State Governments in India have established a procurement system to provide market stability for the cultivator-producer as well as for the lower income consumers. Under the system they purchase at a guaranteed minimum price, any stocks not sold at a higher level (1969-70 procurement price Rs. 76.00/Quintal). Such stocks are stored and sold to the consumer through a series of "fair-price" shops on a rationed basis. These shops sell six million tons per year comprising at present, two-fifths domestically procured and three-fifths imported

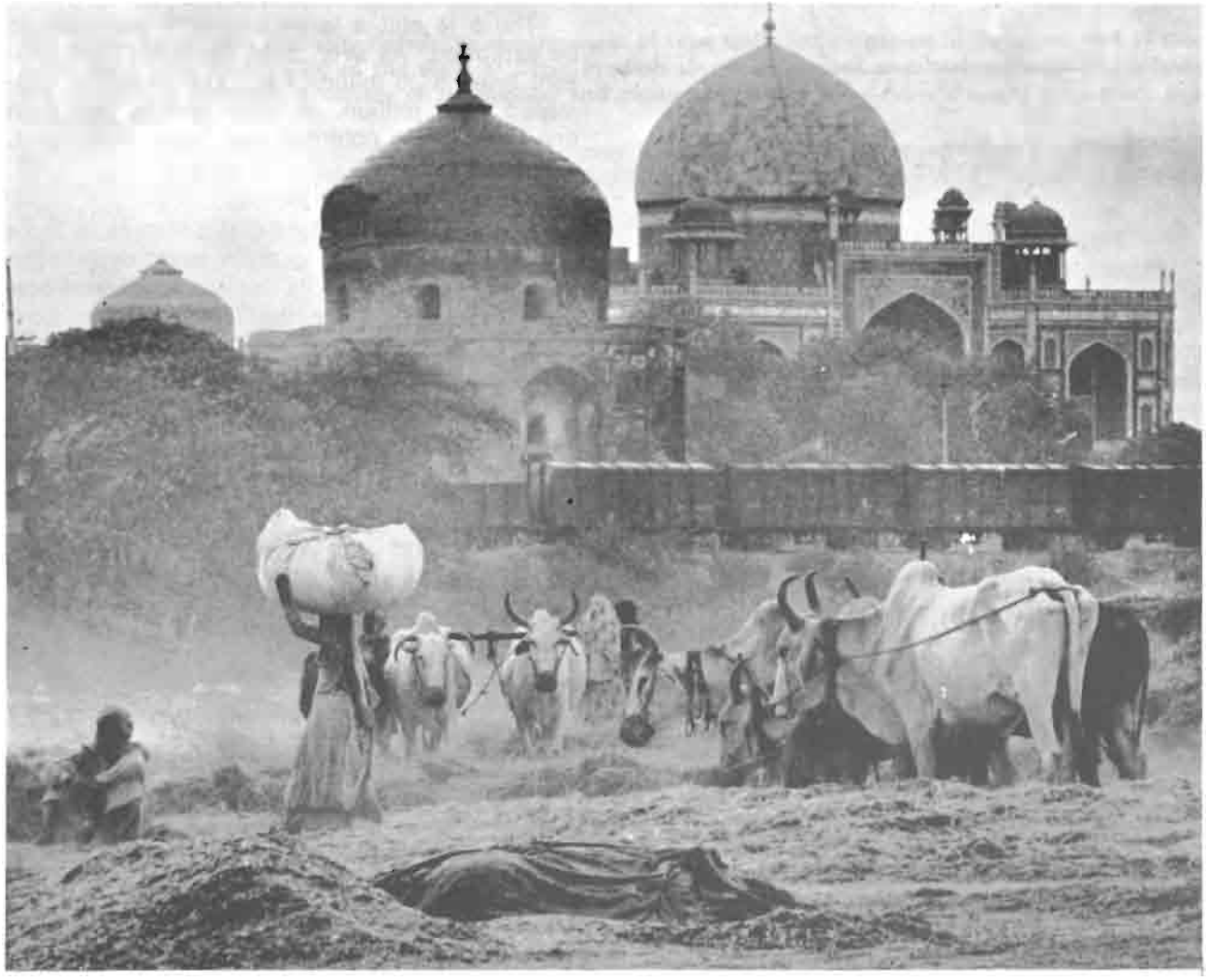
TABLE W14. Irrigation project targets for 1973-74, end of the Fourth Plan Period.

Year	1968-69	1973-74
Major and Medium Projects (millions of hectares)	16.9	20.8
Minor (millions of hectares)	19.0	22.2
Pumpsets energised (000's)	1087.6	2649.0

wheat. In this way imported cheaper wheat subsidizes the more expensive procured wheat. As production advances the need for imported wheat declines. The subsidy effect of imported wheat similarly declines and if the price level is to be maintained in consumer outlets, the extra funds must be supplied out of the treasury. For this reason the Agricultural Prices Commission in their report recommended a gradual reduction in procurement prices. It was argued that in Punjab, for example, farmers with new varieties get 75 percent more yield and only 15-20 percent less money per quintal as compared with older varieties. The Chief Ministers' Conference disagreed and the previous year level of Rs. 76.00/quintal was retained. State and Central agencies procure wheat in all states except Jammu and Kashmir, Maharashtra and Nagaland.

The effect of a stable market price can be seen in Figure 3, which shows prices in Hapur. This is one of the larger markets of Uttar Pradesh. Prices are remarkably stable in May, the month of heavy postharvest arrivals. However, wide annual fluctuations are the rule. The protection for the farmer is working, that

The increased production using the traditional methods, exemplified by this threshing scene in the shadow of Humayan's tomb, New Delhi has created certain second generation problems for the farmer. A train passing in the background carries surplus wheat to markets in other states (Photo: "Statesman", New Delhi).



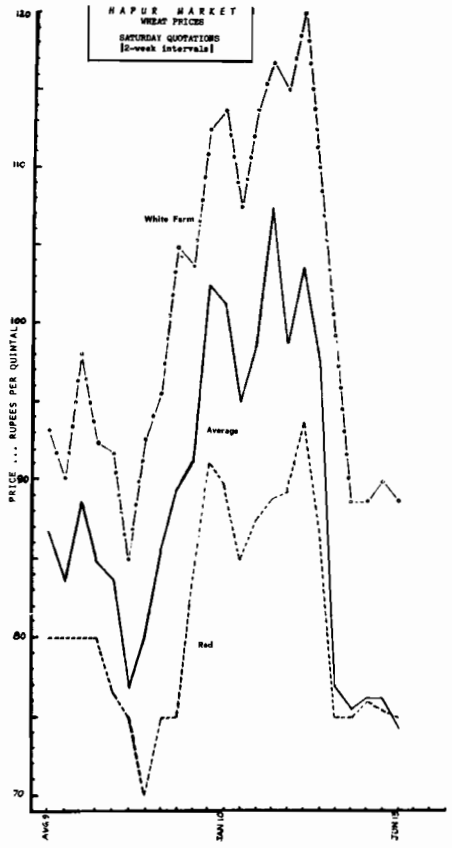


FIGURE W3. Prices for three grades of wheat on the Hapur (Uttar Pradesh) market, quoted for each Saturday from August 9, 1969 to June 13, 1970.

for the consumer is still variable. To reduce these fluctuations the government would require larger buffer stocks for increasing sales in the market as prices rise. It is now considered that stocks of 7 million tons will be required, in the buffer supply.

On the other hand, the increased affluence of farmers from record returns in previous years, now allows them to hold more of the stocks off the market in the post harvest period to take advantage of higher prices later in the season. This has resulted in slow deliveries and some doubt is expressed as to whether the government will be able to procure its 1970 targeted stocks. For the whole country the Central government hopes to buy 4.8 million metric tons of which Punjab would supply 2.4 million and Haryana 350,000. By May only, about 1.0 million of this 2.75 million had been procured.

Farmer held stocks, however, reflect a greater investment in storage and in the long run their market sales at a later date will also tend to regulate the market downward. The low point registered in Figure W3 for late October and early November represents deliveries made prior to storage of the new paddy harvest.

Despite some of the difficulties in implementation, there is no question that the stability created in the selling price to the farmer has stimulated his greater efforts to develop water resource, mobilize credit, increase inputs and become a better farmer. It is the fuel of the Green Revolution.

Food Zones, Storage and Transport

Continuing the trend begun last year, the government removed all restrictions on grain movement. This action has stretched transport facilities still further as grain moves to areas of higher prices. It requires about 43,000 rail cars to move a million tons of grain. By mid-May about 900 cars (20,000 tons) were being despatched each day from Punjab and Haryana. By late May the number passed 1,000. In the period May 1 - May 27, 545,000 tons were shipped by rail from these two states; in 1968 and 1969 the figures were 397,000 and 504,000 respectively. These figures indicate the magnitude of rail movement, however, no figures are available for trucks which form a major adjunct.

In building grain reserves, storage capacity assumes a central role. In 1961 the Cooperative Development Corporation had 800,000 tons of storage capacity; by 1969, 2,600,000. In 1970 the Food Corporation had 2,776,000 tons of capacity under direct control, 2,786,000 on rental and nearly 500,000 under construction. Much of this warehousing is strategically built at the market sites. This is a remarkable increase but the trend must continue to meet demands. Farmer storage is increasing, but its quality is not generally of a high level.

Fertilizers

Without the widespread use of chemical fertilizer there would be no Green Revolution. The use of fertilizers continued the upward trend of previous seasons, particularly its use on wheat. Total nutrient use in 1969-70 varies somewhat according to different estimates. One places the figure at 1,696,000 tons with 952,000 metric tons of it produced domestically. The ratio of N to P_2O_5 is about 2:1. Fertilizer imports are valued at 117.94 crores of rupees (158 million $US). About 64 percent of all fertilizer is marketed through the Cooperative Development Corporation and the remainder sold through private agencies.

TABLE W15. Fertilizer production and consumption for 1968-1969 and targets for 1973-1974 last year of the Fourth Five Year Plan (thousands of tons).

Nutrient	1968-1969		1973-1974	
	Production	Use	Production	Use
N *	541.0	1145.0	2500	3200
P_2O_5	210.0	391.0	900	1400
K_2O	—	160.0	—	900

* Source: Times of India, Mar. 19, 1970.

In Table W15 is shown the fertilizer production and usage figures for 1968-69 and the targetted levels for 1973-74, the last year of the fourth plan.

Targetted figures represent a major investment with goals for production some five times the 1968-69 levels and use up by a factor of three. They must be met if the proposed food production goal of 129.0 million tons is to be achieved.

A new source of phosphate rock, discovered in Rajasthan is now being mined. The total deposit is estimated at 100 million tons. From March 1969, to March of this year 90,000 tons, worth Rs. 760,000 have been shipped. Government hopes to raise production to 2,000 tons daily this year and reach 10,000 daily by 1976. At present values this could be worth over 100 million dollars in foreign exchange savings.

Increases in fertilizer use in India are nothing short of phenomenal. Punjab leads the states with 29.10 kgs per hectare cropped; Kerala, Delhi and Tamil Nady follow closely, with Orissa using the least at 1.57 kgs.' One must be concerned at the continued press reports reputed to have been made by some agricultural leaders that chemical fertilizers are deleterious to the soil. This is patently not so if they are used properly. In certain areas under the higher levels of nitrogen and phosphate applications now being used, certain other minor elements may become limiting but these can be added at little additional cost. Such a case is the shortage of zinc noted more widely now than in the past in the Punjab. Individual fields showing deficiency were identified in previous years but it has become more widespread. Remedial actions must be taken through direct application of zinc or perhaps through regular additions of zinc ion to the fertilizer being produced. Its cost is infinitesimal.

At present prices of fertilizer, one kilogram of N costs about Rs. 2.06. A half kg of P_2O_5 costs Rs. 1.00 or a little less. Together they can produce 20-40 kgs of grain worth Rs. 0.75/kg. It therefore requires about four kilos of grain to buy the necessary fertilizer to produce 20-40 kilos of grain —a 5:1 or 10:1 return. Good business in either case. Fertilizer is one of the fuel inputs providing the thrust to production.

Farm Mechanization

Before the advent of the Green Revolution, unsold tractors accumulated at the factories. Currently farmers wishing to purchase a tractor must sign up and wait for 1½ to 2 years for delivery. Consequently, a flourishing black market has sprung up on tractor sales. The total current member of tractors on farms is estimated to be 100,000. There are five firms producing tractors and production has now reached a level of 16-20,000 units per year. In 1969-70 an additional 35,000 were imported. The industry produced its first tractor in 1961-62 and since then 63,000 tractors have been marketed. Estimates of annual demand vary from 52,000-90,000. Negotiations for manufacturing rights are in progress with eight additional concerns. It is anticipated that production will surpass 20,000 by 1973-74. Most tractors are purchased by the larger landholders. Many are now doing custom work for other small cultivators.

Five years ago most threshing was done by treading with animals. Mechanical threshing is now the general rule in North-West India but the traditional methods prevail in the lower Gangetic Plain. Although the Ludhiasa thresher or similar "bhusa" making types, is the most common machine, 20 combines were put into operation on a hire basis by a governmental agency in Punjab in 1970. Some of the larger seed farms under government or quasi-government control also thresh by combine. Because of the increasing use of grain by roller flour mills, now grinding more than 4 million tons annually, the need for grit free grain produced through mechanical threshing becomes urgent.

The increase in mechanical lifting of water by motor, either electric or diesel, has already been mentioned.

The Effect of Higher Incomes on Consumption

Cultivators who have grown the new wheats successfully have enhanced their income. The increased demand for goods has stimulated not only the direct agro-industries, fertilizers, pumps, machinery, etc., but also expanded the

market for consumer goods. How much money is involved? Taking the 1964-65 record crop as a base year of the pre-dwarf era there was a production of 12.3 million tons. If we assume a 20 million crop in 1969-70, 7.7 million extra tons were produced. If we further assume a Rs. 76.00/quintal price (the most conservative figure), there is a gross money (income) addition to the rural sector of Rs. 438.0 crosses (585.2 million $US) from the 1969-70 crop over that record year.

Possibly a quarter of this is used directly for inputs. The remainder can then be used for other capital and consumer goods. That portion used for such capital items as pumps, tractors, etc., has already been discussed. In some villages, brick houses are replacing rammed earth, new storage structures are being built and greater use of electricity is evident.

On the consumer item schedule, it is stated that in Punjab most houses have a transistor and/or a radio. In 1965 there were 258,000 licensed receivers —in 1968, 600,000. Motor scooters and motorcycles are becoming common, sewing machines and synthetic fabrics are finding their way to the villages. The increased use of transistors in itself can be a great force for good, if used wisely. Educational programs to enlighten the people and extension of information on agricultural and family planning topics presented in the right way, will be a greater force for action than can be achieved by the limited direct contact approach.

In a general review of the economy issued in February 1970, the increased output of certain industries was enumerated for 1968 over the previous year — it can be considered that the trend is accelerating in 1970. Radios had gone up in production by 60 percent; sewing machines, 16 percent; bicycles, 13 percent; motorcycle and scooters, 23 percent; motor vehicles, 13 percent, and drugs and cosmetics, 10 percent. This increased consumption reflects increased prosperity, even though a few undesirable treads have been noted.

Varietal Performance and Breeding Results

India is now entering the third and fourth cycle of dwarf wheat variety development. The varieties originally introduced from Mexico, Lerma Rojo 64 and Sonora 64, have largely been replaced by better varieties developed in India. The second eschelon of varieties which now constitutes the major acreage and trust of the green revolution includes Kalyansona, Sonalika, Safed Lerma, S 331 (Chotti Lerma) were derived by reselecting in India from partially developed but still segregating genetic material introduced from Mexico. The third and fourth cycles of dwarf varieties are now nearly ready for commercial distribution. The third cycle varieties represents Indian varieties developed from introduced F_2 materials and subsequently selected entirely under Indian conditions. The fourth cycle represents varieties that are being developed from crosses made in India, most frequently involving crosses between India and CIMMYT-Mexican parents. The development of the varieties in cycle three and four of the breeding program is discussed in some detail in the following paragraphs.

The amber-seeded varieties have now taken over almost the entire area under dwarfs. Kalyansona is most popular in Punjab and Haryana; Sonalika and Kalyansona in U. P. and West Bengal; Sonalika, Safed Lerma, and Sharbati Sonora in Bihar; Kalyansona in Rajasthan; S 331, Safed Lerma and red-grained Lerma Rojo 64 for reasons of rust resistance in the irrigated areas of the south. There is now plenty of seed of amber-grained types to supply all needs.

There are approximately 450 coordinated yield and agronomic tests conducted across the country. Member institutions are rapidly expanding the breeding, agronomic, and plant pathology research base on wheat, and continuously improving its quality. Two of the larger institutions are processing more than 1,000 new crosses each year. In one the figure of nearly 1,400 crosses has been reached comprising 10 heads in each cross. Some stations sow up to 70 acres of yield tests and segregating materials. The output of genetically superior lines from the station level tests has now reached a point in one zone where two Coordinated Initial Zonal Evaluation Tests of 36 varieties each had to be established to provide for ample testing of the new materials.

Three new Indian dwarf varieties of relatively local adaptation have been released during the past year from the All India program. The first known as Lal Bahadur, a three gene dwarf, derived from a cross of an unnamed Mexican variety with RS-31-1 of Rajasthan, was bred and released in that state. Although it has good adaptability under disease free conditions, its high susceptibility to all three rusts and mildew will limit the possible area of commercial production to the dry and essentially rust free areas of the state of Rajasthan alone. The second variety known as U. P. 301 selected at Uttar Pradesh Agricultural University comes from the cross Lerma Rojo 64 x

Sonora 64. Like the aforementioned new variety, it also is a three-gene dwarf. It has high resistance to stripe and stem rust and adequate resistance to leaf rust. It is resistant to mildew. It will diversify the disease resistance now available in commercial varieties, and therein lies its greatest value. It is best adapted to the North-western Plains but is somewhat inferior to Kalyansona yield in most areas. It has larger grain. A third variety to be known as Kiran was approved for release. Its parentage is Frontana x Kenia 58-Newthatch x [(Norin 10-Brevor 21 x P 14) Kentana 54 B.] —This variety was selected and tested under its introduction number E 4870, by the Bhowali Station. It has a very high degree of resistance to all three species of rust. It is adapted to the high elevation wheat culture of the Himalayas.

In the more advanced material, two new durum varieties, known as HI 6-23 and A-2-30-1 are now in the final stages of testing. These varieties are being developed at Indore M.P. and Arnej in Gujarat and appear promising in some of the dryland areas.

In the past two years a large number of newer 3-gene dwarfs have been under test. In 1968-69 three varieties with wide adaptation were identified in a nationally grown test. These three identified as HD 1941, HD 1944 and HD 1949, developed at the Indian Agricultural Research Institute, yielded more than the principal commercial variety Kalyansona. It was felt that this could have been the result of their early heading and somewhat earlier maturity since early varieties were favored in the weather conditions last year. On the basis of tests conducted at four of the northern stations, however, an average increase of 22.4, 18.6 and 17.7 percent respectively above Kalyansona was obtained in all tests except at one location where heavy yellow rust and mildew attacked HD 1944 and HD 1949. HD 1941 has good resistance to stripe and stem rusts and to mildew. It is moderately susceptible to leaf rust. HD 1944 is resistant to stem rust but susceptible to stripe rust, leaf rust and mildew. HD 1949 is resistant to stem rust and moderately resistant to leaf rust. It is susceptible to stripe rust and mildew. Aside from its weaknesses in disease susceptibility HD 1949 is the most widely adapted of the three. Parentages are HD 1941 —(Yaktana 54 x Norin 10-Brevor) x Sonora 64; HD 1944 -(Yaktana 54 x Norin 10-Brevor) XNP 875, and HD 1949-(Yaktana 54 x Norin 10-Brevor) XNP 852. These or other lines when approved for release will further diversify the disease resistance and will provide additional protection to the commercial crops.

Among the lines which are showing promise at an earlier stage of testing, are several from the CIMMYT-Mexican Bluebird cross 23584 [(Ciano "s") x (Sonora 64-Klein Rendidor) x 8156]. Many other crosses and selections aside from those specifically mentioned have given promising preliminary results.

Agronomic Research

One hundred and five agronomic trials were sown this year. These included 71 under irrigation, 31 on dryland, one on weed control and one on dwarf durums.

The following trials were conducted under irrigated culture:

1. Trials on date and rate of seeding with varieties were conducted at ten centers.
2. A rates of nitrogen test at fourteen.
3. A rates x time and method of nitrogen application at eleven.
4. An optimum time of first irrigation at nine.
5. One on critical stages of irrigation at ten.
6. A rates of P_2O_5 application on ten cultivators' fields.
7. A row spacing by seed rate trial with three gene dwarfs at seven centers.

On "barani" (rainfed) culture the trials included:

1. Rates of N at ten centers.
2. Rates and methods of application of N at eight.
3. Row-spacing x seed rate x varieties at nine.
4. Late sown studies at four.

Two special studies, one on weed control at Powarkheda and one on rates of N on dwarf durums at Rajendianagar, were conducted. Results from these tests have not yet been compiled.

During the past year, based on favorable findings in previous years, officers of the IARI[1] and ICAR[2] with financial support from USAID, supervised an aerial spray application of 20 and 40 percent urea mixed with fungicides and insecticides over 2,000 hectares in south-

[1] I.A.R.I. = Indian Agricultural Research Institute.
[2] I.C.A.R. = Indian Council of Agricultural Research.

ern Rajasthan. At 20% urea concentration yields were increased from a base of 6.8 quintals/ha by 30 percent; at 40% concentration by 45 percent. Further research will be done.

Pathology

None of the three rusts had a significant effect on Indian wheat production during the 1969-70 crop cycle. The present dwarf varieties continued to show adequate resistance in the main wheat area but leaf rust races capable of atacking Lerma Rojo 64 A, Safed Lerma and S 331 appeared in epidemic form in the south in Mysore, causing perhaps some local minor reduction in yield.

Considering stem rust, two years of study have established that the primary inoculum develops in the Nilgiri Hills, southern Mysore and moves northward as temperatures rise. Stem rust inoculum the past season was kept at a low level by a combination of several factors. The three dwarf varieties recommended in the state, viz: Lerma Rojo 64, Safed Lerma, S 331 are resistant to the Kalyansona attacking isolates. Although some local (native) durums were completely destroyed by rust, isolates taken from them were largely a virulent on Kalyansona indicating a lack of competitive ability of the Kalyansona race on the durums. In the central zone, in addition to the very dry climate with its limiting effect on spore production, the varieties Hybrid 65 and NP 839 grown over a wide area are also resistant to these isolates. Finally the cold temperatures in the north usually delay infection until the grain is in the late stages of fill. This was not, however, an exceptional year from the standpoint of the chronological development of stem rust.

In the case of leaf rust, it has been demonstrated that two populations develop: one in the south, and another which attacks the seedling crop in the north. The latter stays in a quiescent state until the warmer weather of late February and early March. The two populations subsequently merge in North Central India where population exchanges can occur.

Stripe rust tends to develop first at certain points along the foothills of the mountains on the north side of the Gangetic Plain. The rust moves out from the northwest to a line drawn approximately east and west through Delhi where it meets the advancing rise in temperature from the south. There is rarely extensive damage beyond the north-western and north-central regions. The present varieties with the exception of Sharbati Sonora are still resistant. This valuable service has been ably organized and guided with the assistance of Dr. Eugene Saari of the Ford Foundation working in close collaboration with the Indian pathologists.

Leaf yellowing in Kalyansona was again sometimes mistakenly thought to be an attack of *Alternaria* in the north. This was an adverse agronomic condition brought on by excessive rain leading to temporaly nitrogen starvation.

Loose smut has been increasing to some degree in Sonalika. Kalyansona is still essentially free in commercial production.

Although karnal bunt has been reported from several areas it remains unimportant. Powdery mildew which formerly caused damage only in the hill regions now appears at stations on the northern edge of the plain. Fortunately, the commercial varieties have good resistance and there is no damage.

In the past season the race surveys for rusts referred to in previous paragraphs were continued and expanded. Twenty-one survey trips were made involving five trainees with two vehicles. In all, 48,000 kilometers were logged. In addition, officers of various Research Institutions, and the Ford and Rockefeller Foundations travelled widely in areas not covered in the regular survey. The results of these surveys and reports submitted from many research centers were compiled and circulated to the research workers in eight fourth-nightly newsletters.

A plant pathology trap nursery, which included all the principal commercial varieties and a few susceptible and other very resistant genotypes, was grown at 45 locations in the country. A comparison of reactions at the different centers provides an excellent opportunity for assessing the appearance of new virulence types.

The spore-trapping experiment conducted in cooperation with The Rust Laboratory of the USDA at St. Paul, Minnesota, was carried at 18 locations. Slides were received at the Indian Agricultural Research Institute, where the spore counts were made.

Over 3,000 samples of rust were collected by the different groups and submitted for identification. Some 900 cultures were established. Virulence on commercial varieties is tested for all culture. Old and new collections are stored in a liquid air refrigerator.

Plant pathologists have introduced a new method of field inoculation using an ultra low volume sprayer to apply spores suspended in oil. This has been very successful and improves the level of infection attained at an early stage.

Various other experiments on diseases have been conducted. A coordinated test designed with the object of assessing rust damage was continued. Seed treatment with Vitavax gave good control of loose smut, flag smut and bunt. Two sprays of Plantvax or Dithane gave good control of leaf rust.

Recently, Dr. L. M. Joshi has been named associate coordinator for wheat pathology. He will be charged with the responsibility of bringing together the various research findings on pathology and utilizing them effectively for increasing the efficiency of the overall development of the All-Indian Coordinated Wheat Improvement Program. The development of the strong plant pathology program in India during the past two years is of great importance to wheat production through the Indian subcontinent and neighboring countries.

Entomology

No serious insect attacks were observed in the 1969-70 season. As in the past, termites continue to be a problem in the dryland areas. These are effectively controlled by the use of such chemicals as Aldrin applied in the soil. Hairy caterpillars moved from mustard to wheat, but control measures developed earlier continued to be effective. The armyworm appears to be on the increase; fortunately, it attacks the wheat plant fairly late in the season. Undoubtedly, even the late removal of all leaves causes some reduction in yields. In breeding plots where the insect has a choice, certain genotypes seem to be more resistant than others. Spider mite, whitefly, grasshoppers, thrips and stem borer appeared in different areas, but losses were negligible.

Storage insects are of much greater importance. The amount lost has not been determined. Losses are greatest in farm-storage. Grain marketed in early spring is often badly damaged. In governmental storage adequate measures for fumigation have been developed and grain normally suffers much less damage

Quality

Nutritional quality is now receiving greater stress than ever before. In the new era of wheat production, the protein level has advanced appreciably through the much greater use of nitrogenous fertilizers. Formerly, the average protein levels were with the native (des.) varieties, 9-11 percent with an occasional 12 percent. Now the levels on high yield dwarf varieties are 12-14 percent with 15 fairly common and occasionally as high as 18-20 percent. Now the next problem is to improve the quality of this protein.

A seminar on wheat quality was held under the auspices of Wheat Associates USA. This covered different aspects of the uses of wheat, the development of the milling and baking industries and the utilization of wheat and its by-products relating to the new high yielding varieties. The session was well attended and reflected the concern with which government and scientists view the problems concerned in the better use of wheat.

Additional quality testing equipment is being gradually provided to different breeding and testing centers. There will be supplied as the need and usefulness arises on a priority basis. It appears necessary to have at least one other major testing center since the volume of work carried out by the center at Delhi is very heavy. The Uttar Pradesh Agricultural University is now building such a center designed to assist in analyzing varieties for quality in depth at an advanced stage of development. Other stations will be eventually provided with equipment which will support the program of selection.

The amount of wheat being processed by the roller flour mills is increasing rapidly. More than four million tons are now processed annually to produce "atta" and flour. As pointed out earlier, bakeries are also expanding. Special varieties with superior baking strength will have to be selected to serve this industry. Other varieties suitable for chapati will continue to occupy the position of greatest production.

Seed Production

The seed industry can now supply all cultivators' needs for amber-seeded released varieties. In the past year, producers had some difficulty in disposing of all stocks. This is the result of an increased saturation of the market. The National Seed Corporation which only recently undertook production of seed wheat (formerly were concerned with other crops only), continued to expand operations. A team of seed specialists from U.S. AID are working with the corporation in their effort to further improve seed quality. The Tarai Development Corporation supported in part by a loan from the World Bank came into being this year. In addition to its function of helping develop the Tarai Region it will have as its main function, seed production. This corporation is head quartered at the U. P. Agricultural University and includes among its shareholders, the University, a large number of Tarai farmers

and other governmental and semi-governmental agencies. It is probably that this organization alone could provide most of the annual seed wheat requirements for the State of Uttar Pradesh. In most of the other states, seed production is centered on State Farms or under University direction. The level of competence is varied. Some produce a good product, others fair to poor. Competence in seed production has grown very rapidly indeed and in the case of some organizations occupies a high place in the confidence of farmers.

Extension

Extension is largely a state concern, whether through the University or the State Department of Agriculture. Its effectiveness is a direct reflection of the degree of aggressiveness of those in charge. Some are very successful, others less so. A number of foreign agencies are also involved. The Ford Foundation through its cooperative program with the Government of India in the Intesive Agricultural District Program has demonstrated the value of supplying a package of inputs on production levels. U.S. AID teams in different states are advancing the new technology. German, Japanese, Swedish and other National teams are working in a more restricted area. AFPRO, an organization of charitable and church groups has been assisting agriculture in a general way. Some idea of the effect of extension on wheat production may be gleaned from such considerations as the very rapid spread of new varieties and technology in Punjab and Haryana, and the increase from 40,000 to 240,000 hectares sown to wheat in West Bengal from 1964 to 1969. These areas are not alone in recording notable advances.

Direct inoculation of rust spores suspended in oil was used for the first time in India in 1969-70 to test rust resistance in new wheats.

PAKISTAN

For the third consecutive year Pakistan is harvesting a record breaking wheat crop. The record production is primarily attributable to two favorably interacting factors, namely, good weather and the further spread of highly yielding dwarf varieties (HYDV) combined with a larger area grown under improved production technology.

The weather during the 1969-70 cycle was mostly favorable for wheat production, although less so than during the 1964-65 or 1967-68 season. Temperatures were normal or slightly below normal during the present season which contributed to a long favorable period for grain filling. This in turn, in contrast to 1968-69, contributed to high yields. There were, however, certain barani (rainfed) areas which suffered severely from a protracted drought which extended from early December until mid-February. More than a half million acres of barani production in Baluchistan and the southern parts of the Frontier Region were lost completely from drought, and a much greater area was damaged. Despite these losses, however, improvements in production in other areas more than compensated to produce a record crop.

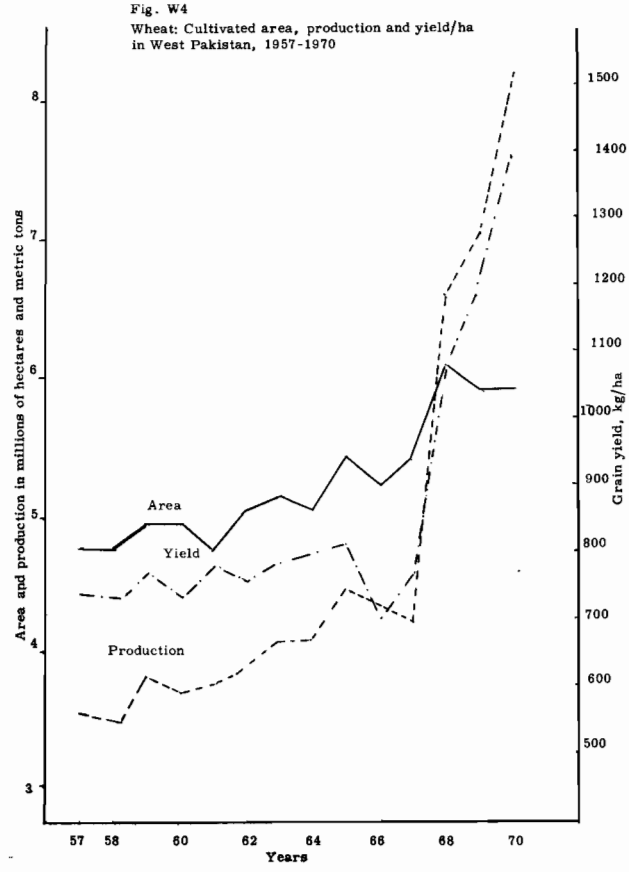
The total area sown to wheat in the fall of 1969 was about the same as it was during each of the past two years. However, the area sown to high yielding dwarf varieties (HYDV) continued to increase. It is estimated that new HYDV covered about 3.30 million hectares in 1969-70 compared to 2.7 million a year earlier. HYDV constituted more than 50% of the total area sown to wheat during 1969-70.

The increased area sown to HYDV, combined with an increased use of fertilized, resulted in a jump in production from 7.2 million metric tons in 1968-69 to an estimated 8.4 million tons harvested in 1970 (Figure W4).

High Yielding Dwarf Varieties Currently in Use

Within the group of HYDV grown commercially a shift in average is taking place. The consumer and/or grain merchants preference for white grain has resulted in the farmer shifting almost exclusively to white grain types. Lerma Rojo 64 and Penjamo 62 have largely disappeared except in a few local areas where grain color does not appear to be considered important. The vast majority of the area has now shifted to the white grained Mexipak 65.

Fig. W4
Wheat: Cultivated area, production and yield/ha in West Pakistan, 1957-1970



The newer white seeded variety Norteño 67 increased rapidly during the last season. The estimated area sown to each of the principal HYDV in West Pakistan during 1969-70 is given in Figure W4.

TABLE W16. Estimated distribution of High Yielding Dwarf Varieties (HYDV) in West Pakistan During 1969-70 Season.

Variety	Number of acres (thousands)	Percent of total acres in HYDV
Mexipak 65	6,500	81.25
Indus 66	1,000	12.50
Norteño 67	350	4.37
Inia 66	100	1.25
Other (Penjamo 62 and Lerma Rojo 64)	50	.63
	8,000	100.00

The Effect of Tube Well Development on Wheat Production

It has been observed that there has been a close correlation between availability of tube well water and high wheat yields. Most of the highest yields are harvested on farms that have supplementary tube well irrigation, which can be used when canal water is short. About 11,000 new tube wells were installed during the 1969-70 fiscal year, bringing the total to more than 85,000. The new wells ensure a supply of water to an additional million acres of wheat. The development of tube well irrigation has been very important in stabilizing wheat production in seasons of drought and when canal water is in short supply.

Fertilizer Use

Assuming that 90 percent of the sales of nitrogen from August to the 15 of February were applied to wheat, it appears that 160, 248 metric tons of nutrients (N and P_2O_5) were used during the last season. This represents an increased consumption of 33,000 metric nutrient tons, or an increase of 26 percent over that of last year. This increase in fertilizer use contributed greatly to the record production. Phosphate fertilizer consumption still lags, although use has increased greatly during the past two years. It is estimated that present consumption ratio of nitrogen to phosphate is 4 to 1 instead of the recommended rate of 2 to 1.

Varietal Performance

In spite of widely spread false rumors concerning the "genetic deterioration" of Mexipak 65 during the 1968-69 season, this variety and its sister Indus 66 continued to be the first choice of most of the progressive wheat growers of West Pakistan. Again, most of the seed sown in 1969 was either held over from the harvest by the farmer themselves or purchased by farmers from farmers.

Mexipak 65 occupied the largest portion of the wheat area. Its yield performance remained consistenly higher than that of all other varieties except its red-grained sister Indus 66. It continued to be resistant to most of the prevalent races of stem rust. Race 42 virulent on Mexipak 65 and Indus 66 appeared late in the season but no losses due to stem rust resulted. Under artificially induced epiphytotics at the Tandojam Agricultural Research Institute, Mexipak 65 was also observed to be highly susceptible to at least one of the common races of *Puccinia recondita.* A few cases were reported in the Sind Region where Mexipak 65 was badly attacked by leaf rust, but the attack came late and caused little or no measurable damage. Mexipak 65 continues to be immune to all the prevalent races of bunt and loose smut in Pakistan.

The Mexican variety Norteño 67 has found its place in Pakistan. Its big white grains are very much liked by the Pakistanis. Norteño 67 has been well accepted by most of the farmers that for various reasons plant wheat late in the season. It is particularly preferred by those farmers who plant wheat after cotton in the middle of December or also by many farmers who prefer to sow wheat after paddy in order to use some of the residual moisture.

The preference by the urban consumer for the hard white big grain of the local (native) varieties has created a price differential of about 10% between Mexipak 65 and the "desi" [1] wheats. Many instances were noticed where Norteño was sold as a "desi" wheat. Some grain traders in small towns were using screens to separate the big grains out of Mexipak 65 and selling them as "desi" grain. The remaining grain was put back for sale, labeled as Mexipak 65. This indicates the arbitrary basis upon which quality is established in the Pakistani market.

Indus 66 and Inia 66 despite their better rust resistance are rapidly loosing ground to Mexipak 65 because of grain color. Red grained wheats such as Indus, and Inia 66, will become popular only after additional wheat mills are constructed for production of flour for urban population. These varieties along with Penjamo 62 remain fairly popular among farmers in the former Swat State area. Penjamo 62 and Inia 66 are at present the varieties most resistant to all the diseases attacking this crop in West Pakistan.

The Govenment is being urged to procure red-grained wheats such as Penjamo 62 and Inia 66 at a preannounced floor price at harvest time, in order to induce the farmers to continue to grow this and other disease resistant red varieties. More diversification of the disease reaction of the Pakistan wheat is now urgently needed since most of the wheat area is rapidly being covered by a single wheat variety, i.e. Mexipak 65.

New Improved Varieties

A large number of advanced uniform lines from the breeding program have been tested for yield performance in various research station trials. The best of them have been included the past 2 years in the extensive net-work of

[1] Indigenous or local.

Micro-Plot Variety Trials (MPVT) located in farmers fields.

For two consecutive years, the line/C272 (Willet x Norin 10-Brevor)/Sonora 64 with the pedigree Pk-146-12a-4a-1a, has significantly outyielded Mexipak 65 both in the research station trials and MPVT. This line has now been named *Chenab 70.* It was included this year (1969-70) in the International Spring Wheat Yield Nursery assembled by CIMMYT. The preliminary data received while this report is being written shows Chenab 70 at the top of the list in yield in Mexico, Saudi Arabia, Lebanon, South Yemen and Pakistan. The average yield of Chenab 70 in 26 semi-commercial trials in West Pakistan was 25% better than Mexipak 65. Sufficient seed of Chenab 70 will be available to sow somewhere between 10,000 to 15,000 acres during the fall of 1971.

Blue Silver (sister line of Sonalika) and Green Valley (sister line of Chotti Lerma) have also shown outstanding yield performance in the MPVT. Khushal and Norteño 67 maintained their good performance compared to Mexipak, especially from late dates of sowing.

Triple Dwarfs — the New Phase of Varietal Development

The most progressive farmers are now clamoring for varieties with shorter straw and greater resistance to lodging than that present in Mexipak 65. Many progressive farmers are now fertilizing at a very high level, 120 to 140 pounds of nitrogen per acre, and irrigating properly. Under these conditions Mexipak 65 sometimes lodges. To overcome this problem the Accelerated Wheat Production and Improved Program has been developing for the past three years a large number of triple dwarf lines. These lines when grown with optimum fertilizer and irrigation reach a height of no more than 70 cms. Some of these triple dwarf lines have been selected to homozygosity and are now available for use in more intensive agronomic studies. Plans are being made for conducting a series of agronomic studies during 1970-71 on the most promising lines so as to determine the optimum seed rates, spacing and levels of fertility for maximum yields.

Among the most promising triple dwarfs are a large number of lines (more than 2,500) selected in Pakistan from the CIMMYT Bluebird Cross 23584 [(Ciano "S" x Sonora 64-Klein Rendidor) x Mexipak]. Among a large number of other triple dwarfs showing outstanding promise are the following lines:

1. (Yt 54_E-GABO x 5840) MEXIPAK 65 Cross PK 2384-2a-0a.

2. (Sonora 64-Tzpp x Y54) MEXIPAK 65 x $Y50_E$ Cross II-26036-1a-100a.

3. (1409-3093 x 5840) QT 254 MEXIPAK 65 Cross PK 2366-12a-0a.

4. (1409-3093 x 5840) Qt 254 MEXIPAK 65 Cross PK 2366-13a-0a.

Changing Emphasis

As production of wheat has risen dramatically over the past three years it now provides an opportunity to strengthen those aspects of research which by necessity because of limitations in staff and budgets, were not given top priority when the effort was being made to achieve a production breakthrough. Among these are the plant pathology and cereal chemistry aspects of wheat improvement.

Improvements in Rust Resistance

Greater protection from rust is being sought through two different approaches. The first is to establish a permanent Summer Breeding Nursery Station in the northern hills. The second is through extensive inoculation studies whereby thousands of lines showing promise in the general breeding program are evaluated for resistance in both the seedling and adult plant stage of development.

During the past two years two young Pakistani scientists who have studied at CIMMYT have been developing skills in rust research. Green house facilities are being developed at the Ayub Agricultural Research Institute to facilitate this work.

Funds have now been made available for establishing a permanent summer nursery station in the northern hills, perhaps in Kaghan Valley. This will greatly enhance the selection of varieties with a broader and deeper spectrum of rust resistance. It will also speed up the rythm of the entire breeding program, permitting the growing of a much larger number of lines in the summer nursery than has been possible in the past.

Cereal Technology

Cereal technology has largely been neglected in the wheat program in the past. Two cereal technology laboratories are now available, and three young Pakistani scientists have received practical training in this discipline while studying at CIMMYT during the past two years. Plans are being made to activate both laboratories during the 1970-71 season.

The Need for Continued Teamwork

One of the principal reasons for the excellent progress in both the research and production programs in West Pakistan during the past five years is attributable to the excellent coordination achieved between the wheat scientists on the staffs of the three agricultural research institutes. The teamwork approach through a province-wide coordinated wheat program was a new experience for Pakistan. It has been outstandingly successful. With the division of West Pakistan into four independent states on June 1, 1970, it becomes even more important to maintain the national teamwork approach in order to assure that the coordinated national program transcends all new state borders. Unless this is done, the wheat research effort will become less efficient, and production will soon stagnate and retrogress.

EAST PAKISTAN

The possibilities of launching a large scale production campaign of the "dwarf" wheats is being seriously considered by the Government of East Pakistan in its global campaigns to solve the food deficit of that Province.

A number of varieties of short duration (early) such as Sonora 64, Norteño 67 and Inia 66 have adapted themselves very successfully to the subtropical lands of East Pakistan, when planted during the "boro" (dry winter) season.

During the harvest of 1969-1970 many farmers in the Kushtia and Dinajpur Districts reported yields superior to 4 tons per hectare. Yields of 3 tons/ha in these Districts were common.

The area planted to wheat in East Pakistan, as a result of the use of these new varieties and improved cultural practices, has more than doubled during the last three years. Consequently, the wheat production has increased greatly.

Efforts will continue to develop early varieties with the disease resistance and quality that are required. It is quite possible that wheat will gradually be substituted for the "boro" rice that inefficiently utilizes the limited irrigation water supply in that season. Preliminary experiments indicate that the water utilized to grow one hectare of "boro" rice can irrigate from 3 to 4 hectares of wheat and produce 3 to 4 times more food grain.

STAFF DEVELOPMENT IN PAKISTAN

For the sixth consecutive year the Accelerated Wheat Improvement Program in Pakistan has maintained an active practical training program at CIMMYT for those young scientists who have shown outstanding characteristics in the fulfillment of their activities.

The number of trainees and officers, and the type of training provided, are shown in Table W17.

During the present change of government administration several of the trained scientists are being considered for key positions in the newly restructured research services of the new provinces.

It has been highly rewarding to observe the continuous and efficient support given to the program by those government officials and scientists that had the opportunity to participate in the training program.

TABLE W17. Trainees sent abroad from Pakistan under the Accelerated Wheat Improvement Program, 1962 through June 1970.

No. of trainees	Place of training	Field of Study	Level of training
28	Mexico	General Wheat Research	CIMMYT-Diploma
16	Mexico and around the world	Observation tour of Agricultural Research Organizations by Government Officials	——
4	U.S.A.	Wheat Breeding	Ph. D.
1	U.S.A.	Soil Science	Ph. D.
1	U.S.A.	Entomology	Ph. D.
1	U.S.A.	Plant Physiology	Ph. D.
1	U.S.A.	Plant Pathology	Ph. D.
1	U.S.A.	Cereal Technology	

TUNISIA

The Project for the Increase of Cereal Production (ACCP) created by the government of Tunisia with technical assistance from U.S. AID, the Ford Foundation and CIMMYT is in its third year of development. The formal research program, however, was not begun until the fall of 1968 when CIMMYT assigned four scientists to the project. During the past two years the Tunisian Project scientists in collaboration with scientists from the aforementioned organizations have been engaged in aggressive "on farm research program" to develop the technology which will make the so-called "Mexican dwarf wheats" highly productive under Tunisian conditions. Moreover, CIMMYT scientists have been actively collaborating with INRAT (Institut National de la Recherche Agronomique Tunisian) in expanding the wheat breeding program.

The outstanding results obtained with Mexican wheats this year (1969-70) on farms where the project recommendations of cultural practices were followed gives great hope that the Green Revolution, which previously has largely been confined to irrigated lands, now will extend across the rainfed areas of Tunisia, as well as much of the other wheat producing areas of North Africa.

Tunisia cultivates approximately one million hectares of wheat. Virtually all of it is dryland winter rainfall production. Yields are very low. The ten year average production is 550,000 metric tons compared to an annual consumption of 800,000 metric tons. Two-thirds of the production is durum wheat, the rest being soft (bread) wheat. Currently the Project (ACCP) is concentrating on the production of soft wheats. However, the breeding aspects of the program are also devoting much effort toward developing new high yielding dwarf durum varieties. Unless high yielding durum varieties are developed rapidly, the high yielding bread (soft) wheats will drive durums out of production.

During the 1968-69 season, a year with rainfall 20 to 60 percent below normal, dwarf Mexican wheats were sown on 12,000 hectares. It was clearly demonstrated that yields of 2,000 to 3,000 kilograms per hectare could be harvested in the 250 to 300 mm rainfall belt when good management practices were used. On the basis of the highly favorable results last year, plans were made to sow 150,000 hectares during the 1969-70 crop season. Two factors adversely intervened to make this target unrealistic. Firstly, early torrential rains caused extensive damage to the transportation infrastructure and, moreover, flooded much of the area programed for wheat. Consequently, fertilizer and seed was not delivered on time and seeding on schedule was impossible on many inundated fields. Secondly, the re-distribution of agricultural lands diverted much of the needed attention away from seed and fertilizer distribution. Despite these difficulties 53,000 hectares were sown to "Mexican dwarfs" during the 1969-70 crop season.

The current harvests on all farms that followed ACCP recommendations is excellent and most gratifying. Grain yields of 2,500 to 4,000 kilograms per hectare were frequently harvested, with an occasional field reaching 5,000 kilos on most areas. In the Governorat of Beja, an overall commercial average yield of 2,300 kg/ha was reported in the south, and 3,400 kg/ha in the north.

The impact of the ACCP on soft (bread) wheat production is already very great. Of the 1969-70 estimated soft wheat harvest, more than half of the estimated crop of 180,000 tons is expected from the 53,000 hectares. Expressed in another way, 19 percent of the area sown to bread (soft) wheat under the ACCP Program will produce more than half of the crop. Moreover it is estimated that of the 53,000 hectares sown to dwarf Mexican wheats during the past cycle, only about 20 percent of the total area had the kind of management technology that can produce high yields consistenly. Therefore, the extension effort side of the Project must now be strengthened and made more dynamic and effective to correct this defect.

The outstanding success of the ACCP during the 1969-70 season now assures that the acreage sown to Mexican dwarfs will increase very rapidly. The main effort of the project must now be to extend the use of the new technology which makes these varieties highly productive. Equally important will be the rapid multiplication and release of newer high yielding dwarf varieties with better disease resistance

of both bread and durum wheats, to provide greater genetic diversity and consequently greater protection from crop losses.

The requirements of inputs such as fertilizer and herbicides will be much greater for the 1970-71 crop. The establishment of a more adequate credit system for the purchase of these inputs is essential, especially for the smaller farmers, if the production targets are to be realized. If these needs are met the Green Revolution will spread rapidly across Tunisia.

The research progress achieved during the past year is briefly summarized in the following subheadings.

Production and Management Research

The season was favorable for wheat production throughout the major wheat producing areas of Tunisia in 1969-70. Very heavy early rain in September and October filled the soil to capacity. November was dry and favorable for seed bed preparation, fertilization and seeding. December was generally wet, but alternate dry and rainy periods were favorable for completion of the seeding. The rainfall was 30 to 80% of normal from mid-January through May. April and May were cool with no prolonged hot weather, which favored good grain development and maturity. As a result, excellent wheat yields were obtained in commercial production fields where recommended seeding dates, fertilizer and weed control were used.

Pests and diseases

However, the weather was also favorable for the development of diseases and insects. Hessian fly damage was severe in many areas on both the early seeded wheat and also in many late seeded fields. Some fields sown to local varieties had infestations exceeding 50% of the plants. Yields were reduced in the heavily infested fields, but an accurate estimate of the damage was impossible because of the absence of any valid uninfested checks. Some damage also occurred from sawfly with infestations of up to 20% and to a lesser degree with stem maggot. Cereal leaf beetle was present throughout the area but never reached epidemic proportions and probably caused no appreciable yield reduction.

Diseases present included stem, leaf and stripe rust, *Septoria* and mildew. Stem rust was severe in the Tunis region, causing complete loss of many early fields of the local commercial durum. The commercial Mexican dwarf bread wheat varieties were resistant to the strains of stem rust prevalent this year in Tunisia. Stripe rust and leaf rust were severe in some regions, but developed late in the season and did not seriously affect yield. *Septoria* develop in the Beja Bou Salem and Matur areas. Some minor yield reduction on susceptible varieties resulted. If the weather had been a little cooler and wetter in February, however, the infection of *Septoria* could have been disastrous on Inia 66 in the high rain areas. Mildew was present in quantity early in many of the drier areas, but it is doubtful if appreciable damage to yield resulted.

Moisture Management

The importance of good soil moisture reserves for wheat production was demonstrated again this year. Yields of 4,800 kg/ha were obtained in the demonstration at Pont Du Fahs this year with less rainfall after seeding than in 1969, when only 400 to 500 kg/ha were produced. The difference can be attributed almost completely to good establishment of wheat in soils with maximum moisture reserve as compared to late emergence in 1969 with no soil moisture reserve. This year the January to April rainfall was 64 mm, compared to 165 last year for the same period. The Tunis, Mornag and Crombalia areas had similar results, with yields up to 45 quintals with 100 to 127 mm of rainfall during the January-April period.

Weed Control

Weed control is the major management problem. Weed pasture during the winter months uses the moisture reserve for the following wheat crop and also perpetuates the weed problem. Most of the weeds are unpalatable and furnish little forage. All of the palatable weeds have been eliminated by centuries of over-grazing. Plowing in December or early January and successive shallow cultivations to kill germinating weeds would preserve the deep subsoil moisture (below 25 cm) for the wheat crop. It would also reduce the weed germination at seeding time and result in less competition to the wheat early in the season.

Effective control of wild oats is a major problem. Over half of the potentially highly productive wheat area is heavily infested with wild oats. Yields are reduced in direct proportion to the percentage of infestation. The application of fertilizer on wheat land badly infested with wild oats is a bad investment. Effective control of wild oats can be obtained and maintained through a combination of shallow tillage and complete elimination of wild oats in row crops grown in rotation with wheat. Until wild oats are controlled only

a portion of the yield potential of the high yielding wheat varieties will be realized.

Less than 25% of the production of Mexican varieties was sprayed with 2, 4-D this season. Yield reduction from broad leafed weeds was severe in many unsprayed fields. Additional harvest costs result from the weeds and fertilizer inputs are inefficiently used. Demonstration of the yield advantage of timely application of 2, 4-D and some of the new pre-emergence and post-emergence sprays like Karmex and Buctril must be part of the continuing research for production management.

Varietal Evaluations

The results of the variety demonstrations are presented in Table W18. These demonstrations consisted of duplicated 5 meter x 50 meter plots, with 2.5 meter x 50 meter plots used where seed supply was limited. Fifteen dryland locations and one irrigated demonstration were planted. The demonstrations included seven standard varieties from Mexico, three varieties from India, two Tunisian bread wheats and two Tunisian durum varieties and eleven advanced selections from the Tunisian and CIMMYT breeding programs. Nine of the new selections were included primarily for

TABLE W18. Summary of variety demonstration yield and disease data from 16 farm demonstrations throughout Northern Tunisia in 1969-1970.

Var. No.	Variety Name or Line Pedigree	Locations	Yield Q/ha[1]	Yield % Inia	Yield % F. Aurore	Septoria[2]	Stem Rust	Stripe Rust	Leaf Rust	Mildew	Source
1	Inia-66	16	42.35	100.0	126.4	8-S	0	T-R	5-MS	9-S	Mexico
2	Florence-Aurore[3]	16	33.47	79.0	100.0	8-S	10-MS	T-R	20-S	2-R	Tunisia
3	Tobari-66	16	41.03	96.8	122.6	5-MR	0	0	0	3-R	Mexico
4	Penjamo-62	16	40.97	96.7	122.4	3-R	0	0	0	3-R	Mexico
5	Red River	15	40.07	92.7	117.7	7-MS	0	0	0	3-R	U.S.A.
6	Siete Cerros	15	38.67	94.7	120.1	9-HS	5-MS	5-MS	20-S	1-R	Mexico
7	Ariana-66	15	39.54	93.6	117.7	7-MS	5-MS	0	T-MS	5-S	Tunisia
8	Sonora-63	8	42.20	89.2	122.8	8-S	T	80-VHS	5-MS	5-S	Mexico
9	Jaral-66	16	35.84	84.6	107.1	3-R	0	0	0	1-R	Mexico
10	Sonalika	11	40.44	100.6	123.4	8-S	0	5-MR	T	7-S	India
11	Safed Lerma	11	41.02	102.1	125.1	8-S	0	5-MS	0	8-S	India
12	Chhoti Lerma	11	43.97	109.4	134.1	8-S	0	80-VHS	0	9-S	India
13	D-5825 (Durum)	16	33.23	78.4	99.3	5-R	20-S	15-HS	45-S	8-S	Tunisia
14	D-56-3A (Durum)	10	27.78	70.6	86.0	9-S	20-S	0	45-S	9-S	Tunisia
15	Mexico 1602 Calidad "s"[4] 22429-16M-1Y-1M-0Y	14	39.98	93.5	119.5	3-R	5-MS	T-MS	0	8-S	Mexico
16	Mexico 1601 Calidad "s" 22429-11M-1Y-1M-0Y	4	41.30	89.9	121.1	3-R	0	0	0	5-S	Mexico
17	Mexico 1603 Calidad "s" 22429-16M-1Y-4M-0Y	4	53.25	97.2	132.4	3-R	0	0	0	5-S	Mexico
18	BT2292 Sonora 64 x Klein Rend. 19975-68Y-1J-1Y-1J-5Y-1T	6	46.63	104.9	133.6	T-R	0	0	0	0	Argentina
19	BT2296 Sonora 64 x Klein Rend. 19975-68Y-1J-6Y-1J-3Y	5	48.70	105.1	135.4	T-R	0	0	0	0	Argentina
20	BT2297 Sonora 64 x Klein Rend. 19975-68Y-1J-4Y-1J-4Y	5	35.60	81.2	104.3	T-R	0	0	0	0	Argentina
21	PMI95 Ciano "s" 19957-18M-2Y-6M-1Y-ZM-1Y	6	45.32	92.7	123.5	5-MR	0	0	0	0	Mexico
22	PMI58 Inia "s" x Napo 63	5	47.86	100.9	120.9	5-MS	0	0	0	3-MR	Mexico
23	PMI8 Mara Backcross Victor I VZ 130	3	52.10	102.4	124.0	0-R	20-HS	40-VHS	20-S	T-R	Italy
24	PMI73 Mara Backcross VZ 133 Mara[3] x Fn x K 58-N	6	42.00	100.6	117.2	0-R	20-HS	40-VHS	20-S	3-MR	Italy
25	Centrifen	2	49.55	97.1	120.1	T-R	0	0	0	3-R	Chile

[1] Q/ha = 100 kilograms/hectare.

[2] Resistance on a scale of 0 to 9 with 0 no visible disease and 9 maximum.
Letter designations indicate reactions: S = Susceptible; R = Resistant; M = Moderate; H = Highly; VH = Very Highly, and T = Trace.

[3] Most important Tunisian soft wheat variety.

[4] "Calidad" — Refers generically to lines from the cross (Tezanos Pintos Precoz x Sonora) x [(Lerma Rojo-Tezanos Pintos Precoz) x Andes dwarf] 22429.

evaluation on *Septoria* resistance. Seed supply was short on many of the new selections, but were seeded in as many locations as possible.

Three of the new selections performed very well. They are being increased and will be named as new varieties for Tunisia in 1971. These are: 1) Tunisian BT 2292, 2) Sonora 64 x Klein Rendidor 19975-68Y-1J-1Y-1J-5Y-1T (ISWYN entry), and a sister selection BT 2296, # Sonora 64 x Klein Rendidor 19975-68Y-1J-6Y-1J-3Y (PM 47Y-65-66), and 3) Calidad "s" — (Tzpp-Son. 64) (LR 64-Tzpp x AN_E) 22429-16M-1Y-4M-0Y (PM-2-Y67-68). These varieties have been equal to or superior to Inia 66 in yield under Tunisian conditions during one to three years of testing. They have the best resistance to *Septoria* of all of the high yielding new selections. Although a trace to light infection of *Septoria* was found on the varieties this year, the resistance appears to be adequate to protect against moderate to heavy *Septoria* infection. They constitute the best resistance now available in high yielding varieties.

Cultural Practice Studies

Management studies were continued on rate and date of seeding, varieties and date of seeding reactions, and soil management. These data indicate that varieties with the maturity date of Inia 66 can be seeded too early. Later maturing varieties like Siete Cerros and Ariana 66 yielded better from early seedings. Inia 66 produced high yields from late November and December seeding. This points out the importance of having a group of varieties with a range of maturity dates for the Tunisian production. In years when moisture is favorable for early seeding, a later maturing variety like Siete Cerros but with good *Septoria* resistance would yield well. In years with later seeding conditions, variety with the maturity date of Inia 66 or even Jaral 66 would be needed.

Inia 66 was the best overall variety, when all dates of seeding, and rainfall areas were considered. Siete Cerros performed well in the early seeded areas of moderate rainfall, but *Septoria* reduced the yield in Bou Salem, Beja and Matur areas. Inia 66 was also heavily infected at these sites, but apparently the attack did not materially reduce the yield. Tobari 66 was moderately infected with *Septoria* and yielded almost as well as Inia 66 in the high rainfall areas. It should be grown in these regions along with Inia 66 to provide some protection against *Septoria*. Penjamo 62, however, has shown less infection than Tobari 66 and should be used in the high rainfall areas until the new selections mentioned above are increased and put into commercial production.

Fertilizer Studies

The necessity for an expanded and accelerated soil fertility and fertilizer use program

Three new selections have been found highly yielding and resistant to Septoria in Tunisia. These will be increased in 1971. Meanwhile, Inia 66, Siete Cerros, Penjamo 62 and Tobari 66 are being planted in different areas, depending on availability of seed, date of planting, and rainfall.

in Tunisia was brought about by the introduction of the high yielding, fertilizer responsive, semi-dwarf Mexican wheat varieties. These varieties were first tested on a large scale in 1967-68 and were found to be very well adapted to Tunisian growing conditions (climate, soil, etc.), especially under medium to high levels of fertility and proper management.

In the fall of 1968, the Accelerated Cereals Production Program (ACPP) initiated a program, of fertilizer experimentation for the 1968-69 crop season. Several experiments were conducted with the major plant nutrients (nitrogen, phosphorous, potassium) in the northern wheat growing area of the country. Most of the work was concentrated in the Governorats of Beja, Kef, Tunis, Bizerte and Jendouba. Resulting wheat yields were relatively low in many regions due to abnormaly low rainfall and inadequate soil moisture reserves. Nitrogen response in those regions receiving less than 300 mm were, in general, insignificant. However, in the more favorable rainfall areas, i.e., 300 mm or more definite positive nitrogen responses were obtained. Encouraged by the results of our research efforts an expanded program of fertilizer experimentation was designed for the 1969-70 crop season.

The main objective of the fertilizer research program is to determine as accurately as possible the optimum rates of the various fertilizer elements (N, P, K) needed for maximum production. Secondary objectives are to learn which of the various forms of fertilizers are the most efficient and economical to use, the best method of placement and the proper time of application. Soil type, preceeding crop, long-time average rainfall patterns, soil moisture reserves, varieties, etc. were some of the variables considered in designing meaningful and practical experiments to meet our objectives.

Five types of fertilizer trials were implemented during the 1969-70 campaign. They include the following:

1. Rate and date of nitrogen application (RDN).
2. Phosphate rates and method of placement with nitrogen (P_2O_5 + nitrogen).
3. Comparison of three different sources of nitrogen (ammonium nitrate, ammonium sulfate and urea) at different rates.
4. Nitrogen, phosphorous and potassium at different rates (NPK).
5. Micro-element study.

A total of 21 experiments were completed at 18 different locations in the aforementioned important wheat producing area of the country. The variety Inia 66 was used for all fertilizer trials. All fertilizer trials were conducted on farmer fields. Whenever possible the production research and variety demonstration activities of the ACCP were conducted at the same site. This expedited implementation of experiments and made the use of limited equipment more efficient.

Heavy rains in October before planting built up soil moisture reserves and set the stage for high yields this season. Subsequent rains in succeeding months, although somewhat less than the 50 year average, were sufficient in most areas for excellent yields.

Most of the fertilizer trials showed a positive nitrogen response this season. The average yield for all trials at all locations was 32.9 qx/ha. This is quite high when one considers the wide range of conditions and locations that these trials were conducted under. A 7.1 qx/ha average yield increase (39.2%) was obtained from the use of nitrogen for all experiments at the recommended rates as compared to the check. The yield increases from nitrogen usage ranged from 0 to 23.4 qx/ha (0-308%) depending on the level of base fertility, preceeding crop and rainfall. In general, the larger nitrogen responses were obtained in the more favorable rainfall regions of the country.

None of the seven phosphate trials showed any significant yield increases. Nor were there differences among rate or method of phosphate placement. Apparently there has been an accumulation of available phosphate due to relatively low grain yields the last few years. Also, many farmers have been applying phosphate annually for a number of years. It appears that farmers should continue this established phosphate fertilization program but must increase nitrogen utilization for maximum production.

A yield increase and cost benefit ratio of 3:1 is normally necessary for farmers to readily adopt a new fertilizer practice. Considering the cost of ammonium nitrate as the source of nitrogen to the farmers in Tunisia, a cost benefit ratio has been calculated for the 21 fertilizer trials given in Table W18 as follows:

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

$$= \frac{7.1 \text{ quintals/hectare} \times 4^{D} 200/\text{quintal}}{10^{D} \quad 343^{a}} = 2.9$$

a) Refers to the cost of 77 kilos/ha of nitrogen in the form of ammonium nitrate on the field in Tunisia.

A cost benefit ratio of 2.9 to 1 is considered exceptionally good for dryland agriculture. These fertilizer results should be used to encourage the Tunisian technicians and farmers to utilize more nitrogen in the future in order to increase their production and income.

Breeding of New Varieties

Results from the first crop year 1968-69 following initiation of the Tunisian Accelerated Cereal Production Project showed the varieties Inia and Tobari to be the best suited for commercial production from the standpoint of yield and general adaptation. Siete Cerros yields well in certain northern regions, however, its high susceptibility to Septoria necessarily limits production to the drier irrigated regions of the south.

Distribution and cultivation of Penjamo and Tobari were encouraged during 1969-70 throughout the higher rainfall zones of the north to provide added protection against the threat of *Septoria*. Jaral has been eliminated from multiplication due to its extreme earliness causing extreme loss from bird damage. Although Inia continues to produce the highest average yields of all commercial varieties being grown, its susceptibility to mildew, *Septoria* and increasing prevalence of leaf rust will warrant replacement with new varieties as soon as possible.

This year there were micro-yield trials, involving 115 bread and durum wheats from the breeding program, distributed and evaluated in several locations in the major wheat growing regions of Tunisia. The outstanding lines in these tests combining good disease resistance and yields equivalent to or better than the best commercial variety Inia are listed in Table W19.. Outstading lines from these trials will be submitted to the production section for inclusion in the widely distributed varietal demonstrations during the coming year.

The breeding gene pool was expanded this year with further introduction of lines and varieties from Mexico, Pakistan, India, U.S.A., Lebanon, Portugal and the Netherlands. The majority of the materials were segregating lines from the first three mentioned countries. Lines from the latter four countries were obtained for testing against specific diseases and insects. Approximately 5,000 lines of bread wheat in Screening and Observation Nurseries were tested at the National Institute of Agriculture adjacent to Tunis and also at Bou Salem Research Station 130 kilometers west of Tunis. The Bou Salem station is a good site for selection of resistance to *Septoria* and stripe rust. Tunis, being located on the sea, normally has good development of mildew as well as stem and leaf rust and thus facilitates selection. Development of diseases within the breeding nurseries are also encouraged with intermittent irrigations throughout the crop season using a sprinkler system. Table W20 lists the crosses within the Screening Nurseries that consistently looked good from the stand-

TABLE W19. The 25 most promising bread wheat lines identified in yield tests conducted in Tunis during the 1969-70 season.

Pedigree	Yield	
	qx/ha	% of Inia
Inia "s" x Napo 63 22403-6M-4Y-1M-1Y-0M-0Y	41.4	135.4
ND102 x P4160$^{3}_{E}$-Son 64 19879-1T-1T-3T	40.2	131.4
(Son 64-Y50$^{5}_{E}$ x Gto) Inia "s" 23528-7M-1T-1M1Y-0M-0Y	38.3	125.2
ND102 x P4160$^{3}_{E}$-Son 64 19879-1T-1K-7T-2T	38.1	124.4
(Son 64-Y50$^{5}_{E}$ x Gto) Inia "s" 23528-7M-1T-1M-6Y-0M-0Y	38.0	123.8
12300 x Bza. 21014-4M-3R-3M-1R	37.8	123.6
(Son 64-TzPP x Y54) (Son 64-Y50$_{E}$ x Gto) 22346-39M-1Y-1R	37.0	120.9
Inia "s" x Napo 63 23398-10M-1R-2M-1Y-1	37.0	120.9
TzPP-Son 64 x 12300 21364-13M-1Y-1M	36.7	119.8
Inia "s" x (Son 64-TzPP x Y54) 22390-20M-9R-2M-2Y	36.7	119.8
Pi "s" (YT54 x N10-B) 21/1C N68	36.1	117.7
Mentana x Thatcher x Reward x Hope-Timstein x Reward x Hope x Thatcher	35.8	117.1
Bb "s" 23584-26Y-2M-1Y-0M-0Y Bb # 2	35.7	116.8
CIANO "s" x Inia 66 23941-14Y-2	35.5	116.1
Bluebird "s" 23584-20M	35.4	115.7
Bluebird "s"23584-37Y-2M-2Y-0M	35.1	114.7
Sonalika	35.0	114.2
CIANO x Inia 23959-32T-1M-3Y-0M	34.9	114.1
Bluebird "s" 23584-303M-1Y-17M-1Y-0M-0Y	34.8	113.6
LR "s" x HuaR HD1675	34.6	113.1
Bluebird "s" 23584-100M-0B-4M-0Y	34.4	112.3
LR 64-P4160$^{3}_{E}$	33.9	110.7
Son 64 x Kl. Rend (BT 2292) 19975-68Y-1J-1Y-1J-5Y-1T	33.6	109.6
Son 64 x Kl. Rend (BT 2296) 19975-68Y-1J-6Y-1J-3Y	33.2	108.4
Inia (Check)	30.6	100.0

TABLE W20. The 17 Most Promising Bread Wheat Crosses Identified on the Basis of Disease Resistance and Agronomic Type in Screening Nurseries at Tunis and Bou Salem, Tunisia 1969-70.

Pedigree	Cross Number
Inia "s" x Napo 63	22398
" " " " "	22402
(Son 64-Y50$^{5}_{E}$ x Gto) Inia "s"	23528
Bluebird # 1	23584-15Y-6M-0Y
" # 2	" -26Y-2M-1Y-0M
" # 3	" -26Y-2M-2Y-0M
" # 4	" -26Y-2M-3Y-1M-0Y
" "s"	" -303M-1Y-17M-1Y-0M
(Kl. Pet-Raf.) 8156 CR^{2}	23957
Ciano "s" x Inia "s" ^{2}	23959
" " " " "	23970
" " " 8156 (B)	25332
(Ciano-Siete Cerros) (Son 64-Y50$_{E}$ x Gto/Tob 66)	25918
Chris x Bluebird	26448
Bluebird "s" x Ciano "s"	26592
Ciano "s" x Siete Cerros	26612

point of disease resistance and favorable agronomic type. In most instances, several sister lines of each cross listed showed promise at both locations.

Durum Wheats

There is an immediate need to develop an improved variety of durum wheat for North Africa. The local demands for hard wheats to prepare couscous, macaroni and spaghetti, coupled with the good market price within and outside Tunisia have encouraged increased acreage of commercial production. A Tunisian cross, D 5825, with good yielding ability is being multiplied for release. It is tall and moderately susceptible to stem rust, however, it will be beneficial in production until dwarf, resistant varieties can be developed. This line, although having susceptibility to the three rusts and mildew, had an average yield of 33 quintal/ha at 16 demonstration locations this year. Its yield was 99.3% of Florence-Aurore and 78.4% of Inia.

Good development of stem rust in the durum breeding nurseries provided optimum conditions for selection. The majority of F_3 segregation populations from Mexico were susceptible, however, a number of individual plants were selected in Tunis with good resistance to prevalent races. Most of the Mexican durum lines in yield trials were also susceptible. Table W21 contains the five most promising advanced Mexican lines combining high yield with resistance to stem rust, stripe rust and *Septoria* at Bou Salem. Since the need for a better durum variety is so great, preliminary multiplication will begin immediately. The line V-015 [CRA$_{E}$-Tc "Stw 63"] x AA "s" cross 27617-18M-6Y-0M is superior to the others in plant type. This line will be multiplied in the Morocco summer nursery and will be increased again in both Tunisia and Morocco during the next crop season.

Diseases as They Relate to Breeding

Tunisia has a wide range of wheat diseases which pose a potential threat to reductions in yield in a given year. The diseases in decreasing order of importance include stem rust, *Septoria*, leaf rust, stripe rust, mildew, *Fusarium*, loose smut and take-all.

This year an epidemic of stem rust developed late in the season on local durum wheats. Several thousands hectares were killed outright and a much larger area suffered reduction in grain yield as well as in grain quality. Had the epidemic developed one or two weeks earlier it would have been disastrous. There was very little stem rust present on the bread wheats, and the Mexican varieties showed good resistance to this disease.

In the past it has been generally believed in Tunisia that stem rust does not pose a serious obstacle to wheat production. With thicker,

TABLE W21. The Most Promising Advanced Generation Durum Lines with Resistance to Stem Rust, Stripe Rust and Septoria in Yield Tests at Bou Salem, Tunisia, 1969-70.

Mexico Variety Number 1969-70	Pedigree	Cross No.
V-012	(Ra-Tc^{1}) Stw 63 x AA "s"	27617-17M-6Y-0M
V-015	" " " 63 " " "	27617-18M-6Y-0M
V-017	(BY$_{E}^{2}$-TAC$_{E}$) D. Buck (TM$_{E}$-TC^{2}) LK	27612-11M-1Y-0M
V-019	BiBal (BY$_{E}^{2}$-TC) x AA "s"	27664-9M-4Y-0M
V-020	" " " " " "	27664-3M-3Y-0M

denser stands resulting from improved production technology, it is almost certain that the hazard from rusts and other diseases will increase. Better disease resistance will be required in the forthcoming new varieties.

During the past season preliminary studies were made on rust (and other diseases) epidemology. Both stem and leaf rust were observed to be multiplying from natural infection by mid-January.

The January daytime temperatures were apparently adequate during the months on January and February for increase both pathogens. Stripe rust from natural infection, for some unexplicable reason, was not observed until early March. The development of both stem and leaf rust was first found in southern Tunisia and at the INRAT station in Tunis. The observed movement of both stem and leaf rust infection and spore movement appeared to be from south to north. Preliminary inoculum apparently comes from spores persisting locally throughout the summer on isolated volunteer wheat plants. These observations are contrary to the former belief that the early infection came from inblown inoculum from Europe.

Severe artificial epidemics of stem, leaf and stripe rusts were developed in the breeding plots of both Tunis and Bou Salem. Artificial inoculation and periodic sprinkling contributed to developing severe epidemics, that were ideal for selecting for resistance to the three rusts. Selection for resistance to mildew was possible at times. *Septoria* develops well in the Beja area where a large number of F_2 populations were grown. In the future this area with cool temperatures combined with a precipitation of 600 mm will be used to select and screen for resistance to *Septoria.*

Insects

The insects which pose problems for Tunisian wheat production are in order of decreasing importance: Hessian fly, sawfly, cereal leaf beetle, wireworm, stem maggot and ants. General infestations of Hessian fly, and cereal leaf beetles, and light attacks of sawfly and stem maggot were observed in all fields.

The Hessian fly was general throughout the wheat area with infestations in commercial fields estimated at between 5 to 50 percent. Cereal leaf beetle was especially heavy in the Bou Salem area, but caused only moderate loss because of the lateness of the infestation. Wireworms caused heavy local loss in isolated local areas where the culture was wheat following wheat. A large black ant in some areas has been observed causing considerable damage. It removes the ripening grain from the head and transports it away. Birds are a serious pest in some areas, and especially on early maturing fields.

MOROCCO

Morocco, once a regular exporter of wheat, must now import wheat in order to feed its people. Annual production prior to 1967-68 averaged 1.2 million metric tons obtained from slightly less than 2.0 million hectares.

Approximately 3/4 of the area is sown to durum wheats and the remainder to bread wheats. During the last three seasons, 1967-70, favorable weather conditions have resulted in higher levels of production. Nevertheless, because of population pressures Morocco must still import approximately 100,000 tons of bread wheat this year.

Recognizing this problem the Moroccan Ministry of Agriculture has given top priority to increasing cereal production. An Agricultural Investment Code which was announced in July 1969 encourages farmers to improve cereal production practices through a program of research, extension credit and subsidies.

The Cereal Improvement Project which is a joint activity of the Moroccan Ministry of Agriculture, U.S. AID, CIMMYT and the Near East Foundation, will be the principal vehicle used to attain the target of a 50% increase in annual production by 1974. Although the last crop season was the third since the project was started, it was only the first year with a full team of scientists available to conduct a complete experimental and demonstration program.

Two CIMMYT technicians, Dr. William Hall and Dr. Aristeo Acosta, who did not arrive until September and November respectively, were nevertheless able to execute nearly all of their planned research program for the

1969-70 season. They, along with Francis Bidinger who is completing his second year, are working with the technicians of the Agronomic Research Division (DPA) to develop high-yielding disease-resistant varieties adapted to North African conditions and to determine the fertilizer and cultural practices required to obtain optimum yields under the rainfed conditions of Morocco.

The project also has four production agronomists stationed in the major cereal production areas who work with the Agricultural Development Division (DMW) of the Ministry of Agriculture in order to introduce the high-yielding varieties together with an associated "package of improved practices" to Moroccan farmers. Three of these agronomists are provided to the project by the Near East Foundation under a contract with U.S. AID/Morocco.

Coordination of project activities is done through a Wheat Committee created in the Ministry of Agriculture for this purpose. The U.S. AID project manager serves on this committee along with representatives from the Research Agricultural Development (Extension) and Planning Divisions of the Ministry of of Agriculture.

In contrast to 1968-69, when disease problems, especially *Septoria,* resulted in disappointing yields from many fields of the Mexican varieties, the results obtained this past season are highly encouraging. The area planted to the Mexican varieties this past year was approximately 10,000 hectares, twice the area seeded in 1968-69. In spite of the relatively low yields obtained the previous year, most farmers recognized the yield potential of these varieties, and were willing to give them a second chance.

Many of these farmers are now reporting yields of 25-40 quintals per hectare where they followed recommended practices. Usually these yields are 50-60% above those obtained with local varieties. Naturally, where recommended practices were not followed the yields obtained were not as satisfactory. The top yields reported from commercial production fields this year have been 45 quintals under rainfed conditions with Tobari 66 near Casablanca, and 52 quintals with Siete Cerros under irrigation near Agadir.

In general, yields from commercial fields have paralleled the results obtained with the demonstrations. Although results are not yet complete the following observations from farm demonstrations seem warranted:

1. When various limiting factors hold yield below thirty quintals/hectare, the advantages of the Mexican varieties tend to disappear. Example: In the plots at Sidi-El-Aidi where, as a result of severe water stress, the top yield was Inia 66 with 17.7 Qx/ha, whereas the local check variety 2,777 yielded 10.3 Qx/ha, only 7 quintals less.

2. When the various limiting factors are removed and yields rise over the 30 Qx/ha then Mexican varieties are really clearly advantageous. Example: The plots at El Gara, where the top yielder was Penjamo with 37.8 Qx/ha contrasted with the check variety 2,777 with a yield of 22.0 Qx/ha though all varieties at this location came through with good yields. The three Mexican varieties all yielded over 33 Qx/ha.

3. It became apparent this year that too little fertilizer is being applied on the demonstration plots. At Mediouna, with an additional 20 kg/ha of nitrogen applied at booting (accompanied by adequate soil-water reserves), yields were pushed up to over 50 Qx/ha on two Mexican varieties (Norteño 67 and Tobari 66). The local varieties were unable to benefit appreciably from this extra application.

4. Fertilizer is obviously not the limiting factor, however, nor in some instances the most important. For example: at Gervais, El Gara, four different varieties yielded more than 35.0 Qx/ha, whereas at Berrechid under similar moisture and the same fertilizer levels these same varieties yielded only 26.0 Qx/ha.

Failure to adequately control weeds combined with poor fertilizer application contributed to the lower yields at Berrechid.

Current expectations are that commercial production of the Mexican varieties will average nearly 20 quintals per hectare this year, contrasted to slightly over 11 quintals in 1968-69 and to a national average for all wheat this year of about 12 quintals per hectare. This increase has largely resulted from better placement of varieties. Siete Cerros was moved to the drier southern areas where *Septoria* is not serious, while Tobari and Penjamo were recommended and used in the wetter northern areas. As previously states, where recommended practices were followed, yields in the range of 25-35 quintals were not uncommon.

These results have already generated sufficient interest among farmers throughout the country, so that it appears likely that there will not be sufficient quantities of certified seed to meet demand for the 1970 plantings. Consequently many farmers are holding back all or part of their production for their own

seed needs for next year and for possible sale to other farmers.

It is extremely difficult to predict the area that will be planted to the Mexican varieties in 1970-71 since this will be in a large part a function of seed availability. However, it is not unreasonable to expect that 45,000 to 50,000 hectares will be seeded to these varieties, although the large areas which will be seeded with uncertified farmer seed will make verification nearly impossible.

The widespread use of the dwarf bread wheat varieties raises the possibility of a serious problem within the next few years. Such a problem may result from the high yielding bread wheat varieties replacing durum varieties and thereby upsetting the long-time balance between these wheat types. Given the enormous demand for durum for production of couscous (the staple dish of the Moroccan diet), it is essential to develop in the near future semi-dwarf durums capable of competing with the high yielding bread wheat varieties. Efforts along this line will receive maximum attention in the breeding programs now underway. Otherwise, Morocco could find itself in five years with a surplus of bread wheat and a shortage of durum wheat, just the opposite of the present situation.

Production Research

It is evident that a high degree of variation in yield from year to year will continue to be a normal situation in wheat production in Morocco. The dryland wheat regions are largely areas of shallow soils, often less than 50 cm in depth, making agriculture susceptible to the highly variable rainfall patterns. In contrast to similar climatic areas such as those of the American Pacific Northwest where research has learned to adapt fertilization and management practice to measurable moisture parameters, Morocco's shallow soils and shorter wheat season make such adaptive practices more difficult.

However, the development of proper management practices combined with better varieties can decrease this variability from year to year while increasing average yields. Two years of varietal demonstration conducted by the wheat project in cooperation with the extension service have shown repeatedly two things: (1) the local varieties have a genetic yield potential of 30 quintals/ha under good management; (2) it is absolutely necessary to push yields above this level to demonstrate the clearcut genetic superiority of the Mexican varieties. Unfortunately many uncontrolable variables in the package of practices recom-

A large demonstration campaign is being carried out with farmers in Morocco involving new wheats and production practices. Dr. H. D. Floyd, USAID, and farmer cooperator supervise harvest of one of these demonstrations in the Casablanca area.

mended have often given poor results in the demonstrations.

Morocco and Tunisia are the first large-scale development projects with the Mexican varieties under dryland conditions. Less of the accumulate experience with these varieties under irrigation is directly transferable here from elsewhere. Yet the increased yielding ability of these varieties on dryland even under very low rainfall conditions is relatively as great as that of the same varieties under irrigation.

Stand density is a major problem adversely affecting the dwarf varieties. Many farmers seed by hand and cover with a disc harrow, and resulting thin stands permit increased weed competition and decrease fertilizer efficiency. The Mexican varieties in the cooler northern regions have not tillered as well as elsewhere. The reasons are not completely understood; possibly inadequate nitrogen nutrition or loss of applied preplant nitrogen, and in some cases long periods of saturated soil conditions.

A date of planting study was initiated during 1969-70 to attempt to verify the observation that the Mexican varieties profit from a later planting date than that recommended for the local varieties. Fertilizer response has been irregular, especially in the higher moisture areas, and calculated coefficients of nitrogen utilization have been low. Phosphate response has not been as evident on farmer's fields as in experiment station trials.

Fertilizer Research

As the amount of field information on fertilizer requirements of the Mexican varieties in Morocco is very limited and the number of climatic, soil and management factors influencing response are large, the soil fertility program used only two basic trials during 1969-70 and distributed them over as wide a geographic area as feasible. One was a nitrogen use study consisting of all combinations of three preplant rates (40, 60 and 80 kg/ha) and three topdressing rates (0, 20 and 40 kg/ha). The second trial consisted of different rates of several phosphorus-potassium formulations.

The treatments in the nitrogen trial were selected to obtain information on several points: (1) the effect of different rates of nitrogen applied at planting on tillering; (2) the response to topdressing on different preplant rates, and (3) the effect of different ways of splitting the higher doses. Local nitrogen fertilization practices stress the importance of topdressing as a means to limit early growth of tall, easily lodged local varieties, and develop large heads, especially on the durum varieties. The important consideration for dwarf varieties, however, is that conditions during the early stage of growth are adequate for tillering, which in turn is necessary to obtain high yields. Fields of these varieties fertilized with 20 kg/ha of nitrogen at planting and topdressed with 20 to 40 kg/ha have tillered poorly. This suggests the need to develop new recommendations adjusted to the specific needs of the dwarf varieties. Higher rates of early nitrogen applications appear to be indicated.

The phosphate-potassium trials consisted of 45 to 90 kg/ha of K_2O, combined with 0, 45 and 90 kg/ha of P_2O_5 plus several heavy rates of P_2O_5. Combinations were chosen to take advantage of phosphorus-potassium formulations available locally. Phosphorus is widely recognized by both farmers and technicians as benefitting Moroccan soils; its use in most areas is more common than that of nitrogen. The need for potassium fertilization has not been clearly established by results obtained in field trials. It has been suggested that both, previous crop and yield level, may influence the need for these two elements.

The experimental results obtained this year showed no significant response to either phosphorus or potassium. The failure to observe a response to phosphorus fertilization was possibly due to the fact that the trials were generally conducted on large farms that had been fertilized with phosphorus for many years.

Phosphate fixation by these soils is presently being investigated by the national research service. Their results indicate that very heavy rates of P_2O_5 are necessary for obtaining maximum yields of crops other than cereals. The effect of phosphorus fertilization on the entire rotation rather than on a single crop is being studied. Results obtained in this work should eventually permit the use of information on previous cropping history to arrive at a more precise phosphate recommendation.

Rainfall distribution played an important role in determining yield response to nitrogen at a number of locations (Table W22). The general precipitation pattern for the country was a very rainy early winter season followed by a dry spring. Locations in the normally wetter parts of the country suffered from an excess of moisture early in the season. The trial at Toulal (Meknes) received 290 mm during the 30 days immediately following planting resulting in satured soil conditions for a period of at least a month. Under these conditions, the

TABLE W22. Effect of different rates and times of application of nitrogenous fertilizer on grain yields of wheat in quintales per hectare.

Applied nitrogen kg/ha		Sidi Kacem	Toulal	Moulay Idriss	Ras Tebouda	Khourigba	Settat			Ben Ahmed
Before planting	Side-dressing						Dry land	Irrigated	Combined data	
0	0	28.3	13.5f*	16.5d	46.0	17.0b	9.9	17.0	13.4c	22.7
40	0	35.6	14.6ef	19.5cd	53.3	21.9a	17.0	33.4	25.0cd	26.3
40	20	33.6	15.7def	21.0c	51.4	22.3a	14.2	32.5	23.3d	26.5
40	40	36.6	18.6abcd	23.6bc	52.1	22.9a	17.5	35.3	26.3cd	27.0
60	0	33.1	15.9def	21.4c	46.7	22.2a	16.0	34.8	25.4cd	25.8
60	20	36.3	17.5cde	22.5bc	52.6		20.2	37.6	28.9abcd	
60	40	38.9	19.6abc	23.1bc	53.9		19.6	45.7	32.6ab	
60	60	38.9	20.5abc	28.9a	50.2		18.6	36.6	27.7bcd	
80	0	37.8	18.2bcd	23.1bc	53.0	21.9a	17.2	36.7	27.0cd	26.8
80	20	35.5	19.3abc	28.5a	53.0		17.1	42.3	29.7abc	
80	40	38.1	21.7a	29.0a	50.7		21.6	46.2	33.9a	
120	0	39.8	21.2ab	26.1ab	50.8	23.4a	22.5	42.6	32.5ab	
Average		36.0	18.0	23.6	51.1	21.7	17.6	36.7	27.1	25.8
Coefficient of variation		13.2%	10.7%	12.9%	7.7%	5.8%			12.8%	13.7%

* Yields followed by unlike letters are significantly different at the 5% level.

wheat did not tiller, and the average yield for the entire trial was 18 Qx/ha. The response to nitrogen in this trial was small but highly significant. Undoubtedly, under more favorable conditions the magnitude of response would have been much larger.

Apparently a similar condition occurred at the experiment station near Moulay Idriss. Here, as at Toulal, the nitrogen was applied six weeks before seeding, with heavy rains occurring in the interim period.

Although a significant response to nitrogen was obtained at both Toulal and Moulay Idriss, the estimated fertilizer use efficiency was only about 20% (it was assumed that with 100% efficiency, 25 kg of nitrogen would have produced an increase in yield of one ton) (Table W23). Also the percent utilization of applied nitrogen tended to increase as the rate of fertilization increased. At Settat, on the other hand, where excess soil moisture was not a problem, the average percent utilization was 69, and it decreased at higher levels of fertilization. These data suggest that the low yields obtained at the two former locations resulted from losses of nitrogen during periods of excess soil moisture, and that these losses were relatively less at higher levels of fertilization.

TABLE W23. Yield increases due to nitrogen fertilization and percent utilization of applied nitrogen in three experiments.

Amount of applied nitrogen kg/ha	Toulal		Moulay Idriss		Settat (irrigated)	
	Increase in yield (qx/ha)	Percent * utilization	Increase in yield (qx/ha)	Percent * utilization	Increase in yield (qx/ha)	Percent * utilization
40	1.1	7	3.0	19	16.4	104
60	2.8	12	4.7	19	15.5	69
80	4.6	14	6.6	21	19.5	61
100	6.0	15	9.3	23	27.0	67
120	7.6	16	11.5	24	21.5	45
Average		13		21		69

* Based on the assumption that at 100% efficiency 25 kilograms of nitrogen would have produced an increase in yield of one ton.

The rainfall from October 1 to December 31 at Toulal and Moulay Idriss was fairly high, but by no means unusual for these two areas. If nitrogen losses from preplant applications did occur under these rainfall conditions, this suggests the need to delay the application of nitrogen until planting time. However, this will represent a problem for farmers with large acreages who will find it difficult to simultaneously fertilize and plant all their wheat during the optimum planting period.

Rainfall conditions in the central and southern areas of Morocco were quite different from those in the north. Adequate soil moisture during the winter months resulted in excellent early growth but lack of spring rains reduced the yield potential significantly. The nitrogen trial near Settat, normally a 350 mm rainfall area, received approximately 350 mm by January 31, but only 65 mm from that date until harvest. The cooperating farmers inadvertently irrigated two replications of the trial. Unirrigated yields averaged 17.6 Qx/ha with little response to rates of nitrogen higher than 40 kg/ha. The irrigated plots yielded an average of 36.7 Qx/ha with plots receiving 100 to 120 kg/ha of nitrogen producing 40 to 45 Qx/ha.

Previous cropping history also influenced nitrogen response very significantly. The trial at Ras Tebouda (Fez), in an area of heavy early rainfall but on a well-drained slope, was planted following a green manure crop and yielding more than 50 Qx/ha without response to nitrogen. A previous crop of sugar beets at Sidi Kacem had a similar, although somewhat smaller, effect on yield and nitrogen response.

Trials in the drier central region showed a similar response to nitrogen fertilization. The two trials seeded in January at Ben Ahmed and Khourigba ran out of moisture before maturity. Nevertheless the latter, planted following wheat, showed a nitrogen response, while the former, after fallow, also produced a higher yield (26 Qx/ha vs. 22 Qx/ha).

Varietal Improvement

It has become clear after two years of experimental work that Morocco offers an unusually favorable set of climatic conditions for the development of high-yielding, disease and insect-resistant varieties of spring wheats. It is an ideal location for expanding both the spectrum and depth of disease resistance of the so-called Mexican type dwarf bread and durum varieties. *Septoria* sp., mildew and all three rusts of wheat occur in Morocco. With the proper modification of the CIMMYT gene pool and a wise choice of nursery sites for identifying lines with a wide range of disease resistance it should be possible to rapidly develop varieties which combine resistance to all of these diseases.

Morocco also offers a unique challenge in breeding for insect resistance. Within the country, Hessian fly *(Phytophagus destructor)* sawfly *(Cephus pugmaeus* and *C. cinctus),* cereal leaf beetle *(Oulema* sp.), and stem maggot *(Meromyza* sp.) occur endemically. Several of these insects, especially the Hessian fly and sawfly reach levels of severe infestation over large areas nearly every year. If a proper selection of nursery sites is made, it should therefore be possible to develop varieties with a combined broad spectrum of resistance to both diseases and insects. Such an accomplishment would not only be valuable to Morocco and to neighboring North African countries, but would also be valuable in many parts of the world.

During the past season for the first time breeding nurseries under the supervision of Dr. Aristeo Acosta were grown at four locations, namely Merchouch, Sidi Kacem, Fez and El Gara. A wide range of genetic material, mostly from CIMMYT, ranging from F_2 to fixed lines and yield tests were included in these nurseries. Despite many difficulties such as the shortage of technical assistance and the late planting of the nurseries, much valuable data was obtained and many potentially valuable selections were made.

Despite the long dry period from mid-January through March, sufficient *Septoria* and leaf rust developed to permit effective selection.

Severe infestations of the Hessian fly, sawfly and to a lesser extent stem maggot, occurred in all nurseries, but conditions for selection at Merchouch were particularly favorable. At this nursery site the percentage of tillers attacked ranged from traces up to 50 percent. Frequently both Hessian fly and sawfly were present in the same tiller. The most promising lines and varieties identified in the Merchouch nursery from both a grain yield and insect-resistance standpoint are indicated in Table W24. It should be pointed out that many lines in this nursery exhibited 40 to 50 percent of insect damage. Sawfly and Hessian fly were both important, but more of the damage at Merchouch was caused by the former. It became apparent in this nursery, where Siete Cerros appeared frequently as a check, that this variety possesses a considerable degree of resistance to sawfly. It was frequently found

TABLE W24. The Highest Yielding Lines in the Experimental Plots at Merchouch, Morocco, 1969-70.

Variety number 1969-70	Variety or Cross	Pedigree	Insect damage % of tillers attacked[1]	Grain yield	
				kg/ha	% of Siete Cerros
*718	Jar 66 x CIANO "S"	25067-32M-2Y-1M-1Y-0M	10	3993	126
800	CIANO x SON. 64-KI. Rend./8156	23584-102Y-4M-1T-4M-1Y-0M	5	3940	125
753	TOB. 66 x CIANO "S"	24908-30M-6Y-1M-2Y-0M	5	3913	124
*706	TOB. 66 x CIANO "S"	24908-26M-2Y-3M-1Y-0M	15	3860	123
*861	TOB. 66 x CIANO "'S"	24908-11M-2T-8M-3T-0M	10	3820	121
630	INIA 66		10	3780	120
1085	Bluebird # 2 (White) = Yecora 70		10	3747	119
*731	TOB. 66 x CIANO "S"	25000-26M-1Y-1M-3Y-0M	5	3707	118
1234	PENJAMO 62		10	3700	117
*1109	23584/CIANO x NAD-Chris	28110-25Y-0M	15	3653	116
*1003	CIANO "S" x INIA "S"	23959-27T-4M-5Y-0M	Tr.	3667	116
649	CIANO-JAR x 23584	25913-20Y-2M-6Y-0M	5	3680	116
700	NO "S" x CIANO "S"	24941-13M-3Y-1M-2Y-1M	15	3633	115
*1223	23584 x CIANO "S"	26572-61Y-3M-0Y	15	3600	114
1237	LR 64-SON. 64 x NAPO/CIANO	28036-63M-0Y	5	3500	111
*737	CIANO "S" x PJ 62	25093-30M-1T-2M-1Y-0M	10	3460	110
*937	23584 x INIA 66	26591-3T-1M-5Y-0M	5	3407	108
*739	CIANO "S"-Crespo	25341-4M-1T-10M-1Y-0M	5	3340	106
645	Bluebird # 2 (Red)		5	3260	103
	*SIETE CERROS		Tr.	3147	100
908	908 (Local Check)		10-15	1963	63

* Good agronomic type.
[1] Combined damage of sawfly and Hessian fly.

standing with only a few fallen tillers, whereas adjacent rows of susceptible lines had 30 to 50 percent of fallen (broken) tillers. The most promising lines and varieties identified in the trial at Merchouch, are shown in Table W24.

Summer Nurseries

Two summer nursery plantings have been made recently. More than 1,500 F_3 and F_4 lines were sown under irrigation at Announceur, at an altitude of 1,400 meters.

A second increase nursery was sown at Almis de Gigou, at an elevation of 1,600 meters. The materials included in this planting are those that showed most promise in either small plots and/or yield tests during the 1969-70 cycle. Morever, since an adequate site for summer nursery plantings is not available in Tunisia, one of the promising dwarf durum lines from the Tunisian and Mexican breeding programs is also being multiplied in this nursery.

AFGHANISTAN

Wheat is the principal agricultural crop of Afghanistan. It is the mainstay of the economy. It covers an acreage of 2.3 million hectares, 1.3 under irrigation and 1.0 on dryland. Before 1966, production was estimated to be about 2.3 million tons with production of 1,300 kg/ha under irrigation and 432 kg/ha on dryland. Consumption exceeded production by 272,000 tons.

In 1964, H.M.G. of Afghanistan entered into an agreement with the United States Agency for International Development as an Accelerated Wheat Improvement and Production Program. A number of experiment stations and sub-stations were developed where variety and agronomic trials are conducted. By 1968, the varieties Kenya-Mentana, Vilofen, Lerma Rojo 64A, Justin, Tascosa, UN 639, Indus 66 and Mexipak 65 were identified and released as superior varieties. Through the use of improved varieties, cultural practices and greater use of fertilizers, average production on irrigated land rose to 2,800 kg/ha. Individual fields reached 5,600 kg/ha.

By the 1968-69 season, the new varieties were grown on 200,000 hectares. Estimates for 1969-70 are somewhat variable. One estimate was 275,000 ha, but judging from the amount of seed distributed the acreage could reach 600,000 hectares.

Dryland wheat is grown in the northern and central parts of the country, irrigated wheat in the river valleys. The largest irrigation scheme is located in the Helmand Valley of the southwest. Currently, another major system is being developed in the Koh Daman Valley, north of Kabul, in collaboration with the Government of the People's Republic of China. When completed, this scheme will provide an assured water supply to this valley,

considered to be potentially one of the richest in the country.

Research stations are located in each of the wheat growing areas. The Darul Amas Station located on the outskirts of Kabul is the National Center. Materials suitable for production at lower elevations are grown at Jalalabad on the Kabul Peshawar road. Other centers extensively test varieties for adaptability to their respective regions.

Dr. Ernie Staker and Dr. Ed Rice of U.S. AID working in conjunction with their Afghan colleagues, have developed an integrated program for testing varieties and development of agronomic techniques respectively. Other Afghan and U.S. AID colleagues deal with production aspects.

In past years a number of young Afghan scientists were trained in Mexico. On their return they brought with them materials for selection at home. These have been further selected and some are now in a national trial. There are similar trials for fall-sown spring type wheats and fall-sown winter type wheats with the latter sown at higher elevations. In the past year, CIMMYT, through Dr. J. A. Rupert in California, supplied some 1,200 wheat lines, derived from intercrosses between spring and winter types. Although they arrived late, a portion of the seed of each line was sown at Jalalabad in January to assess their value at low elevation. Testing at the higher elevation of Darul Amas is envisaged. Other materials under test include the International Spring Wheat Yield Nursery, the Screening Nursery from Mexico and the International Winter Wheat Yield Trial from Nebraska. An interesting group of indigenous Afghan wheats, collected by Dr. Irma Bennett of FAO, was grown at both Darul Amas and Jalalabad.

In the 1969-70 season, rainfall was very low and much of the dryland area suffered accordingly. Estimates indicate that as much as 300,000-400,000 hectares are expected to produce little or no yield. This will mean a low production year. It further points out the need for maximizing production in the irrigated areas. Present facilities must be expanded, adequate fertilizer supplied, agronomic research intensified and the creation of an incentive price to encourage farmers to use inputs. Research competence is growing and the young scientists are dedicated in approach. If they are to succeed they must be fully supported with necessary facilities by government. Initiative must be rewarded by an adequate salary structure, which is completely irrealistic at present. If full attention is directed toward removing all unnecessary hindrances, Afghanistan can be self-sufficient in wheat in the very near future.

IRAN

The Food and Agriculture Organization has been involved in the wheat improvement program in Iran for a number of years. Their activities involve assistance in both technical personnel and equipment. In particular they have assisted in breeding, agronomy, and seed technology. Special short term appointees have also assisted in particular fields. The FAO project is under the direction of Dr. Rogerer who succeeded Dr. Mudra. His staff works closely with their Iranian colleagues.

Wheat is the most important crop in Iran. The acreage under this crop varies between four and five million hectares. In years of above average rainfall the acreage in dryland increases. About 1.3 million hectares are irrigated and the remainder rainfed. Irrigated wheat land occupies river valleys in areas where rainfall is low, particularly in the south and southeast. The rainfed acreage lies in Azerbaijan area of the northwest, the mountain valleys and the Caspian Plain of the northeast. Most rainfed areas receive 300 mm or less annually with occasional areas of 400 mm. In the provinces of Mazasdaran and Gorgan which lie to the south and east of the Caspian, rainfall of 600 mm is fairly common, tapering to lower precipitation in the Turkman Plain of the northeast.

Average consumption and seed requirements of wheat is about 4.5 million tons per *annum* —120 kg per capita. Average production for the last three years has been between four and five million tons. The country is therefore more or less self-sufficient with the shortfall of one year made up by the supplies held over. Officials this year estimate that the production will reach six million tons. Although the average is about one ton/ha, it is possible to get much greater returns. For example on 10,000 ha of seed production, of which 3,000 were grown on dryland, 2.5 tons per hectare on the average were obtained.

In the 1969-70 season, Mexican dwarf varieties and the Russian winter wheat variety Bezostaya are estimated to cover 100,000 hectares. Other improved varieties, introduced at an earlier time, include Akova in the northeast where it occupies nearly all the area not sown

to dwarfs, cover about 20 percent of the wheat areas of central and southern Iran.

The Government has set a base price for wheat at 6,000 reals/ton. Although some of it is purchased at this price, there is insufficient government intervention in the market to stabilize prices. In some areas, organized marketing is in its infancy and prices fall at harvest. Thus in good years prices fall —in poor ones they rise.

Under a recent reorganization of research stations, six have been designated main centers and 16 sub-centers. Crossing is effected at all main centers, but most is now done at Karaj, the National Center near Teheran.

Trials are conducted under the designations of station trials and A, B and C type series. The station trial is nonreplicated with a common check in every fifth plot. The A trials consists of six replicates in a randomized block and are grown in a region. Superior lines enter the B trials, again of six replicates, but in a triple lattice, and form a more advanced zonal trial. Finally, the C trial is conducted on farmers' fields to assess varietal suitability to farm conditions. Since there are six climatic zones in the country, a great diversity of conditions is encountered. At present, tests within a region may carry some different varieties at different centers in the same trial series.

The principal dwarf variety grown in 1969-70 was Penjamo 62. Although this was fairly heavily attacked in the previous year by stripe rust, it yielded well and as a result was sown on a wider acreage in 1969-70. Unfortunately, it was attacked very early in the Caspian area and this combined with a drier than usual year, led to reduced yields. In the 1969-70 plantings H.I.M. Government imported 1,000 tons of Bezostaya to be grown primarily in Azerbaijan in the northwest and 500 tons of Inia to be grown in some of the southern areas and in the Caspian Region. Bezastaya is susceptible to stem rust, but has relatively good resistance to leaf and stripe rust and to mildew. Inia has good resistance to the three rusts, but is susceptible to loose smut and to mildew. Essentially, the Caspian region is Mediterra-

CIMMYT will work closely with Turkey's Cooperative Center of Research and Training. Here, Mrs. Sudetin Demiroz shows experimental materials to visiting scientists from other countries at Adazapari, Turkey.

nean in climate and one could expect similar diseases to occur as those in countries of North Africa and the Near East. Mildew could be a problem in this cool moist condition. In spite of a substantial attack, yields in 1970 are quite good. It should be pointed out that Akova grown in the Caspian area is very susceptible to prevalent races of stem rust. Some fields were completely destroyed —others showed little or no damage.

A number of new varieties are under test. Several of these have been selected from segregating material brought back by scientists visiting or working in the Mexican program. A few of these are now under preliminary multiplication. Most show adequate disease resistance combined with good yield. Several thousand progenies are at various levels of development at Karaj and other stations.

A summer nursery site has been identified and established in a valley near the village of Kelardasht. This is located to the west of the Chalus-Karaj highway perhaps 30-40 miles from the south shore of the Caspian and at 6,500 to 7,000 feet AMSL. A successful nursery was grown in 1968-69 and the present one looks good. This facility should be expanded and placed on a permanent footing, since there are currently no other adequate summer nursery sites in the entire Near East region. The cool temperatures, good soil, availability of irrigation water, long frost-free period and level fields should provide excellent conditions for the experiment crop.

Much progress is being made in research and production, in spite of limited staff and limited facilities. Unusually good dedication is evident among scientists. There is a real need to adopt the "crop-oriented" approach in place of the present "discipline-oriented" approach if greatest returns are to be realized. A greater uniformity of varietal composition in the testing program seems indicated, to provide greater assurance in the selection of varieties. Although Iran is essentially self-sufficient, however, a rapidly increasing population will require increasing amount of wheat in the next 5-10 years. Yields can easily be increased. To accomplish this will require provision of inputs by government, but more important will require the stabilizing of market prices at a remunerative level and the defense of this price in the market. If this stability is not achieved it is unlikely that stability of production will develop. If surpluses are obtained, part of the wheat land can be diverted to production of livestock which are needed to meet growing shortages of protein.

TURKEY

Wheat is the major agricultural crop in Turkey. It is grown on 8.5 million hectares. Of this, 1.5 million hectares is grown in the coastal areas where it is grown either under adequate rainfall or under irrigation. The remaining seven million hectares lies in the transitional zone and the higher Anatolian Plateau. Fall-sown, spring habit wheats are grown along the coast at low elevation-fall-sown, winter habit wheats on the plateau. Bread wheats occupy the greatest acreage. The traditionally grown spring habit variety was Florence-Aurore. The winter habit varieties are mostly of the local "Turkey" type. Among durums, the variety Senatore Capelli, an old italian variety occupies almost the entire acreage. A very significant acreage of *compactum* wheats is still grown in eastern Turkey because of its relatively better cold resistance.

Production is considered to be about ten million tons per year. Most of the wheat is utilized in making leavened bread. A per capita consumption of 200 kilograms or one-fifth of a ton of bread per year, makes Turkey one of, if not, the highest users of bread in the world. Wheat production, therefore, ranks high in the list of priorities. With consumption already well ahead of production, the need for greater output is evident.

In 1967-68, the Government of Turkey imported 22,000 tons of seed from Mexico. In cooperation with technical personnel of the United States Agency for International Development, an accelerated production program was launched in the coastal region. This was an outstanding success and by 1968-69, most of the area was under dwarf wheat. Varieties included Siete Cerros, Tobari 66, Inia 66, Lerma Rojo 64 and Penjamo 62. Siete Cerros, which covered a major acreage, gave good yields, but suffered an attack of stripe rust in certain areas which caused some damage.

In 1969-70, the area along the south coast was sown mainly to Penjamo 62 and Lerma Rojo 64. Penjamo 62 underwent some reduction in yield due to a *Septoria* attack

which removed the leaves during the filling stage. Lerma Rojo 64 was much more severely damaged. In addition to loss of leaves, the neck and head were also attacked. This will result in a marked reduction in yield for this variety. Certain Italian, French and other varieties showed excellent resistance and will be used in hybridization work. In the Sea of Marmora Region of the north, mildew appeared to be quite serious. Varieties were not killed, but suffered some reduction in yield. Leaf rust was present, but of only minor importance. Stripe rust was essentially absent during the year.

Such disease attacks, point up the real need for the production program to be supported by adequate research. Varietal shortcomings can then be identified before heavy losses are encountered in the production field.

In 1969, the Ministry of Agriculture of the Government of Turkey and the Rockefeller Foundation, entered into an agreement for the founding of a Cooperative Center of Research and Training in Wheat Improvement for Turkey and the Neighboring Countries.

After initial delays, the program is to get underway in July under the joint direction of Dr. Ahmet Demirlicakmak for the Government and Dr. B. C. Wright for the Foundation. Staff members of Oregon State University, especially *Dr. Warren Kronsted and Dr. M. Bolton, are associated. The program envisages a coordinated, multi-discipline* approach to the problem of obtaining higher yields. Aspects of spring and winter bread and durum wheat research will be undertaken. It is anticipated that this center will become a major force for change, not only in Turkey but other countries of the region. Its activities will be closely associated with those of CIMMYT and country program with which it is interlinked. The spring-winter hybridization program of Dr. J. A. Rupert, CIMMYT staff member at the University of California, will have particular application on the Anatolian Plateau, and also to the Iranian Plateau.

Turkey has a considerable number of trained, competent research scientists who have wheat materials at different stages of development. Stations near the coast are naturally working with spring type wheats while those in the interior have winter wheat programs. In the latter case a large number of winter varieties are under test or multiplication. The Russian variety Bezostaya, which proved superior in the First International Winter Wheat Trial is being increased on a major scale. Other Russian varieties Mironovskaja, Odeskaja and Harkovskaja and the American varieties Brevor, Gaines, Nugaines, Wanser, Warrior, Gage, Scout, Lancer and the French variety Druchamp are under test and preliminary increase. A considerable number of experimental lines developed at Eskesehir look promising. Research, however, must be reorganized. All disciplines must jointly concern themselves with solving problems, each contributing its own parts of the answer. In the present system disciplines are separated. Under such an arrangement, the body of knowledge concerning a problem are not or cannot be brought together to give a full solution.

In 1969-70, rainfall in Turkey was abnormally low. This was true not only of Turkey, but of a wide belt-extending eastward through Iran, Afghanistan and the Kashmir. Many consider it the worst drought of recent history. As a result, barring late rains, many fields of the Anatolian Plateau can be expected to give little or no yield. The shortage of wheat will lead to greater than normal import needs. There is some danger from the possible expansion of spring wheat dwarfs into the Anatolian Plateau where they are unlikely to be adapted. Encouraged by the results obtained in the coastal area, some farmers in the interior have also sown some acreage to these varieties. The past winter was mild and they *are obtaining good results. This could lead to further expansion. This must be discouraged.* A severe winter can be expected to cause a major failure of stand.

In addition to those factors concerned with varieties, other problems stand in the way of increased production particularly on the Anatolian Plateau. Like many other countries of the Mediterranean Region the limited rainfall makes it necessary to observe a fallow season between successive wheat crops. Unfortunately, the conservation of moisture in this intercrop period is minimal. Once the crop has been harvested, sheep are pastured from July to the following March when the land is plowed. Most of the rainfall occurs in late autumn. As a consequence, fields develop heavy weed growth which uses up most of the moisture which falls and should be otherwise available, if conserved, for the succeeding wheat crop. Even after plowing, the soil surface is left rough so that air spaces can dry out the soil to a depth of many inches. Agronomic experiments have and are being conducted which indicated that sub-surface tillage where a straw mulch is retained on top, conserves moisture very well. Such measures can greatly stabilize yield on dryland. Asso-

ciated with and a direct result of the aforementioned inadequate practices is the heavy weed population in the wheat crop. Weed control on most farms is inadequate. Thirdly, insufficient or no fertilizer is used on most fields. A judicious use of nitrogen and phosphorous to promote early vigorous growth can greatly increase yields even at low moisture levels. In some areas, research must find the ways to make it possible to "grow" the nitrogen by adopting effective sheep-grain rotations similar to those in Australia. This should be investigated. It would mean, however, that the farmer would have to go into a mixed farming operation.

Turkey can readily become self-sufficient in wheat and in the process release some of the land for other purposes. The Government must take determined action to ensure availability of fertilizer and agricultural chemicals for the control of weeds and insects. Seed production seems well advanced. Top priority must be given to research in order to determine how to best raise yields and minimize crop losses.

ARGENTINA

For several years, the wheat program in Argentina carried out by INTA, has had the collaboration of the Ford Foundation and CIMMYT.

During 1969, a large number of lines from the cooperative breeding program were evaluated in yield trials at Marcos Juárez, Pergamino, Paraná, Balcarce and Bordenave. For the third consecutive year a number of sister lines from three crosses, namely (Sonora x Tezanos Pintos Precoz-Náinari 60) cross II 18889;* Sonora 64 x Klein Rendidor cross II 19975, and Sonora 64 x Knott 2** cross II 18892 were among the most outstanding materials. Several of the most promising of these lines are now being considered for commercial release in Argentina.

Two lines that are very promising in Argentina, namely, Sonora x Klein Rendidor selections II 19975-68Y-1Y-5Y-1T, and II 19975-68Y-1J-6Y-1J-8Y which were developed by selection in alternate generations in Argentina and Mexico, were also top yielders in Tunisia during 1969-70. Both of the lines are also resistant to *Septoria tritici* and mildew under Tunisian conditions. The former of these two lines was included in the Fifth International Spring Wheat Yield Test last year and ranked fifth in overall yield in different parts of the world, indicating boht broad adaptation and yield stability. Both of these lines are now being multiplied for commercial release by the Tunisian program.

It has become apparent during the past year that the selection pressures for resistance to rusts, *Septoria* and mildew in Argentina, and Tunisia and Morocco are similar. Data and materials developed in one of these widely separated areas is likely to be of value in the other and vice versa.

Septoria Resistance

During the past year a moderately severe epidemic of *Septoria tritici* developed in the nursery plots of Balcarce, in southern Argentina, and considerable number of lines with a high degree of resistance to *Septoria* were identified. Among the most promising newer lines were:

1. "PATO" - (Tezanos Pinto Precoz-Sonora 64) x Nariño Cross II-21974-4R-4M-2R-0Y (6 sister selections).

2. "PATO"/Sonora 64 — Purdue x Ciano-Inia Cross II-28268-3B-300b (18 sister lines).

3. CIANO 67-Penjamo 62 Cross II-24287-8B-1J-1B-0b-(300-308b).

4. Penjamo 62-Purdue/Sonora x Selkirk$_E$ Andes Cross II-24263-2B-23J-1B-0b-(300-311b).

Green Bug Resistance

A severe infestation of greenbug (*Schizaphis* sp.) developed for the second time within the past three years across a vast portion of the wheat producing area of Argentina. Although no accurate figures are available on the losses caused by this pest, it probably reduced the harvest by a million tons.

The nursery plots at Pergamino were very severely infested and provided an excellent opportunity to evaluate the breeding materials for resistance. Several thousand lines were under test. All of the material was severely attacked and damaged except for 18 sister lines all from one cross. The leaves of the lines from the cross Cheg-Gaboto x Jaral "s"/ Klein Rendidor x Sonora 64 cross II-M-1023-6P-2B-9P-2B-1P (and 18 sister selections) all remained green and functional until maturity, whereas the leaves of all other lines in the nursery were killed before the grain reached

* Sister to the Mexican variety Jaral 66.

** Knott 2 = is a line developed from a double converging Thatcher backcross developed by Dr. D. Knott of the University of Saskatchewan.

the milk stage of development. It is not known whether the 18 so called "resistant lines" were unpalatable to the aphid, or resistant to the toxic effect of the feeding greenbugs.

Both, the new sources of resistance to *Septoria* and the lines apparently carrying resistance to greenbug have alredy been incorporated into the CIMMYT gene pool through a series of new crosses made in CIANO in April of 1970.

CHILE

The Chilean wheat breeding program is collaborating with Dr. J. R. Rupert of CIMMYT in attempting to develop superior wheats of intermediate growth habit. This is being sought by intercrossing the Chilean winter wheats and the Mexican and Chilean spring wheats. Some lines and varieties of direct chilean origin such as Kenya x Mentana, and Vilofen are currently being grown commercially in Afghanistan.

BRAZIL

Wheat production in Brazil declined steadily from 1960-1968. Imports of wheat on the other hand had steadily climbed during the same period resulting in a heavy drain on foreign exchange.

About two years ago the government of Brazil decided to take action and attempt to increase wheat production. As a result, an Accelerated Wheat Improvement Program (Programa Acelerado de Melhoramento do Trigo) was launched. This program is jointly supported by the Ministry of Agriculture, the Confederation of Wheat Cooperatives and Massey-Ferguson Implement Company. Part of the wheat program financial support is also obtained through a UNDP grant and technical assistance is also provided by FAO.

During the past year CIMMYT has been assisting the Brazilian program in to ways.

1. It has supplied many thousands of wheat lines for evaluation and reselection under Brazilian conditions. These materials include early generation segregating materials F_2, F_3 and F_4 as well as advanced lines, screening nurseries, and CIMMYT Elite Line Preliminary Yield Tests.

2. Within the past year five young Brazilian scientists have studied in Mexico under the CIMMYT training program. Three have already returned and are now actively assisting in the Accelerated Improvement Program.

In the past Brazilian wheat production has been limited by low yields caused primarily by infertile soils and losses from diseases. Within the past five years a considerable amount of research has been done which has given data on how to cope with the soils problems. The new breeding program is vigorously attacking the disease problem. Varieties are needed with resistance to the three rusts, to scab (*Giberella* sp.) and to *Septoria tritici* and *S. nodorum.* Lines and varieties developed with resistance to these diseases under Brazilian conditions may also be valuable in North Africa and the Middle East countries. CIMMYT is very pleased to have an opportunity to collaborate indirectly with the Brazilian wheat program for it will add still another valuable link to the effort to improve wheat as a crop throughout the world.

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PRODUCTION RESEARCH AND PRACTICES

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INTRODUCTION

The CIMMYT Production Program was organized in early 1970 to supplement activities of the Maize and Wheat Programs. Its staff consists of a small nucleus of scientists involved in production research within the former CIMMYT Soils and Plant Nutrition Program and the Puebla Project.

This group works closely with current programs to accelerate production research and stimulate use of improved production practices. Activities are centered in three distinct, but closely related, areas: (1) research in Mexico on production practices and methodology, (2) development of cooperative programs in various countries to complement and reinforce projects presently underway, and (3) selection and training of production research specialists to work in cooperative national programs.

Additions to the staff are planned for late 1970 and in 1971.

PROMOTION OF ACCELERATED MAIZE PRODUCTION PROGRAMS

The UNDP and CIMMYT signed an agreement in March, 1970 to promote the joint development and use of high yielding, high lysine corn in Latin America. Subsistence farmers in Mexico, Central America, and the Andean Region of South America are the primary clientele.

Experience gained in the Puebla Project should prove useful in this work. Since 1967, this project has field tested and refined a model to speed up the adoption of new corn varieties and production practices among small farmers. This model, which combines applied research, extension and coordination of infra-structural activities, offers a useful framework for programs now being organized in other countries.

CIMMYT's participation in these programs includes: assistance in the identification of a project area; selection and training of a team of (approx.) five agronomists; purchase of some vehicles for direct use in the project, and technical assistance to the project team during the initial stages of operation. Cooperating countries are expected to cover the operational costs of salaries, vehicle operation and repair, supplies and equipment.

Cooperative maize production programs have entered initial stages in three countries. A project area has been identified in Ecuador; and Colombia and Peru will select project sites during 1970. Colombia's team of agronomists was selected and sent to Mexico for training in July. A team from Peru is expected in Mexico for training by the end of 1970 and a team from Ecuador is due in 1971.

In most cases, the training in Mexico will consist of a degree program at the Graduate College at Chapingo, plus direct participation in the field activities of the Puebla Project. This will generally require two years; hence it is expected that applied research activities in the cooperative program will be initiated in 1971 through use of personnel and facilities of the country research institutes.

Much of the world's food production is produced on small holdings by families who manage to provide enough for themselves and their farm animals, with little or no surplus to sell. The Puebla Project is aimed directly at bringing the benefits of modern production technology to these families, with an integrated program of improved practices, applied research and close work with agricultural agencies, political leaders, and agronomic input suppliers. A varietal demonstration is shown below, providing the farmers with first-hand knowledge of the new technology.

CORN AND WHEAT PRODUCTION RESEARCH IN ARGENTINA

The National Institute of Agricultural Technology of Argentina (INTA), the Ford Foundation, and CIMMYT continued their cooperative program to accelerate corn and wheat production in Argentina. A field study of wheat production was carried out in 1969 at locations distributed throughout most of the wheat region, from La Banda and Reconquista in the north, to Balcarce and Bordenave in the south. Experiments to measure the response of wheat to several rates of nitrogen and phosphorus were conducted at 32 locations. The yielding abilities of six wheat varieties were compared at three levels of fertilization at eight sites.

Fertilizer rate studies were conducted on farmers' fields under natural rainfall conditions, except for one irrigated trial at La Banda. Recommended varieties and rates of seeding (usually 90 kg/ha) were employed. Weeds were controlled chemically in about 40 percent of the experiments and insecticides were used to combat the green aphid at 25 percent of the sites. Information was obtained at most locations on soil moisture conditions, rainfall, soil characteristics, previous cropping history, management practices, and the effects of insects, diseases, birds, rodents, etc.

Data are available on the results obtained in 27 of the rate studies. Moderate to severe drought damage was observed at 14 locations. Damage due to green aphids, weeds, frost, or hail was reported in one or more of the trials. Three experiments were lost due to a combination of severe drought and green aphid damage.

The yield of unfertilized wheat in the 24 harvested experiments ranged from 0.6 to 2.9 ton/ha with an average of 1.8 ton/ha. There was a response to fertilization in 16 of the experiments, with 12 experiments showing response to nitrogen and 14 showing response to phosphorus. Increases in yield due to fertilization varied from 0.2 to 1.4 ton/ha with an average of 0.7 ton/ha.

All of the variety-fertilizer studies were conducted at experiment stations (two experiments received one or more irrigations). Yields ranged from 1.5 to 4.3 ton/ha. A response to fertilization was observed at four locations. Experimental wheat varieties showed greater yields than commercial varieties in 6 of the trials.

The corn production research program coordinated by the staff at the Pergamino Experiment Station in 1969-70 was considerably broader in scope than that of the previous year. Most of the experiments were located near the Pergamino Station, but other trials were conducted at experiment stations in areas of Argentina where corn production is important, or potentially so.

Four types of experiments were conducted:

Type I was a fertilizer rate study with eight combinations of four levels of nitrogen and two of phosphorus, plus two additional treatments to measure the effect of a "pop-up" fertilizer application (in contact with the seed).

Type II consisted of three varieties, four fertilizer treatments, and three population densities.

Type III compared deep chiseling of soil versus no chiseling, at 4 levels of fertilization.

Type IV consisted of 12 treatments in which herbicides and cultivations were compared separately and in combinations.

The number of experiments of types I, II, III and IV were 14, 12, 8, and 6, respectively.

Grain yields, without fertilization, in the 14 fertilizer rate studies varied from 0.85 to 6.41 ton/ha with an average of 3.95 ton/ha. There was a positive response to nitrogen at nine of the locations. The increases in yield from the application of 50 kg of nitrogen per hectare in the nine experiments varied from 0.20 to 2.35 ton/ha, with increases of more than one ton per hectare at four sites. Within the 14 experiments, the average increase in yield from the application of 50 kg of nitrogen per hectare was 0.62 ton/ha. At one location with a heavy weed infestation, yields were reduced by the application of nitrogen.

The addition of 50 kg of P_2O_5 per hectare as started fertilizer increased yields by 0.45 and 0.66 ton/ha at two locations. At these locations, a "pop-up" application of 10 kg of nitrogen plus 25 kg of P_2O_5 per hectare was as effective as the starter application of 50 kg/ha of P_2O_5. At the 12 sites not responding to phosphorus, the "pop-up" application had about the same effect as 10 kg/ha of

nitrogen applied in the usual manner. With the best fertilizer treatment, the yields at the 14 sites ranged from 1.44 to 8.44 ton/ha, with an average of 5.13 ton/ha. Rainfall during 1969-70 was quite adequate, with only one location reporting severe damage due to drought.

Although the analyses of the data obtained in the other three types of experiments have not been completed, a few observations may be made. Maximum grain yields obtained in variety-fertilizer-density studies under irrigation at Corrientes and Ascasubi were 9.42 and 11.00 ton/ha, respectively. Deep chiseling apparently had no effect on yields at any level of fertilization. The best weed control treatment was a combination of herbicides and cultivations.

PRODUCTION RESEARCH IN MEXICO

Production factors influencing the yield and nutrient uptake by different varieties of wheat and triticale are being studied at the Northwest Agricultural Research Center near Cd. Obregon. These studies are cooperative ventures of the Graduate College at Chapingo; the Mexican National Agricultural Research Institute; Dr. S. K. Ries, Michigan State University; and Drs. Lewis H. Stolzy and S. D. Van Gundy of the University of California at Riverside. The fertilization of maize on Andosols in Western Mexico is also under study.

Influence of Nitrogen Fertilization on Wheat

The influence of nitrogen fertilization on wheat development and nutrient uptake was investigated in a 1968-69 experiment involving 9 levels of applied nitrogen (0 to 400 kg/ha) and two varieties, INIA and CIANO. Grain yields of INIA were increased in a logarithmic manner from 0.9 ton/ha, without applied nitrogen, to a maximum of 5.5 ton/ha with the addition of 250 kg of nitrogen per hectare. The response of CIANO to fertilization was similar, except maximum yield which was only 4.5 ton/ha. The straw-to-grain ratio of CIANO was 1.43, without nitrogen fertilization, increasing to a maximum of 2.05 at the 150 kg/ha rate of fertilization. The straw-to-grain ratio of INIA varied only from 1.64 to 1.87, as the rate of fertilization increased from 0 to 400 kg/ha.

Other findings:

Average volume weight of grain of the two varieties increased from 83.1 kg/hl without applied nitrogen, to a maximum of 84.7 kg/hl with 100 kg/ha of nitrogen. These weights then gradually declined to a minimum of 82.4 kg/hl at the 350 kg/ha rate.

Average grain size increased from 39 mgm, without applied nitrogen, to a maximum of 46 mgm with the application of 100 or 150 kg/ha of nitrogen. Grain size then decreased to 43 mgm at the 350 kg/ha rate.

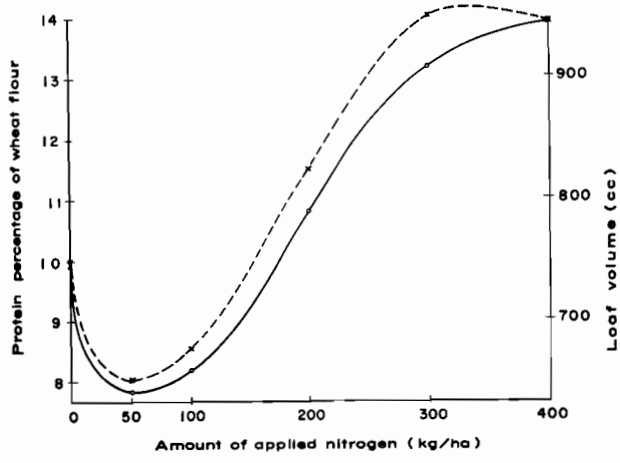
The number of spikelets per head increased rapidly from 8.3 without applied nitrogen, to 13.1 with the 50 kg/ha rate; then climbed very slowly to a maximum of 14.3 with the addition of 250 kg of nitrogen per hectare.

The number of heads per square meter increased logarithmically from 170, without applied nitrogen, to a maximum of 470 at the 400 kg/ha rate.

Plant height at maturity was increased from 67 cm, without applied nitrogen, to a maximum of 113 cm with 200 kg/ha of nitrogen.

The effect of nitrogen fertilization on the baking quality of grain from INIA and CIANO was very similar. The average relationships between two parameters of quality —protein content of the flour and loaf volume— and rate of nitrogen fertilization are shown in Fig. 1.

Fig. 1. The relationships between two baking quality parameters: protein percentage of the wheat-flour and loaf volume and the rate of nitrogen fertilization. Values are averages for the Inia and Ciano varieties.



As it is generally found when the initial level of available nitrogen is low, the addition of a small amount of nitrogen reduced both the protein content of the flour and the loaf volume. These two parameters, after reaching a minimum with the application of about 50 kg of nitrogen per hectare, increased with higher rates of fertilization in a nearly linear fashion up to the 300 kg/ha rate. Above this level of fertilization the protein percentage continued to increase while the loaf volume remained unchanged.

Sedimentation volume of the flour from the two varieties was affected similarly by nitrogen fertilization. The first increment of nitrogen fertilization reduced the sedimentation volume from 43 to 33 cc; higher rates gradually increased the sedimentation volume to a maximum of 63 cc with the application of 400 kg of nitrogen per hectare. The effect of nitrogen fertilization on the general strength index of the flour was very similar to the effect on protein percentage.

Plant samples were taken from each experimental plot at 36, 67, 95 and 126 days after planting. The second sampling was made at heading and the last at physiological maturity. Except at the first sampling, the plants were divided into leaf, stem and spike tissue. The samples were washed, dried, ground and analyzed for total nitrogen, phosphorus, and potassium.

The effect of nitrogen fertilization on the nitrogen percentage in the wheat stems at 67, 95 and 126 days after planting is shown in Fig. 2. At the two earlier sampling dates, the application of 100 kg of nitrogen per hectare clearly reduced the nitrogen percentage in the stems. Higher rates of nitrogen fertilization produced a logarithmic type increase in the nitrogen percentage. At 67 days after planting, the nitrogen percentage in the stem was increased from 1.13 to 2.25 by the application of 400 kg of nitrogen per hectare.

The effect of nitrogen fertilization on the nitrogen percentage in the wheat leaves and spikes was similar to the effect on the stems. A reduction in the nitrogen percentage with the application of 100 kg of nitrogen per hectare was noted in the leaf at 95 and 126 days, and in the grain at 126 days. Logarithmic or linear increases in the nitrogen percentage of both leaves and spikes were observed at higher rates of nitrogen fertilization at all sam-

Plant analyses of the wheat samples are carried out in the soil fertility laboratory of the Graduate College at Chapingo. Total nitrogen is determined by the micro-Kjeldahl method, which is shown here at distillation stage.

pling dates. Nitrogen fertilization increased the nitrogen percentage in the leaf from 2.59 percent to 4.24 percent at 67 days; from 1.91 percent to 3.76 percent at 95 days; and from 0.69 percent to 1.49 percent at 126 days.

The phosphorus percentage in wheat tissue was decreased by nitrogen fertilization at all sampling dates, except for the spike at 67 days. The major reduction in the phosphorus percentage occurred with the application of 100 kg of nitrogen per hectare. The 200 kg/ha rate reduced the phosphorus percentage in the stem from 0.30 percent to 0.20 percent at 67 days, from 0.20 percent to 0.08 percent at 95 days, and from 0.18 percent to 0.03 percent at 126 days. The phosphorus percentages in the grain at maturity were 0.34 percent, 0.32 percent and 0.29 percent, with the application of 0, 100, and 200 kg/ha of nitrogen, respectively.

The potassium percentage in wheat tissue was increased by nitrogen fertilization at all sampling dates, except for the grain at 95 and 126 days. The application of 400 kg of nitrogen per hectare increased the potassium percentage of the stem from 3.27 percent to 4.73 percent at 67 days, from 1.58 percent to 2.89 percent at 95 days, and from 1.73 percent to 2.46 percent at 126 days. The potassium percentage of the grain at maturity was 0.58 percent, 0.46 percent and 0.40 percent, with the application of 0, 200, and 400 kg/ha of nitrogen, respectively.

The nutrient contents of the aerial portion of the wheat plant as a function of time are shown in Fig. 3, with the relationships describing a sigmoid-type curve. These data are average values for INIA and CIANO wheat fertilized with 400 kg of nitrogen per hectare. Maximum uptake rate occurred just before and just after heading. Apparently, nutrient uptake continued until the wheat was about 100 days old. At lower rates of nitrogen fertilization, the nutrient uptake-time curves were more nearly logarithmic than sigmoidal.

Total nitrogen uptake by the wheat plant was increased from 22.5 kg/ha in unfertilized wheat to 203.2 kg/ha in wheat fertilized with 400 kg/ha of nitrogen. The average percentage of applied nitrogen present in the wheat plant at maturity was 57 percent at the 100 and 200 kg/ha rates. Total phosphorus uptake was increased from 5.5 kg/ha in unfertilized wheat to 16.2 kg/ha at the 200 kg/ha rate; larger applications of nitrogen did not increase phosphorus uptake. Total potassium uptake was increased from 29.9 kg/ha in unfertilized wheat to 257.8 kg/ha with the application of 400 kg of nitrogen per hectare.

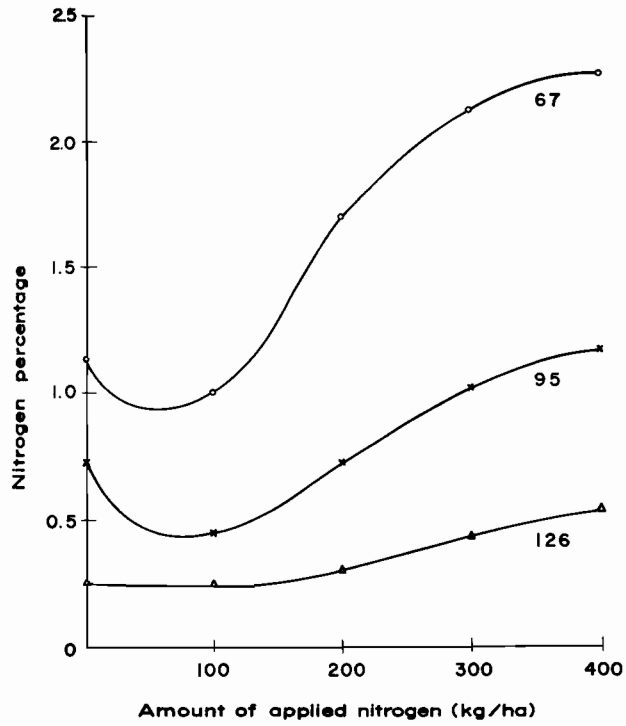


Fig. 2. The relationship between the nitrogen percentage of the stems of wheat plants and the rate of nitrogen fertilization at three sampling dates (number of days after planting). Values are averages for the Inia and Ciano varieties.

The production of dry matter by wheat as a function of time describes a sigmoid curve as shown in Fig. 4. These data are average values for INIA and CIANO fertilized with 200 300, and 400 kg of nitrogen per hectare. Similar relationships were found for wheat fertilized with 0 and 100 kg of nitrogen per hectare.

The maximum rate of dry matter production occurred during the month following heading. Percentage of total dry matter produced at heading was 28 percent in fertilized wheat and 34 percent in unfertilized wheat. Dry weight of stems increased very rapidly during the month following heading and reached a maximum at about 105 days, while dry weight of leaves increased very little after heading and declined slightly during the last month of the growing season. Dry weight of the spike increased linearly from heading until physiological maturity. Rates of increase in spike weight were 12 kg/ha/day, 47 kg/ha/day, and 70 kg/ha/day at the 0, 100 and 300 kg/ha rates of fertilization, respectively.

Results obtained in this 1968-69 study illustrate the multiple effects of nitrogen fertilization on the development of the wheat plant.

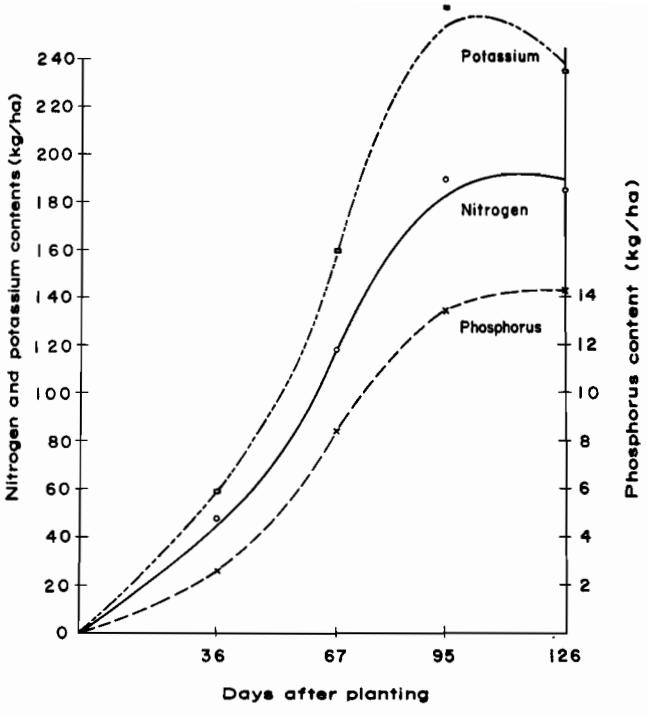


Fig. 3. The accumulative nutrient contents of the aerial portion of the wheat plant from emergence to maturity. Values are averages for the Inia and Ciano varieties fertilized with 400 kg of nitrogen per hectare.

The qualitative response of the Inia and Ciano varieties to applied nitrogen was similar in all comparisons, while the quantitative effect of applied nitrogen on the two varieties frequently was different, as discussed earlier. This difference among varieties in their reaction to applied nitrogen is seen very clearly in the results obtained in a variety-nitrogen rate study conducted in 1969-70. As shown in Fig. 5, the four wheat varieties yielded about the same, without applied nitrogen. However, they responded very differently to nitrogen especially at rates greater than 150 kg/ha.

The 1969-70 experiment was planted very late (January 13) and the results do not represent the relative response of the four varieties when planted during the optimum period. Leaf rust attack in Inia was very probably more severe than it would have been in an earlier planting. In any case, it is interesting to observe that grain production by this lowest yielding variety (Inia) leveled off at the 200 kg/ha rate of fertilization, while the other varieties responded to the higher rates. At the 300 kg/ha rate of nitrogen fertilization, PM2 yielded 1.64 ton/ha more grain than Inia. PM2 is one of the new triple dwarf varieties not yet being produced commercially.

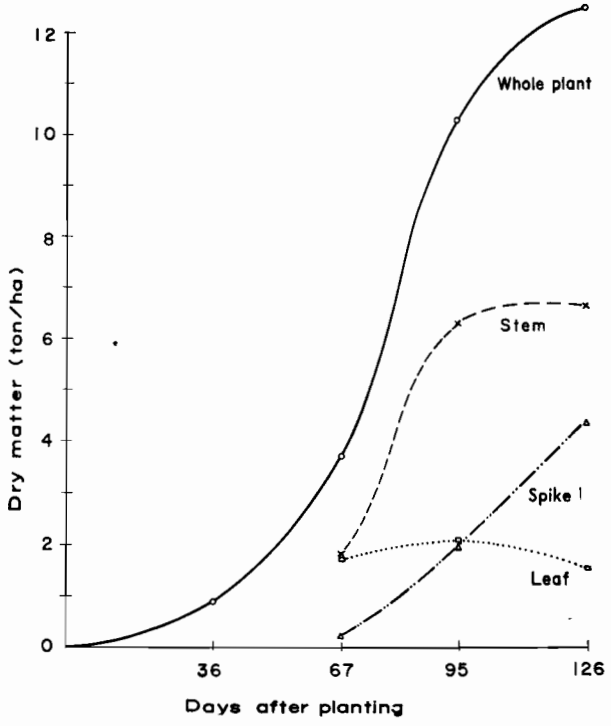


Fig. 4. The accumulative production of dry matter by the aerial portion of the wheat plant from emergence to maturity. Values are averages for the Inia and Ciano varieties fertilized with 200, 300, and 400 kg/ha of nitrogen.

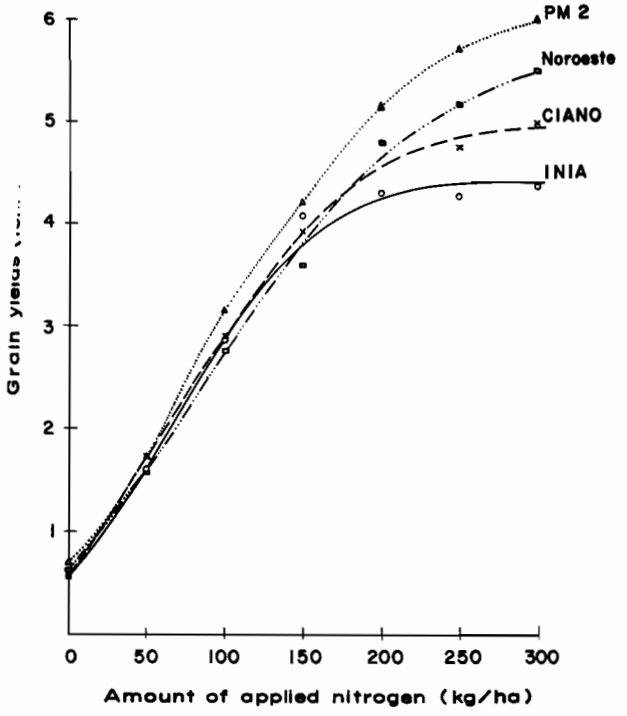


Fig. 5. The effect of nitrogen fertilization on grain production by four wheat varieties.

Averaged over the 7 rates of nitrogen fertilization the straw-to-grain ratios for Inia, Ciano, Noroeste and PM2 were 1.45, 1.36, 1.42, and 1.22, respectively. All of these ratios are low and indicate that the wheat plants were very efficient in producing grain. This is normally not true for very late plantings and probably reflects the influence of a relatively cool April. The PM2 plants were about 15% more efficient in grain production than the double dwarf varieties.

Effect of Flooding on Wheat Development

In irrigated agriculture, the root zone of slowly permeable soils is often partially saturated for several days following an irrigation. Similar soil conditions occur in rainfed agriculture during periods of continuous rains.

Reports indicate that the development and yield of wheat are adversely affected by the low oxygen diffusion rates in the root zone associated with such saturated soil conditions. The way in which an excess of soil

The movement of water into the soil on irrigating is observed using a set of tensiometers installed at varying depths from six inches to 5 feet. Show here, the tensiometers are being read on one tier of plots, while another tier is irrigated.

The interaction among 3 variables was studied in a wheat experiment comprising three varieties, 4 rates of nitrogen and 4 irrigation treatments. The experiment as shown below included a two meter strip across the center of the irrigation treatments for sampling to determine moisture contents.

moisture affects wheat development is believed to depend upon the stage of growth at the time it occurs. Reported effects include a reduction in the number of tillers, the fertility of the spikes, and the size of the grain.

The effects of flooding on wheat development have been studied at the Northwest Agricultural Research Center (CIANO) Mexico, during the past two seasons. The soils in this region are heavy clays and farmers have an ample supply of low cost irrigation water; these conditions suggested that an excess of soil moisture after irrigating might be a yield-limiting factor.

In 1969-70, wheat production in normally irrigated plots was compared with that in plots flooded for 4 or 8 days at different times during the growing season. The soil was a heavy clay with a bulk density that varied with depth from 1.1 in the 0-30 cm horizon, to 1.35 in the 60-90 cm horizon, to 1.20 at the 120 cm depth. Apparently the more dense horizon below 60 cm was almost impermeable to water, as little penetration occurred below that depth, even in plots flooded for as long as 4 days. Oxygen diffusion rates were measured as soon as possible after flooding and the measurements were continued until the rates were adequate for normal growth. After a normal irrigation, the oxygen diffusion rate remained below 0.2 micrograms/cm^2/min at a soil depth of 15 cm for a period of 9 to 12 days. Following 4 days of flooding, the oxygen diffusion rate was less than 0.2 micrograms/cm^2/min at a 15 cm depth for 12 to 15 days.

Flooding was found to affect plant development in several ways:

Flooding for 4 days at planting time reduced plant emergence by 17 percent and plant height at 26 days by 11 percent. The number of heads and grain yield decreased very slightly.

Flooding for 4 days, at 15 and 30 days after planting, increased plant height and the number of tillers per plant at 53 days. Straw yields were increased by about 16 percent.

At 45 days after planting, flooding reduced plant height, tiller density at 53 days, grain size, grain yield and straw yield; it did not change the number of grains per head.

Flooding for 4 days at 60 and 75 days after planting had no significant effect on wheat development.

Flooding for 8 days at 65 days after planting slightly increased both grain size and yield.

The INIA variety used in this study flowered at 61 days after planting.

Evidently, as far as grain yield was concerned, the INIA wheat variety was most sensitive to a low oxygen diffusion rate at planting time and about 45 days later. The effect of flooding at 45 days was similar to that observed in 1968-69, when flooding at 38 days reduced both plant height and straw yields. Surprisingly, flooding for four days at 15, 30, 60 and 75 days after planting, did not reduce grain yields; while flooding for 8 days, at 65 days after planting, slightly increased yields. Similar results were obtained in a growth chamber study at the University of California at Riverside, which found that maximum production of wheat grain occurred at atmospheric oxygen levels about one-fourth normal level.

Results obtained in studies conducted during the past two years clearly indicate that present wheat varieties can tolerate several days of flooding without important reductions in yield. Further information is needed on the quantitative effects of low oxygen diffusion rates occurring about 45 days after planting.

Timing of the Second Irrigation for Wheat

Field studies conducted in India over the past 5 years have shown that maximum wheat yields are obtained when the first irrigation after planting is made 20 to 25 days following planting, when crown root development begins. CIANO experiments in 1969-1970 have obtained more information on this point. Second irrigations in both years were applied 15, 22, 29, 36 and 43 days after planting. The varieties used in the 1969 experiments were Sonora 64 and Tobari, while Sonora 64 and INIA were used in 1970.

Grain yields of Sonora 64 and Tobari were 5.00 and 4.78 ton/ha, respectively, in 1969. Timing of the second irrigation did not affect yields significantly.

The INIA variety produced equal yields of 3.67 ton/ha in 1970 when the second irrigation was applied 15, 22, 29, and 36 days after planting. Delaying the second irrigation until 43 days after planting reduced the grain yield to 3.46 ton/ha.

The Sonora 64 variety produced the highest yields, 4.30 ton/ha, when the second irrigation was applied at 22 or 29 days after planting. Yields were slightly less (4.00 ton/ha) when the second irrigation was applied at 15 or 36 days after planting.

These results are not conclusive, but, in the case of Sonora 64, do provide some evidence that application of the second irrigation at about 25 days after planting is essential for maximum grain production.

Response of Triticales to Nitrogen Fertilization

Highly fertile lines of triticales have been developed in recent years. Their potential for grain and forage production is great, however only limited information on appropriate cultural practices is available. Agronomic trials to obtain preliminary information on the reaction of experimental lines to nitrogen fertilization and other variables were conducted at CIANO in 1970.

Generally, the response function of the triticale lines to nitrogen fertilization was similar to that of the wheat varieties shown in Fig. 5. However, the slope of the curve for the triticale lines, at rates of nitrogen fertilization up to 120 kg/ha, was less than that for the wheat varieties. In this range of nitrogen fertilization, for example, each kilo of applied nitrogen increased grain production of the triticale lines by 18 kilos, while the INIA and PM2 wheat varieties increased by 23 kilos. Similarly, the maximum yield produced with the triticale lines was 3.5 ton/ha, significantly less than the lowest yielding wheat varieties in Fig. 5. Lodging was not a problem in this experiment, even at levels of nitrogen fertilization of 300 kg/ha, probably because the experiment was planted in mid-January and vegetative growth was not excessive.

Corn Fertilization in Andosols

Andosols are widely distributed in Mexico, Central America, parts of the Andean zone of South America, Japan, New Zealand, and other volcanic regions of the world. These soils, formed from volcanic ash, are medium textured with clay fractions dominated by amorphous materials. They are characterized by a high moisture retention capacity, high content of organic matter, and a low bulk density.

Andosols in Mexico are found in regions with adequate rainfall, but their productivity is limited by a nutritional problem believed to be related to a high level of amorphous aluminum oxides. These oxides are thought in some way to limit the utilization of native and applied phosphates, and perhaps other essential anions. Thus, crop yields without fertilization are usually low. The efficiency of

The broadcast of 400 kg of P_2O_5/ha as ordinary superphosphate was effective in increasing the productivity of Andosols in Michoacan. Measured in terms of yield, broadcast application was more effective than band application which in turn was more effective than hill application.

applied phosphorus, measured in terms of increase in production per kilogram of applied phosphorus, is very low in comparison with other phosphorus deficient soils.

In 1969, a study of the fertilization of corn on Andosols was begun in the Sierra Tarasca, Michoacán, Mexico to determine management practices whereby yields could be doubled or tripled in an economical manner. Among the factors involved in the field experiments were: rates and methods of applying phosphorus and chicken manure, sources of phosphorus fertilizer, foliar feeding, and liming.

Table 1 shows average response in terms of grain and stover yields to rates and methods of applying ordinary superphosphate. Yields obtained without applied phosphorus were approximately 55% of those obtained with the highest rate of fertilization. This indicates that the phosphorus deficiency of these soils for corn production is only moderate in intensity. The general response to rates of phosphorus fertilization between 0 and 8000 kg of P_2O_5 per hectare is clearly logarithmic, with the largest increase in yield corresponding to the first 100 kg/ha increment of P_2O_5. However, the yield response does not level off; it increases slowly to the maximum rate studied.

TABLE 1. The effect of rates and methods of applying superphosphate on the production of corn grain and stover with 12% moisture. All treatments received 150 kg of nitrogen per hectare.

Treatment		Average yield at 4 sites ton/ha	
P_2O_5 (kg/ha)	Application method	Grain	Stover
0	—	2.70	4.46
100	Hill	3.48	5.64
100	Band	3.65	5.85
100*	Band	4.26	7.35
200	Hill	3.41	5.32
200	Band	3.75	6.13
400	Hill	3.68	5.75
400	Band	3.70	6.26
400	Broadcast	4.37	6.68
800	Band	4.28	6.47
800	Broadcast	4.42	6.54
8000	Broadcast	4.81	8.29
Least significant difference (5%)		0.35	0.65

* This treatment included 2.5 ton/ha of calcium silicate in band application. Yields are averages for two sites only.

Table 1 P is noteworthy in that the relationship between phosphorus fertilizer efficiency and the degree of contact between fertilizer and soil is shown to be exactly opposite that expected of a soil in which the phosphate fixing capacity is the main factor governing plant response. Measured in terms of yield increases, application of superphosphate by broadcasting and plowing-in was more effective than banding. Hill application was least effective.

The response of corn to massive liming, calcium silicate, and phosphorus fertilization is shown in Table 2. Corn responded very notably when phosphorus fertilization was applied alone, and yields were clearly increased by the application of 50 tons of lime per hectare. However, when both lime and phosphorus were applied, the additional increase above that obtained from lime alone was not significant. This massive application of lime was approximately twice the amount needed to raise the soil pH to 7.

TABLE 2. The effect of applications of lime, phosphorus and calcium silicate on corn yields. All plots received 150 kg of nitrogen and 40 kg of K_2O per hectare.

Lime ton/ha	P_2O_5 kg/ha	Calcium silicate ton/ha	Grain yield
0	0	0	2.24
0	400	0	4.16
0	4000	0	4.30
50	0	0	3.39
50	400	0	3.54
50	4000	0	3.52
0	400	10	6.65*

Least significant difference (5%):

For two phosphorus levels at the same level of lime 0.73
For two phosphorus levels at different levels of lime 1.08

* This treatment was not replicated, whereas the other treatments were replicated 4 times.

A single observation was made of the effect on grain yields obtained with 10 ton/ha of calcium silicate, plus 400 kg of P_2O_5 per hectare. As shown in Table 2, the yield obtained with this treatment was more than 2 ton/ha above any other value. Additional information indicating a response to calcium silicate is found in Table 1, where grain yields are shown to increase by 0.61 ton/ha with the application of 2.5 ton/ha of calcium silicate.

The results of these studies do not support the hypothesis that a high phosphate fixing capacity is the only nutritional problem of these soils. The relative superiority of the broadcast application of phosphorus, plus the fact that corn yields were increased by applications of phosphorus, lime, or calcium silicate, does not eliminate high phosphate fixation as a problem. However, these findings do lend support to the hypothesis that a basic

problem is due to aluminum toxicity. Additional laboratory and field studies are needed to explain the effects and interactions among phosphorus, lime, and silicate.

Results of the 1969 studies clearly indicated that local varieties were poorly adapted to high levels of productivity. This fact was reflected in a significant increase in the stoner: grain ratio of the harvest from plots receiving chicken manure. A systematic collection of varieties from ecologically similar areas was made in cooperation with the Graduate School at Chapingo in early 1970, and these varieties are being tested at high levels of productivity.

As a part of the study of Andosols, arrangements are being made for the publication of a review of the Japanese experience with this type of soil. Dr. Yoshiaki Ishizuka, Hokkaido University, Sapporo, Japan, has agreed to serve as coordinator-editor for the monograph. Drs. Tomoharu Egawa, Hideo Okajima and Akira Tanaka of Hokkaido University and Dr. Shinobu Yamada of Obihiro University have agreed to contribute chapters on "Properties of Andosols", "Amelioration of Andosols", "Maintenance of Fertility and Fertilizer Use" and "Distribution and Morphology of Andosols". It is expected that the manuscript will be prepared and edited by the end of 1970.

METHODOLOGICAL RESEARCH

Research is being continued to determine more efficient procedures for agronomic field trials and for interpreting experimental results. Dr. Foster B. Cady, University of Kentucky, is participating in the methodological studies.

Visual symptoms of plant wilting as an index of moisture stress

In rainfed agriculture, available soil moisture is an uncontrolled production factor that may vary significantly from plot to plot and contribute to a greatly inflated experimental error.

To adjust plot yields for random differenences in the effect of moisture stress, this variable must be characterized at the plot level on many dates during the growing season. Visual symptom of wilting in corn, have been measured on individual plots and used as a covariate to adjust for differences in moisture stress within an experiment. These visual symptoms of wilting provide a measure of moisture stress that can be estimated rapidly and economically where labor costs are low.

The degree of wilting in a plot of corn was estimated by counting the numbers of slightly and severely wilted plants. These numbers were then expressed as fractions of the total, with the fractions multiplied by empirical factors and summed to give the drought coefficient.

These daily coefficients for each plot were transformed to a single value (the drought index) by multiplying by empirical factors and summing the products over the entire growing season. Empirical factors were estimated from the experiences of many investigators and reflect the relative importance of stress on yield at different physiological stages of growth.

Since several observers of the same plot at the same time do not provide identical readings on wilting, an independent estimate was made of variance due to the observer. A group of observers was selected and the same group of observers took readings on the degree of wilting within each experimental plot. The daily drought coefficients were calculated from these readings, and the variance of these coefficients due to observers was calculated. This variance was used to calculate the variance due to observer, or measurement error, for the drought index.

Before using drought indices as a covariate in the analysis of yield data, a preliminary test was made to determine whether the variation in drought indexes among plots was significantly greater than the measurement error.

The overall mean squared deviation of the drought indices for the plots in an experiment was calculated. As this variance is a measure of the true variability among drought indices for the different plots, plus the variance due to observer, the F value (overall mean squared deviation) ÷ (variance due to measurement) was calculated. A significant F value was interpreted to mean that the true variability in the drought indices among plots was greater than measurement error, thus the drought indices could be used as a covariate.

The next step in evaluating drought index for use as a covariate was to measure the degree of association between the drought index and the experimental treatments and blocks. This association was measured by

performing a conventional analysis of variance of the drought indices and testing the significance of treatment and block effects. A high association between drought indices and treatments was taken to mean that the definition of a given treament should include not only the direct effect of the applied treatment on yield, but also the indirect effect of the moisture stress that is associated with the treatment. In such a case, the drought indices should be adjusted for treatments and only the remaining variation among the drought indices used as a covariate. Drought indices should also be adjusted for blocks, in case of a significant association bewteen indices and blocks.

In summary, it is seen that the evaluation of the drought index, for use as a covariate, requires three operations: (1) an estimate of measurement error, (2) comparison of the total variability with measurement error by means of an F test, and (3) analysis of variance of the drought indices and tests of significance of treatment and block effects. When either or both of these effects is significant, it is necessary to adjust the drought indices for the indicated effects. This procedure is applicable in the evaluation of other production factors for use as a covariate in the analysis of yield data.

Evaluation of the Predictive Ability of Regression Models

Fertilizer recommendations for farmers are commonly developed using information generated in a large number of well-conducted field trials. These trials are distributed over time and geographical area to sample a wide range of values among important factors affecting yields. Variables are described carefully for each experiment at the plot or site level, and the results are combined into a prediction function, using multiple linear regression procedures.

The number of potential variables to be included in the prediction equation is large as it includes applied fertilizer variables, site variables, and interaction variables. Currently most investigators select the variables for the prediction equation by means of a stepwise procedure. One such approach introduces potential variables into the equation in an order determined by their correlation with the yield or response variable. A second stepwise procedure begins with all the potential predictor variables and eliminates some of them, one at a time, until a satisfactory prediction equation is obtained.

These procedures are known by the terms *forward selection* and *backward elimination,* respectively. The criterion used in the selection or elimination of a variable is the change in the residual sum of squares, calculated by using the differences between the observed and predicted observations.

Recent CIMMYT studies have shown that the full model (the equation containing all potential predictor variables) performs well when used in predicting yields for combinations of the site variables measured at the experimental sites. However, the full model performs poorly when used to predict yields for combinations which are not the specific combinations measured in the study. This holds true even though the combinations are within the range of values studied. The backward elimination model and, to a lesser extent the forward selection model, provide about the same general results.

These irregularities led to CIMMYT's development of a new criterion for the selection of predictor variables in the general yield function. Called the predictive sum of squares, it is based on the performance of the estimated equation for predicting observations not included in the estimation of the predictor variable coefficients. Calculation is similar to the commonly used residual sum of squares, as both are the sum of squares of the deviations between the observed and predicted observations.

A predictor variable selection procedure, based on the predictive sum of squares criterion, involves the following steps:

The total number of fertilizer trials is randomly divided into a small number of groups. Setting aside one of the groups, the prediction equations is estimated for each of the potential predictor variables; the yields predicted; and the predictive sum of squares calculated for the omitted group. The procedure is then repeated, with each of the groups set aside in turn. At the end of the cycle, the total predictive sum of squares is calculated by summing over the omitted groups, and the predictor with the smallest value is selected. The entire procedure is then repeated in a stepwise manner for the one-by-one selection of several predictor variables.

As is commonly known, the residual sum of squares decreases as more predictors are added to the general yield function and asymptotically approaches zero as the number of variables approaches the number of observations. With the usual significance levels of

five percent and one percent as stopping rules, the stepwise procedures generate a prediction equation with a high degree of correlation among the variables. Subsequently, poor performance is obtained when predicting for values of the variables not used in the estimation part of the stepwise procedure. With the stepwise procedure, it is very difficult to develop a modified stopping rule.

In the procedure reported here it has been shown that, as variables are added, the predictive sum of squares decreases and reaches a minimum value. With additional variables, the predictive sum of squares increases. The minimum value is reached with a number of variables smaller than that obtained with the stepwise procedures using the common stopping rule.

Application of Game Theory to the Selection of Strategies of Production

Most agronomic research, at present, makes the implicit assumption that for each unit of land there is a specific combination of the controlled factors of production which will maximize profit over a number of years.

However, recent research under limiting rainfall conditions in the Puebla Project has suggested that the risk associated with rainfall distribution may be managed better with mixed strategies of production, rather than with a pure strategy as outlined above.

An optimum strategy of production cannot be fully defined using only agronomic considerations. For example, availability of capital, farmer expectations, and market fluctuations, are extra-agronomic factors that must be considered.

In the Puebla Project, agronomic research involving rates and time of applying fertilizer, population density, planting dates, and plant genotypes, has shown very clearly that both the optimum combination of these factors and the corresponding yield are largely determined by the actual rainfall regime. Since we cannot predict the latter, it follows that we can predict neither the optimum combination of controlled factors nor the associated yield.

Under these circumstances, seeking to recommend a pure strategy of production (one planting date, one plant genotype, one population density, one rate and timing of fertilizer application, etc.) is much like betting all resources on a single card, with no options. Betting on several equally probable cards to distribute the risk would seem the rational thing to do. However, this decision would seek to combine, or pool, global risk, productive capacity of the land, and the farmer expectations.

The global quantitative knowledge of the production relationships, the models of game theory, plus knowledge on the extra-agronomic factors mentioned above, are the tools required to design rational strategies of production.

The models of game theory can be adapted to decisions in agriculture, as has been shown by several scientists in the field of economics. Solutions that maximize profit with a certain amount of risk, or that minimize the maximum loss, etc., can be found through this theory. Work is being conducted in the Puebla Project area which will be analyzed with the framework of game theory to design rational strategies of production.

Treatment Designs for Studying Optimum Time for Applying Fertilizer

The conventional way of studying optimum time of fertilizer application does not lead to a simultaneous determination of both the optimum rate and timing of application. It is customary to select two or three rates of the nutrient and distribute them in several ways, over two or three times of fertilizer application

For instance, rates A and B of the nutrient are applied at times C and D. This could generate the following treatments:

		TIME OF APPLICATION		
Treatment	**Rates**	**C**		**D**
1	A =	⅓A	+	⅔A
2	A =	½A	+	½A
3	A =	⅔A	+	⅓A
4	B =	⅓B	+	⅔B
5	B =	½B	+	½B
6	B =	⅔B	+	⅓B

This approach will permit the selection of the best of the 6 treatments. However, if the optimum rate were a value between A and B, we would be unable to get unbiased information on that rate or on the best way to distribute it over times C and D.

One way of attacking this problem is the following: Consider the amount of nutrient applied at time C as a different factor than the amount applied at time D. Define several levels of each and fit a quadratic polynomial in two variables.

Suppose that we select 3 levels of the nutrient (for example 0, 20 and 40) for each of the times. This would lead to factorial arrangement of 9 treatments:

	N_1	N_2
1	0	0
2	0	20
3	0	40
4	20	0
5	20	20
6	20	40
7	40	0
8	40	20
9	40	40

This would permit the estimation of the following equation:

$$Y = a_0 + a_1N_1 + a_2N_2 + a_{11}N_1^2 + a_{22}N_2^2 + a_{12}N_1N_2$$

An economical analysis to the limit will result in the estimation of the optimum value of N_1 and N_2. In other words, both the optimum rate and time of application would be obtained.

Extending the Usefulness of the Quadratic Model for Representing Production Relationships by Careful Selection of the Factor Space

Quadratic polynomial approximations of agronomic production relationships are useful as a criterion of resource allocation. They are appealing because the parameters are easy to estimate and the economical analysis at the limit is easy to perform. However, the explored factor space has to comply with two necessary conditions so that the economical analysis yields meaningful data. The factor space must be such that the real relationship has a downward concavity and a nearly constant curvature (independently related to each of the factor axes). In other words, the downward concavity and the curvature of response to any factor must be independent of the other factors.

In agronomic research, situations may arise which make the quadratic polynomial approximation inadequate for the dual purpose of description and economical analysis at the limit. Consider the use of a quadratic polynomial to approximate the plant response in productivity trials. These trials are often conducted on soils extremely deficient in one of the studied nutrients and only moderately deficient in the other. Let A and B the extremely and moderately deficient nutrients respectively. An addition of nutrient B to the soil, with no application of A, will very likely bring about a moderate negative response. On the other hand, applications of B, at a high level of application of A, may bring about a strong positive response. In this situation, it seems unlikely that the curvature of response to B would be constant. Also the response to A may have an upward and a downward concavity to the A axis, which would rule out the use of the quadratic polynomial as an adequate approximation because another term would be needed. This situation has occurred in the Puebla Project where soils are extremely deficient in nitrogen. An example is the following equation in terms of nitrogen, N, phosphorus, P, and D (which is the population density in thousands expressed as deviations from 30).

$$Y = 321 + 37.05N + 2.53P - 34.78D - 0.0912N^2 - 0.067P^2 + 0.400D^2 + 0.145NP + 0.195ND + 0.99PD$$

This equation shows an upward concavity to the population density axis, since the coefficient of D^2 is positive. The economic analysis at the limit will give a minimum for population density. These values for N, P and D are: 252, 195 and (minus) — 42. The last figure represents (minus) — 12000 plants/ha. The economic analysis in this example, therefore leads to an irrational solution.

One way of bypassing this problem, if one wished to keep the quadratic polynomial, would be to change the explored range of N. In the above example the N range was 0 to 200 kg/ha. The following year, the N range was changed to 80 to 240 kg of N/ha. In doing, it was expected that the responses to both applied phosphorus and to population density would have more nearly constant curvatures. The equation obtained in a similar locale, after adjusting the explored N range, was the following:

$$Y = 240 + 47.36N + 14.09D - 0.113N^2 - 0.475D^2 + 0.120ND$$

No response to P was found in the experiment. After performing the economical analysis, the values for N and D that maximized profit were 180 and 37.5. The latter figure represents 67,600 plants/ha. Thus we see that by adjusting the factor space, we obtain an equation with (1) a total downward concavity, (2) a nearly constant curvature, and (3) the economical analysis yields meaningful data.

COMMUNICATIONS

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INTRODUCTION

Through a variety of printed and audio-visual media, CIMMYT's communications program reaches around the world to stimulate the exchange of information about maize and wheat.

Two key audiences are linked by these services, (1) agronomic scientists and technicians on every continent, and (2) maize and wheat farmers, who are urged to adopt the most economical and productive practices.

As broad as these services are at present (Table C1), CIMMYT has scarcely tapped the range of potential services open to it as an international clearing house and "data center".

Too often, agricultural scientists in developing nations are severely hampered by lack of access to the vast scientific literature generated in the "developed" countries. In addition there is inadequate exchange of knowledge among the growing number of capable scientists in the developing nations. Thus, millions of dollars in research expenditures are misdirected annually, due to inadequate knowledge of existing research and the difficult task of literature search with present retrieval capabilities. CIMMYT and cooperating institutions make an important contribution in establishing information linkages to prevent these communications breakdowns.

Informational support also is needed for campaigns to gain farmer acceptance of the more productive varieties and better cultural practices developed by CIMMYT researchers and cooperating scientists. Realization of this potential depends heavily on effective communication with the farmers who make the final decisions about changing production practices. The communications program has at least three important roles to play in this area: (1) to produce farmer-oriented materials which also may serve as prototypes in other regions, (2) to work closely in producing communications materials with the geneticists and agronomists in countries which show an interest in improving agricultural production, and (3) to provide advanced training in Mexico so that communicators can be tied more closely to agronomic research.

WRITTEN INFORMATION

Editing activities were centered around publications produced in the regular CIMMYT series and information released to mass media outlets covering CIMMYT activities and results. Publications included:

"CIMMYT News" (six numbers, in both English and Spanish versions)

"CIMMYT Report 1968-69" (English and Spanish)

"The Puebla Project 1967-69" (English and Spanish)

Research Bulletin No. 14, "A Survey on Stem Rust Resistance in the USDA World Durum Collection and in CIMMYT Durum Breeding Lines"

Among the other materials edited were: English and Spanish editions of a guide for scholars, a manual for the International Corn and Wheat Yield Nurseries, and special materials presented at the annual meeting of the Puebla Project.

In answer to continuing requests, the following were reprinted:

Research Bulletin No. 2, "Statistical Genetic Theory and Procedures Useful in Studying Varieties and Inter-Varietal Crosses in Maize"

Research Bulletin No. 4, "Exotic Germ Plasm for Improvement of Corn Belt Maize"

"The Puebla Project 1967-69" (English and Spanish)

"The Incorporation of Opaque-2 into Tropical Varieties of Maize"

"Integration of Rural Market into the National Economy of Mexico"

In addition, reprints of the following articles were obtained for CIMMYT distribution: "Wheat Breeding and Its Impact on World Food Supply", by N. E. Borlaug, and "A Green Revolution Yields a Golden Harvest", by N. E. Borlaug, Ignacio Narvaez, Oddvar Aresvik and R. Glenn Anderson, published by the Colombia Journal of World Business.

Distribution

Readers of CIMMYT publications continue to grow in number. The mailing list now includes 4,700 scientists, institutions and libraries in 116 countries as shown in Table C1. Information is distributed free to scientists and others interested in agricultural development, through this list and/or upon individual request. Significantly, very few publications are returned because of unannounced address changes.

While there has been no systematic study of the impact of CIMMYT publications, another evidence of their value is the number of requests which arrive daily at CIMMYT. Last year, the Communications Department handled more than 1,500 requests from 88 countries. These were in addition to publications sent to individuals on the permanent mailing list. Many requests were for specific publications; while others asked for the names of scientists working on a specific problem. Some readers sought additional information based on notes published in the CIMMYT News, and others asked to be included in the mailing list. In most cases, requests were from individuals who had seen CIMMYT materials in the news media or in their libraries, or had heard about them through colleagues.

This response provides continuous feedback indicating CIMMYT's international stature as a source of scientific information on maize and wheat. At the same time it reveals the needs of many information users.

TABLE C1. DISTRIBUTION OF CIMMYT REPORT.

Destination	No. of Addresses
USA and CANADA	1,155
MEXICO	632
CENTRAL AMERICA	321
Costa Rica 97; El Salvador 26; Guatemala 67; Honduras 45; Nicaragua 57; Panamá 29	
CARIBBEAN AREA	67
Barbados 2; Cuba 3; Dominican Republic 21; Guadalupe Island 1; Haití 7; Jamaica 4; Martinique 1; Puerto Rico 16; Trinidad 13	
SOUTH AMERICA	1,362
Argentina 298; Bolivia 29; Brazil 277; Guyana 5; Chile 77; Colombia 127; Surinam 1; Ecuador 52; Paraguay 20; Peru 284; Uruguay 55; Venezuela 137	
EUROPE	254
Austria 1; Belgium 3, Bulgaria 3; Czechoslovakia 2; Denmark 6; England 35; Finland 4; France 22; Germany 29; Greece 5; Holland 14; Hungary 4; Ireland 2; Italy 38; Malta 1; Norway 1; Poland 26; Portugal 9; Romania 3; Spain 11; Sweden 11; Switzerland 12; USSR 2; Yugoslavia 11	
MIDDLE EAST	81
Israel 8; Jordan 9; Lebanon 13; Saudi Arabia 3; Syria 5; Turkey 23; UAR 20	
AFRICA	196
Algeria 7; Angola 2; Burundi 1; Cameroon 2; Central African Rep. 2; Chad 1; Congo 7; Dahomey 2; Ethiopia 18; Gabon 1; Ghana 11; Guinea 1; Ivory Coast 1; Kenya 21; Lesotho 1; Liberia 3; Lybia 3; Malagasy 1; Malawi 4; Mali 2; Morocco 8; Nigeria 20; Rhodesia 9; Rwanda 2; Senegal 5; Sierra Leone 3; Somalia 1; South Africa 12; Sudan 5; Tanzania 6; Togo 3; Tunisia 13; Uganda 12; Upper Volta 3; Zambia 3	
ASIA	574
Afghanistan 12; Burma 1; Cambodia 1; Ceylon 4; China 17; Cyprus 1; Fiji Islands 1; India 175; Indonesia 23; Iran 15; Irak 10; Japan 74; Korea 8; Laos 3; Malaysia 11; Nepal 6; Pakistan 114; Philippines 58; Thailand 34; Vietnam 6	
AUSTRALIA	80
Total English edition, including libraries	2,340
Total Spanish edition, including libraries	2,382
TOTAL EDITION	4,722

Cooperation with Other Media

Information published by CIMMYT reached additional audiences through subsequent adaptation and reprinting by newspapers, magazines, and other media in many countries. The national newspapers in Mexico gave extensive coverage to the annual meeting of the international board of directors held in September and published news notes on CIMMYT's activities and accomplishments throughout the year.

Articles about CIMMYT activities and research results appeared in regional newspapers in Mexico, and in international magazines such as "El Surco", "Agricultura de las Américas", "World Trade News" and "Siete Días" of Lima, Peru. Articles on CIMMYT also appeared in the "New York Times", "Christian Science Monitor", "Wall Street Journal", and the "Financial Times" of London.

The Puebla Project also received special news coverage in the newspapers "La Nación" of Costa Rica; "Foreign Agriculture, an international magazine of the U.S. Department of Agriculture; and in "Expansión", a Spanish language magazine with broad coverage at policy levels in Latin America. Material published directly by CIMMYT was used as basic background information by reporters for these news outlets, which then developed personalized coverage for particular audiences.

Information services at CIMMYT now cover a wide range of media, although the potential has scarcely been tapped. Plans are underway to enlarge CIMMYT's role as an international clearing house and "data center".

AUDIO-VISUAL MATERIALS

The potential of audio-visual materials for communication among farmers in developing countries is well recognized. CIMMYT's staff of three in this field has recently developed two 16 mm films and slide sets, and a film strip on two subjects: "How to Emasculate and Pollinate Wheat" and "Field Technique for Fertilizer Experiments". These were announced in CIMMYT News and made available at cost to other educational, research and extension programs.

Other agencies are willing to pay a modest price to have these visual aids permanent use. Requests from research and educational institutions in Germany, Australia, Canada, Spain, Israel, Holland, Argentina, Brazil, Ecuador, Venezuela and Trinidad.

The same media are being used effectively in the CIMMYT training program. All technicians currently in training are being familarized with these media and it is probable that many will find them useful in their home countries. One advantage of these visual aids is that they give information in step-by-step sequence so that when the technicians go to the field they already have a good idea of how to conduct many research procedures.

The only audio-visual materials made last year for direct use with farmers were those requested by the Puebla Project. The film produced last year, "Would You Like to Increase Your Corn Harvest?", was highly effective in forming 50 new groups of participating farmers in the Puebla Project. The film was made especially to interest farmers in the Project and show them how they could increase their corn yields.

The agronomists working in the project are enthusiastic about the impact of the film. For example, at a meeting in the village of Santa María Atexcac, the coordinator of the Puebla Project asked why the participation in the village had increased from only six farmers, last year to more than 90 this year. Their answer was that the project farm advisor had shown a film in which they could see the corn plantings, neighboring villages and people they knew. The film showed how the corn was cultivated and how certain farmers obtained a better harvest. Thus, they concluded, "We could see that it was the truth". Many of them became enthused with the idea of participating and were openly receptive to the farm advisor's detailed instructions in the field.

During late 1969 and early 1970, the corn film was used in the Puebla area at a total of 103 exhibitions in 98 locations with a total attendance of 7,866 persons. The film is supplemented with an information sheet giving specific recommendations on fertilizer applications for each of five zones in the region.

A second film, on the topic of credit, has just been completed for use with farmers in the Puebla Project. One of the most important determinants of success or failure of the Projects, at this moment, is the effective use of credit for purchasing inputs such as fertilizer. Traditionally, in the Puebla region, credit has been used for emergencies, and seldom for productive purposes. As the area is capital-poor, the introduction of heavy rates of fertilization demands an infusion of capital from outside the region, and simultaneously requires that farmers learn how to use credit effectively and repay on time. Agronomists involved in the Project see these changes in habit and attitude as a top priority problem. The Communications Department has cooperated by producing a film that shows how farmers in the area can use credit effectively, following technical recommendations.

This film, like the general film on raising yields, was made specifically for use in the Puebla area. However, the message may be applicable to groups of farmers in other developing countries, and can serve as a prototype for producing similar materials in countries with work similar to the Puebla Project.

The communications training provided by CIMMYT prepares the scientist to function as a catalyst in agricultural change. Practical training is provided, building upon a base of communications theory.

A third film on the Puebla Project will be completed during 1970. It will tell the Puebla story to development agencies, extension and educational institutions, distributors of inputs, and state and national officials in developing countries. This presentation explains the philosophy and methodology of the Project, as well as the strategies of action. It shows how farmer groups are organized in the Puebla area; the participation and support of local, regional and national organizations; the importance of support by credit institutions; and the need for trained and highly motivated personnel to carry out research and extension activities.

Training in audio-visual methods is conducted in cooperation with the Graduate College, with the CIMMYT audio-visual specialist as instructor. CIMMYT trainees, as well as other students of the College, obtain a theoretical base and practical experience in the laboratory and in the field. They learn to produce photos and slide series, as well as films and other educational materials. The goal is to provide practical training that will make it possible for graduates to move directly into development programs in their home countries.

The photographic laboratory is responsible for documenting all of the research activities of CIMMYT. Photos are used to illustrate technical publications, reports, and articles in the press and agricultural magazines. Assistance also is provided to the research staff in the preparation of graphic material.

Because of limitations of staff and budget, little photographic coverage was given to CIMMYT activities outside of Mexico last year. Plans for the future include greater photographic coverage of CIMMYT activities abroad, and audio-visual back-stopping for agronomists in other countries.

TRAINING IN COOPERATION WITH THE GRADUATE COLLEGE

To provide more complete communications training for CIMMYT scholars, close cooperation has been arranged with the Communications Department of the Graduate College at Chapingo. CIMMYT staff members now serve on the professorial staff: teaching courses, directing thesis problems, providing in-service training, and supervising research. Courses include: "Decision-Making Processes in Agricultural Development", "Production and Use of Audio-Visual Materials", "Technical Editing", and "Processes and Effects of Communications".

CIMMYT scholars enrolled in the College under this cooperative arrangement are: Juan Parodi of Honduras, Moisés Díaz of Mexico, Arturo Vázquez of Peru, and Eduardo Pereira of Uruguay. Díaz and Vázquez are candidates for the Master Science degree. Parodi and Pereira are carrying out special programs on communications methods and strategies for revising production technology.

The training prepares the individual to function as a catalyst in agricultural change, which requires a theoretical base, as well as practical training, in the right combination. The first aspect is covered by the academic program at the Graduate College, while the second is provided by the scholar's participation in the Puebla Project. Training is being expanded at both the graduate and in-service levels, due in part to interest generated by the Puebla Project.

CONFERENCES

From time to time, CIMMYT has organized small conferences to facilitate the exchange of ideas and information on specific research problems. Two conferences of wider scope were held in Puebla, August 3-7, 1970, to bring together individuals interested in a specific production problem: "How farmers, who still farm with traditional methods on small land holdings can be helped to produce more efficiently".

The conferences were sponsored jointly by CIMMYT and the Mexican Ministry of Agriculture. The first conference, August 3-5, was for Latin Americans involved in agricultural development programs; while the second, August 6-7, brought together leaders of international development agencies.

The meetings were concerned specifically with strategies to assure that small farmers benefit from the advances in modern agricultural technology. A case study method was used to examine a number of cases where corn yields have increased rapidly on small holdings. This procedure revealed key points at which the poverty-low yield linkage could be broken, with costs that developing countries can afford. A key group of Latin Americans actively involved in agricultural development attended the first meeting, including participants from: Brazil, Colombia, Costa, Rica, Dominican Republic, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Peru, Venezuela and Argentina.

Small conferences are arranged to provide an exchange of ideas and information on specific subject matter. Two conferences at Puebla in August, 1970 were devoted to the question: How can the subsistence farmer share in the benefits of modern production technology".

As a general criterion, three types of individuals were sought from each country: one from a key position in a government planning post or central bank; one agronomist actively engaged in agricultural research, and one man involved in extension or some aspect of agricultural infrastructure such as credit, fertilizer distribution or marketing. In the discussions preceding these conferences, several countries requested CIMMYT counsel in developing work similar to the Puebla Project.

The second meeting brought together policy level representatives of about 20 agencies deeply involved in international agricultural development.

No attempt was made to arrive at general approval of any particular recommendations, but it appears that the thorough exploration of the problem may lead to various policy recommendations at a later date. The proceedings of both conferences will be published by CIMMYT and made available on a world-wide basis.

LIBRARY SERVICES

The demand for library services has grown rapidly during the past year, in step with the growth in scientific staff and the larger number of scholars being trained at CIMMYT. Facilities of the library have been expanded to provide greater informational support to the scientists assigned to the Center in Mexico and to the outreach programs.

The library has subscribed to an electronic documentation service which, each week, provides lists of articles published in some 2,500 scientific journals around the world. In addition, it provides indices of journals, plus periodic indices of the principal compilation services in the biological sciences covering another 7,500 journals. The librarian selects the titles of those articles which may be relevant for the different specialists of CIMMYT and prepares and distributes a weekly list. When the scientist locates a tittle of interest he may obtain a xerox copy or a summary of the article through the library. Obtaining copies of such articles is facilitated by close cooperation with the National Agricultural Library at Chapingo, the FAO Library in Mexico, and other Mexican libraries that participate in an information interchange.

A separate project financed by the Rockefeller Foundation with CIMMYT interests in mind should be of great future importance. A world-wide bibliography is being prepared consisting of some 46,000 references on corn and wheat. This bibliography, covering the past 10 years, is being prepared by the Biological Sciences Communication Project at George Washington University. Plans are still under discussion in CIMMYT as to how CIMMYT can provide a rapid and complete scientific information service to its staff and to other interested scientists throughout the world. The bibliography must also be up-dated periodically, so that it may continue to make a valuable contribution to research on these two crops.

In the area of documentation, Dr. R. J. Laird, head of CIMMYT's Crop Production Program, has taken the lead in arranging with a group of distinguished soil scientists in Japan, headed by Dr. Yoshiaki Ishizuka of Hokkaido University, to prepare a review of research on andosols. These soils are important in many maize and wheat producing areas of the world; however, much of the research on this type of soil has been done in Japan and the results have been published in Japanese. For this reason knowledge of the Japanese experiences will be valuable to other researchers interested in achieving higher yields on these types of soils. The objective is to bring together an integrated picture of the research that has been conducted and the results obtained. This will be CIMMYT's first experience with this kind of review. If successful, it might lead to similar efforts on other scientific subjects.

SOURCES OF SUPPORT FOR 1970

GENERAL SUPPORT

The Ford Foundation	750,000
The Rockefeller Foundation	750,000
U.S. AID	525,000
Sales and Overhead from Special Grants	83,775
Total	2,108,775

RESTRICTED GRANTS AND/OR CONTRACTS

The Ford Foundation	
66-446A West Pakistan Wheat Improvement 2 years beginning April 24, 1968. Renewal in process.	360,000
68-848 Maize and Wheat Program, United Arab Republic and North Africa, 2 years beginning September 10, 1968. Renewal in process.	293,000
68-880 Maize and Wheat Improvement Program, Argentina, 2 years beginning September 25, 1968. Renewal in process.	96,400
65-345 Maize Program, United Arab Republic, 2 years beginning October 1, 1968.	94,900
The Rockefeller Foundation	
Puebla Pilot Program, 1970 Calendar Year.	89,110
Central America and Caribbean Crop Project, 1970 Calendar Year.	7,500
Wheat Project, Davis, California, 1970 Calendar Year.	37,000
66-074 Towards costs of headquarters in Mexico (Balance in grant as of December 31, 1969).	2,200,000
Protein Quality Laboratory, 1970 Calendar Year.	47,000
69-946 12223 International Potato Program, 1970 Calendar Year.	69,500
68-051 West Pakistan Potato Program, 3 years beginning June 1, 1968.	130,000
Masters Degree Scholarship Program, two years beginning January 1, 1970.	80,000
Post Doctoral Program in Entomology, one year beginning September 1, 1969.	12,500
Study of daylength insensitivity in wheat, 18 months beginning February 1, 1970.	15,000
In-Service training for Middle-East scholars 1 year beginning January 1, 1970.	9,000
Proofreading maize and wheat bibliographies and compiling lists of Latin-American Agricultural Journals, 1 year beginning July 1, 1970.	15,000
Support of special committees on preservation of maize and wheat germ plasm, 1 year beginning July 1, 1970.	13,800
Costs of two conferences related to accelerating production by the small farmer, 1 year beginning July 1, 1970.	24,600
In-Service training for wheat scientists from Turkey, 1 year beginning July 1, 1970.	15,000
United Nations Development Program	
Development and Utilization of high-lysine corn, 3 years beginning March 16, 1970.	1,543,000
U.S. Agency for International Development	
Wheat Program, Tunisia and Morocco, contract No. AID/afr 573, from June 28, 1968 to June 30, 1970. Renewal in process.	337,000