ON PROGRESS TOWARD INCREASING YIELDS OF MAIZE AND WHEAT

CIMMYT REPORT 1968-69
CIMMYT

AN AUTONOMOUS RESEARCH and educational institution incorporated under the laws of Mexico. Governed by an international board of directors consisting of distinguished citizens of several countries of the world. The core staff are a small group of highly skilled scientists of various disciplines and nationalities.

CIMMYT's main purpose is to help increase maize and wheat production in the food deficit areas of the world that can grow these two crops efficiently. Some of the basic research is done at CIMMYT facilities in Mexico, but most work is carried on in cooperation with national programs in the tropics and sub-tropics around the world.
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THE POWER OF THE IMPROVED, HIGH YIELDING, disease-resistant, and fertilizer-responsive varieties in revolutionizing agricultural production is clearly shown by the acceleration of wheat production in Mexico, India, Pakistan, and Turkey. The CIMMYT-Mexican dwarf wheats have had a striking impact throughout this vast area.

These new wheats or their derivatives were sown during the past year on more than 7,457,000 hectares (18,642,500 acres) in the Asia-Near East wheat belt. In addition, a considerable area was sown in Guatemala, Southwestern United States, North and South Africa, Rhodesia, Kenya, and Europe. The total area planted to these wheats is now ten times greater than that sown in Mexico where they were developed in collaboration with Mexico's research centers.

With these high yielding varieties as a catalyst, wheat production in Pakistan has increased from 4.6 million tons in 1965 to 8 million tons in 1969. During the same period, the production in India grew from 12.3 to 19.5 million tons. The total value of the production increase obtained during 1968 and 1969 in these two countries is approximately 1576.7 million dollars. In Turkey, it is estimated that the dwarf wheats added 80 million dollars to agricultural income in 1968. In Mexico, with a wheat area of about 800,000 hectares, average yields have doubled during the past decade from about 1,500 kg/ha in 1960 to 3,000 in 1969. And in Tunisia, 12,000 hectares were planted to the Mexican wheats this past season with a production of approximately 50% more grain than would have been produced had the area been sown to native varieties with the same improved production technology.

These varieties have suddenly made wheat production highly profitable in many areas of the world for both the farmer and the country as a whole. In India and Pakistan, for example, the demand for pumps, motors, and casings for tube-wells has increased many-fold. In India alone, in each of the past two years, about 200,000 tube-wells have been established, bringing about 3.2 million additional hectares under controlled irrigation. The production increases have stimulated the demand for fertilizer, pesticides, farm machinery, sewing machines, and transistor radios. There is a growing demand for better housing, more and better schools, more warehouses, more trucks, better roads, and more electricity. All of this means a better life for many people.

Wheat breeding

CIMMYT is continuing to concentrate heavily on varietal improvement. There are two main reasons for this: new races of rusts and other diseases are a constant threat, and improvement in the yield potential of grains is one of the most efficient ways to help farmers bring about yield increases.

CIMMYT wheat breeders, in collaboration with an ever increasing number of competent breeders in national programs, are rapidly diversifying the types
of disease resistance found in the present commercial dwarf varieties of the Near
and Middle East. India, as a safeguard, is multiplying seed of three new vari­
eties: Sonalika, Chhoti Lerma, and Safed Lerma. All have a different type of
rust resistance from that involved in the first introduction from Mexico. Pak­
istan is also increasing a number of new varieties with different genetic constitu­
tions; namely, Mangla 69, Khushar, Mexipak 69, and Mayab 70. In addition,
seed of the new Mexican varieties Inia 66 and Norteño 67 is being increased.
As an added protection, CIMMYT has developed several new lines from a cross
with II-8156; these not only outyield the original derivatives of II-8156, now
so extensively grown in the Middle East, but are also highly resistant to all
prevalent races of stem, leaf, and stripe rusts in Mexico. They will be widely
tested in plantings in the Near and Middle East during the next crop cycle.

Losses from septoria leaf blotch in Morocco this past year emphasize the
need to develop varieties resistant to this disease. Septoria is prevalent in the
wheat producing areas of the Mediterranean, Argentina, and Brazil. In years
when the rainfall is abnormally heavy after wheat has reached the flowering stage,
Septoria causes severe damage and in some fields reduces yields to zero. In
Morocco, the varieties Siete Cerros and Super X were the most severely damaged;
Penjamo and Tobari showed considerable resistance. CIMMYT’s wheat breeders,
in cooperation with breeders in North Africa, Portugal, Argentina, and Brazil,
have set out to conquer this problem. In the latter two countries, the fusarium
root rots are an added obstacle.

The main challenges faced by the wheat breeders at this time are:
1. The disease problems mentioned above.
2. The development of double dwarfs that will further increase yields
under irrigation.
3. The incorporation of more and better protein.
4. The incorporation of genes for a more permanent type of disease resis­
tance in all varieties.

**Maize Breeding**

CIMMYT’s maize breeders are equally concerned with the development of
high-yielding, disease-resistant, widely-adapted varieties of corn. The approach,
however, is a bit different. Instead of developing varieties per se, the approach
is to form gene pools that are highly variable with respect to genes for disease,
insect and drought resistance, protein quantity and quality, and insensitivity to
daylight. These flexible gene pools provide basic raw materials from which
national breeders around the world can develop superior varieties for specific
conditions. Many of the national breeders have been trained in Mexico and are
familiar with the simple techniques CIMMYT is promoting for the formation
of open pollinated varieties with high yield potential and resistance to insects
and diseases. The regional programs described in this report have been established
to help national breeders work together in the development of high yielding
varieties adapted over several countries with similar problems and climates.

In the outlying regional programs, CIMMYT supplies breeding materials,
information and technical assistance, and usually sponsors an annual meeting at
which the various workers discuss the results of the previous year and plan for
the coming season.
Most of the outstanding varieties in the tropics today have been, or are being, formed from a broad-based gene pool that involves five main Latin American germ plasm complexes. These five complexes have been put together in different proportions for different areas to form varieties with yield potentials substantially above the varieties formed from local materials. Outstanding varieties have been developed from this racial intermixture in India, Pakistan, Southeast Asia, West Africa, Mexico, Central America, and the lowland tropical areas of South America. CIMMYT itself has formed several widely adapted varieties from this complex; these are proving especially useful in countries that do not have the skills for the adaptive breeding work required to develop their own varieties.

One of the immediate challenges for the maize workers of the tropics is to find the best way to introduce the opaque-2 and/or floury-2 genes into commercial corn varieties. These genes greatly increase the lysine content of the grain, making it about 100% more nutritive for growing children and monogastric animals such as pigs. The results with children suffering from protein malnutrition are so striking that every effort must be made to replace present corn varieties with more nutritive types in the areas where maize constitutes the major part of the human diet.

Expansion of basic research

The remarkable success of the coordinated production campaigns in the Middle East has increased the demand for programs in other areas and has created new pressures for additional research, training, and technical assistance. Fortunately, USAID came in as a third financial partner in 1969, enabling CIMMYT to expand its program to meet some of these new demands. With the additional funds supplied by USAID, the International Varietal Testing Program was expanded to include both wheat and maize, and extended to new areas to provide more help to the breeders in meeting varietal needs for specific ecological conditions.

The increased budget also makes possible research on various physiological processes of maize and wheat in order to breed varieties with higher biological efficiency. It has been found, for example, that senescence sets in rather quickly in the varieties of maize now grown in the hot humid tropics and is one of the factors suppressing yields. With the help of physiologists, the plant breeders expect to form varieties that will be affected less by high temperatures during the grain forming period and may thus make it possible to push the present yield ceiling to a new level. The physiologists will be able to assist in determining the ideal plant architecture for maximum yields of maize or wheat under different environmental situations. They will also be helpful in isolating and manipulating genes affecting response to changes in photoperiod. As a rule, varieties insensitive to changes in daylength would be more widely useful, but in some specific climates, sensitivity is a distinct advantage. The effect of daylength in different environments must be better understood if the genes controlling this character are to be manipulated intelligently.

Protein quality laboratory

The protein quality laboratory plays a key role in the development of protein-
rich varieties. Considerable variation in total protein, tryptophan, and lysine content was observed among the approximately 4,000 samples of maize analyzed last year.

In certain samples consisting of 10 seeds each from individual ears of the varieties Pepitilla and Pinto Salvatori, tryptophan values were almost as high as those in opaque-2 maize. Remnant seed of these ears will be propagated for additional studies to see if this method can be used to rapidly increase the protein quantity and quality of present high yielding maize populations.

In wheat, a chemical test specific for lysine has been adapted for screening a large number of lines in segregating populations. This simple test is proving most useful in screening crosses between the Mexican dwarf varieties and the high lysine varieties isolated by the Nebraska-USAID program from the USDA world wheat collection. Seed of 150 durum strains, 200 triticales, and 60 rye strains grown at CIANO in 1967-68 was also evaluated. The durum strains had a lower protein average (14.8%) than either triticale (15.6%) or rye (16.1%). However, an outstanding family of durum wheat (II-21263) has been identified, possessing from 19 to 20% protein.

No correlation has been observed between lysine and tryptophan content in the protein of durum wheats, ryes, and triticales. However, the variability in both tryptophan and lysine content suggests good prospects for improvement through breeding.

In addition to providing information to CIMMYT's wheat and maize breeders, the laboratory services regional and national programs that are searching for more nutritious germ plasm. It also trains foreign research assistants in laboratory techniques.

Research in production technology

With the advent of double dwarf wheat varieties and the new dwarf varieties of triticales, CIMMYT's soils specialists have begun research on how to obtain maximum yields with these varieties. Studies are underway in collaboration with the Mexican National Institute of Agricultural Research and the Chapingo Graduate College to determine the optimum plant density, fertilizer and water requirements. One of the factors being studied is the effect of flooding, a common practice in the irrigation of wheat. The first year's results suggest that: 1) wheat is capable of transporting oxygen through the aerial portion of the plant to the roots, and 2) flooding for several hours at the time of irrigating is unlikely to reduce yields.

The effect of small dosages of Simazin on yield and protein content of wheat was also studied. When this chemical was applied at a low rate, the protein content of the grain increased, especially in plots receiving low rates of nitrogen fertilization. Grain yields, however, were not significantly improved.

Basic studies of corn fertilization on Andosols are being continued. Andosols are important in Mexico, Japan, Indonesia, New Zealand, Central America, and the Andean Zone of South America, all of which have relatively recent volcanic ash deposits. Cultivated crops generally yield poorly on these soils, apparently because a high level of active aluminum interferes with the uptake of phosphorus and possibly other essential nutrients. Experiments with corn are in progress in
the Sierra Tarasca of Mexico to study the effects of varying applications of \( \text{P}_2\text{O}_5 \), nitrogen, chicken manure, lime and calcium silicate. Different sources of phosphorus and various methods of application are also being tested in an effort to find economic ways to raise yields on the Andosols.

**Special cooperative programs with Mexican institutions**

One of CIMMYT's major objectives is to help strengthen national institutions in the countries where it operates. In Mexico, research of both local and international importance is conducted on a cooperative basis with the National Institute of Agricultural Research (INIA) and the Graduate College at Chapingo.

The dynamic winter wheat program at Ciudad Obregón is a joint effort with INIA. The work during the summer months in the Toluca Valley is done cooperatively with both INIA and the Government of the State of Mexico, with real benefit to all agencies involved.

The Puebla Project is another example of fruitful collaboration. This project is designed to determine how small subsistence farmers can be stimulated to adopt modern production techniques, thus increasing their own levels of living and contributing significantly to the further economic development of their country. The work is conducted with excellent collaboration of the Federal Agricultural Agency in Puebla and the Graduate College at Chapingo. These agencies supply valuable assistance in planning agronomic studies, locating and installing experiments, collecting data on factors affecting yield, and in machine analysis of experimental results. The research results are being extended rapidly among the 50,000 farm families in an area of about 116,000 hectares covered by the project. A report is in press giving the results of the first 2 years of this project. Other projects include the protein quality laboratory installed at Chapingo and the cooperative work with INIA in development of high-yielding, open-pollinated maize gene pools for the different altitudes in Mexico. It is hoped that these gene pools, especially the ones adapted to the lowland tropics, will also be useful in other countries.

**Cooperative production campaigns**

Dr. Ignacio Narvaez has completed four years in West Pakistan and will be stationed in Lebanon this coming crop season to promote increased wheat production in the Near East. In his new assignment, also sponsored by the Ford Foundation, he will be able to help many of the young men who have been trained by CIMMYT in wheat production during the past 5 years through a special cooperative project with FAO. With the help of the Ford Foundation, CIMMYT stationed Dr. Takumi Izuno in West Pakistan to help increase maize and sorghum production.

The cooperative maize project involving the Ministry of Agriculture and the Ford Foundation in Egypt was rejuvenated with the transfer of Dr. N. L. Dhawan from India to help with the breeding work. Fertilizer-responsive varieties with greater yield potential are needed if projected production goals are to be reached. The wheat program for the next crop season will include a large scale evaluation of local and introduced varieties under high fertility and special cultural conditions.

In North Africa, the Regional Wheat Production Campaign being conducted cooperatively with USAID and the Ford Foundation is making rapid strides.
CIMMYT has 5 scientists in the area — four stationed in Tunisia and one in Morocco. Two additional scientists, a crop production specialist and a breeder, will be added next season and stationed in Morocco. The CIMMYT staff are working in close collaboration with national scientists in the development of more adequate varieties for North Africa. They are promoting an extensive field research program to determine the package of practices needed to rapidly improve yields. In North Africa, wheat is grown under natural rainfall conditions, with rains coming at irregular intervals. It is hoped that the varieties and production technology developed in this area will be widely useful in the Mediterranean region as a whole.

In Argentina, the cooperative INTA-CIMMYT-Ford Foundation program for the rapid acceleration of both maize and wheat production got underway with a field research-demonstration program in maize under the general direction of Dr. B. A. Krantz. Although the rainfall was unfavorable, useful results were obtained and are available through INTA. CIMMYT has assigned a production agronomist to Argentina to continue the work begun by Dr. Krantz in corn and establish a similar program in wheat.

The regional maize programs in Southeast Asia, in Central America, and the Andean zone of South America continue to progress. The work in the Andean zone is being developed cooperatively with ICA and CIAT in Colombia. Notable progress has been made with the incorporation of the opaque-2 gene into some of the local varieties.

Training

CIMMYT’s training program is aimed at helping countries increase their food production by developing their own competence in agricultural improvement. Requests for assistance in the formation of competent, well-motivated agricultural scientists are increasing rapidly. Last year, CIMMYT trained 51 young men from various countries of the developing world and greater number are expected this year.

To meet the training needs of these scholars, both facilities and staff are being expanded. With the help of USAID, two production specialists, one in maize and the other in wheat, are being added to the training staff. They will spend full time with the trainees and help round out the present program to include the development of production specialists as well as plant breeders. The training specialists will work closely with the research staff to develop well-integrated methods of accelerating food production.

A larger number of trainees will be brought into a special program being developed in cooperation with the Graduate College for teaching organizational skills and operational procedures for conducting production campaigns among small farmers. In this case the Puebla Project serves as a field laboratory.

Publications and visual aids

CIMMYT publications are now receiving world wide distribution. More than 4,000 key individuals and libraries in 104 countries are included in the permanent mailing list. They received six issues of CIMMYT News, published bi-monthly in both English and Spanish, an annual progress report, and other technical bulletins reporting on maize and wheat research.
Research Bulletin No. 9, *Field Technique for Fertilizer Experiments*, which was mentioned in last year’s report, continued to elicit heavy demand. In addition to the basic mailing list, a total of 234 requests for more than 600 copies were received from agronomists in 48 countries.

CIMMYT publications also provide raw material for articles in newspapers and magazines. During the past year, for example, the magazines *Agricultura de las Américas* and *World Farming* published condensed versions of the 1967-68 Annual Report as well as independent articles based on the work of the center. Also, at the international level the magazine *Life en Español* pointed out the role of CIMMYT in the “green revolution”.

As a result of the strong response from nearly 50 countries of the developing world to the manual *Field Technique for Fertilizer Experiments*, a complete audio-visual package on this subject has now been completed. This includes a 16 mm film in English and in Spanish as well as a slide set and film strip with accompanying narrations.

**Physical facilities in Mexico**

Field research facilities were improved with the procurement of 32 hectares of excellent land near Poza Rica in the State of Veracruz (40 meters elevation) and 43 hectares of similarly good land near Tlaltizapán, Morelos, at an elevation of 1,350 meters. As land leveling, fencing, irrigation and laboratories are developed, these will provide increasingly valuable research facilities.

Plans for construction of the central office and laboratory facilities in El Batán near Chapingo are now completed. It is hoped that these much needed facilities will be ready for use before the end of 1970.
"Our daily bread" means maize tortillas to millions of people. CIMMYT and cooperating agencies are developing new kinds of maize with better protein quality and higher yield potential.
THE MAIZE TEAM AT CIMMYT headquarters, with area representatives in Thailand, India, West Pakistan, Egypt, Kenya and Colombia, and cooperators in other maize growing areas, continued their efforts to improve production of this crop. It is well recognized that a multiple approach involving many disciplines is needed. Principles of physiology affecting more efficient growth and development in the tropics need attention; production practices still present problems in many areas; protection of growing plants and harvested grain presents serious problems; availability of credit for needed inputs as well as education of the farmers and subsequent handlers of the harvested crop need attention also. All of these phases of crop production, including the development of superior, widely adapted, fertilizer-responsive varieties require much time and effort. They are receiving attention. However, only a persistent, well organized effort will bring worthwhile progress in the shortest possible time. Time is already critical in a world where millions are hungry, and the food situation could deteriorate further.

OUTLYING COOPERATIVE PROGRAMS

ANDEAN REGION

Work in the Andean Region is done in cooperation with the Colombian Agricultural Institute. Interest in high lysine maize increased significantly in 1968. The consequences of protein-calorie malnutrition were more generally recognized, and the way protein quality mutants produce more nutritious maize is now more fully understood. The significance of these developments is that maize is a major staple for millions in the Andean Region. It supplies between 30 and 60% of the daily caloric intake of this population, and may be even higher among poor families in the rural areas.

Development of high lysine maize

Maize breeding research in the Andean Region should lead to the introduction of the high lysine mutants, opaque-2 or floury-2, into adapted and improved local varieties. Peru and Venezuela have already achieved limited production of more nutritious maize. This will make possible large scale nutrition research. Colombia has progressed in converting normal hybrids to the opaque-2 genotype. Two new hybrids, ICA H-208 and ICA H-255, were approved for release in 1968. These are adapted to the lowland maize producing region of the Cauca Valley. Hybrids from other elevations in Colombia are also being readied for release. In the Colombian highlands, flint varieties are being converted to the opaque-2 genotype for release there. The release and production of these materials could significantly improve the protein nutrition in Colombia.

Colombia achieved large scale production of opaque-2 hybrids for the Cauca valley during the last growing season. An estimated 150 to 180 metric tons were produced by the ICA experimental station at Palmira and on the research farm of Maizena, a commercial company at Cali. This production has been used in animal feeding experiments, human nutrition studies, and large scale industrial processing experiments. To date, no unusual problems have been encountered in the commercial production of opaque-2 maize.

ICA and CIAT staff members have supervised studies with swine, using various diets based on opaque-2 and normal maize. In one experiment, swine were taken from weaning to mature market weights on rations that compared normal and opaque-2 maize. These results clearly indicate the value of opaque-2 maize in the ration, even though the soybean-maize mixture at a 16% total protein level was superior, as would be expected (Table M1). For many swine producers in the Andean Region, a maize-soybean mixture is not available. In these cases, the ration of opaque-2 maize alone would represent a tremendous advantage.

Subsequent experiments with weaning pigs identified the protein diet level at which the pig will die if it receives only normal maize. At the same level, the animal will grow and develop if opaque-2 maize is used as the protein source. These studies are furnishing information to animal and human pathologists who are making electron microscope studies of body tissues of these animals. Not only
TABLE M1. Diets, average daily gain and feed efficiency of swine that entered the experiment at a 17-kg weaning weight and were fed 112 days on normal and opaque-2 mixtures.

<table>
<thead>
<tr>
<th>Item</th>
<th>Normal maize + soya</th>
<th>Normal maize</th>
<th>Opaque -2 maize</th>
<th>Norm (+ lysine + Op.-2 + tryptophan + lysine)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein level (%)</td>
<td>16%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
</tr>
<tr>
<td>Av. daily gain, g/day</td>
<td>662</td>
<td>125</td>
<td>471</td>
<td>400</td>
</tr>
<tr>
<td>Feed efficiency ratio</td>
<td>3.22</td>
<td>7.26</td>
<td>3.52</td>
<td>3.69</td>
</tr>
</tbody>
</table>

High lysine mutants with better food value are now being grown in Colombia, Peru, and Venezuela. Dr. Daniel Sarria of the Colombian Agricultural Institute shows a colleague how to identify opaque-2 kernels; the starch in these kernels is opaque, while normal corn is translucent.

is it becoming possible to understand the pathology associated with malnourished swine, but considerable information is becoming available on the problem of recovery in the malnourished human. This research receives the willing cooperation of industry and the direct support of government.

Colombia now produces opaque-2 maize commercially. The economics of production, the development of products, the acceptance by the medical profession, food technology, and many other factors will determine the future of this maize in commerce.

**Maize production**
Throughout most of the Andean Region, commercial maize production is using only a fraction of the genetic potential of the improved adapted varieties and hybrids. Studies to maximize production on commercial size fields have been in
Seed of the improved variety VS-2 is multiplied at INIAP's “Pichilingue” station in Ecuador. INIAP delivers foundation seed to qualified producers who multiply it further to increase the supply for distribution to farmers.

progress in Peru and Ecuador and at several ICA experiment stations in Colombia.

One experiment at Palmira, Colombia, involved harvesting costs and losses. Contract labor was hired and two systems of payment arranged, a fixed daily wage and a per kilogram rate. These were tested in sequence with the same group of workers, who were not aware that the measurements of harvest production were being made. Production per man per day on the per kilogram system of payment was higher than when the workers received a fixed daily wage, but 20% of the production was left in the field out of a total production of 7.7 tons/ha. The maize left in the field was at least 100 times more valuable than the most liberal estimates of advantage for the per kilo wage system. Since a per kilo wage is the system commonly used for hand harvest of maize, it is anticipated that the losses in commercial production are as high or higher unless a costly gleaning is made. It is doubtful that this operation would eliminate losses completely, especially as the plant populations approach those necessary for maximum yields.

Maize improvement

Two maize improvement programs in Bolivia tested many introduced improved varieties and hybrids from the Andean Region and from Brazil. The highland program at Cochabamba, Bolivia, began the immediate increase of several Peruvian varieties for potential release in the area. The best of the imported varieties were crossed to locally adapted stocks to get further improvement.

At a lowland station near Santa Cruz, new mass selection experiments were made to improve the local variety Cuba Yellow.

In Ecuador, seed of five new varieties produced by varietal crossing and mass selection has been increased. At least two of these will be distributed as new varieties in the lowland regions. These varieties will be the first put into production in that
The region since the well-known variety VS-2 was released 10 years ago. The new varieties yield 10 to 20% more than VS-2, and are shorter.

**Special studies**

Research is underway to study light interception of various maize genotypes and to relate this to total dry matter accumulation. This research is a cooperative effort involving Cornell University and the International Center for Tropical Agriculture (CIAT) at Cali, Colombia.

**CENTRAL AMERICA**

As reported in previous years, the Central American Maize Improvement Program started out as an appendage of the Cooperative Food Crop Improvement Program between the Mexican Ministry of Agriculture and The Rockefeller Foundation. It has now developed into a full-fledged Central American Cooperative Food Crop Improvement Program that includes maize, sorghum, beans, and rice. CIMMYT continues to provide technical assistance, varieties, breeding materials, and general guidance and encouragement in the acceleration of food production in the area. CIMMYT also helps sponsor a meeting each year at which the previous year’s results are presented and discussed and plans for the next year are made. These meetings are well attended by government research and extension workers and by representatives of private, seed, fertilizer, and chemical firms interested in the promotion of greater production in Central America. The proceedings are published by CIMMYT.

CIMMYT’s greatest contribution to the area is in training young research workers and production specialists. Many of these, as in other developing areas, are forming commercial companies promoting various activities related to agricultural improvement. During the past year, three young men were trained in breeding and production techniques in CIMMYT.

Much of the basic breeding work for Central American tropics is done in Mexico as part of CIMMYT’s program in the development of varieties for the lowland tropical areas. Materials more precisely useful in Central America are channeled to the breeders in the various countries for the development of specifically adapted, high-yielding, disease-resistant, open-pollinated varieties and hybrids. These same materials are available to commercial hybrid seed companies who are developing high-yielding hybrids for both the Central American and Caribbean areas. Two series of uniform tests are prepared and grown each year in collaboration with CIMMYT:

1. New experimental varieties.
2. Commercial varieties and hybrids now in production.

As new varieties are developed for possible use in the area, they are first tested in the experimental varieties series. Following this evaluation, those entries considered most promising for commercial release are included in the commercial variety trial if the originator so desires. After two consecutive years of testing, the process is repeated with a new set of commercial varieties. Performance of these trials is summarized and published each year as part of the Central American Cooperative Food Crops Program. Some of the best commercial varieties have come out of the programs in El Salvador and Honduras. Also, Poey and Pioneer have put together some excellent hybrids for the area and are making seed available.

Once again in 1968, serious losses resulted from stunt virus infection. Coastal areas of El Salvador and part of Nicaragua reported the most damage.

Recently, the Middle American program was extended into the Caribbean — to Jamaica, and the Dominican Republic. The islands, together with Central America and the lowland areas of Mexico, have become a vast proving ground for the devel-

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*At certain times of the year, the attack of stunt virus may nearly eliminate corn plantings in the lowland tropics of Central America. Here Humberto Tapia B. of the Nicaraguan Ministry of Agriculture examines infected plants.*
This variety from the world sorghum collection appears highly promising at San Andrés, El Salvador. Several varieties have been chosen for increase and distribution in Central America.

Development of widely adapted varieties for the lowland tropical belt around the world. The use of native germ plasm from the Caribbean has been especially fruitful in combination with lowland Mexican and Central American germ plasm complexes in the development of varieties for the warm, humid areas of tropical East and West Africa, India, and Southeast Asia, as well as those of Venezuela, Colombia, Peru, and Brazil. Open pollinated varieties developed from these materials gave record yields in the lowlands of East Africa last year and appear to be widely useful throughout the tropics, either directly or with minor adaptation to local situation.

Specific research in the development of better varieties of corn for the humid tropics is described elsewhere in this report as part of the Central breeding activities.

Sorghum

Sorghum is becoming established as a major cereal crop in Central America. Its agronomic characteristics make it a logical supplement to other cereals in the area. The Central American Food Crops Program has established a system of uniform variety trials for sorghum similar to that used for corn. In addition, work on pest and weed control, plant density, and other cultural practices is being conducted in the several Central American countries. During the summer of 1968, 33 different varieties and hybrids were tested in 4 different locations in Central America. Average yields ranged from approximately 2 tons/ha for Hegari to almost 5 tons/ha for the best commercial hybrids. Some of the De Kalb and Northrup King hybrids were outstanding with top yields of from 6 to 7 tons/ha in tests in Nicaragua and Panama. The six top yielding hybrids were De Kalb Br-64, E-57, C-48a, and Northrup-King 300, 320, and 210.

Probably the main problem to date is damage from birds, both migratory and nonmigratory species. Midge flies have been noted also, but as yet no major infestation has been observed. Midge is a serious potential hazard, but proper planting dates and removal of host plants in such a way as to interrupt the midge cycle should help to keep the problem under control.

Sorghum suitable for the cool high altitude areas are being developed. Crosses of collections from Ethiopia (Nyundo, Magune, Mabere) with Ryer Milo and 40-Day Kaffir have resulted in progeny selections that gave excellent seed set at Chapingo in 1968 where check varieties (Early Hegari, Caprock, Redbine, Kaffir, and several commercial hybrids) were almost completely devoid of seed.
These small hut-like silos in Malawi were used in corn storage studies. Corn was treated in various ways to prevent insect damage.

EASTERN AFRICA PROGRAM

This program is administered through EAAFRO at Maguga, near Nairobi. The current report was prepared by the CIMMYT representative in the area. Good technical progress was made by scientists of the national maize research program of Eastern Africa countries and the impact on raising farmers’ yields is increasingly noticeable. Cooperation between maize research workers of the region was also greatly strengthened during the year. Maize is the main staple food crop of many countries of the region and can do more to increase food production in others.

The base for the regional program is Kitale, Kenya, headquarters of the Kenya Government Maize Research Section under the senior Maize Research officer. The two regional maize research workers attached to Kitale are the US/AID/ARS Maize Geneticist and the CIMMYT Regional Coordinator. A most valuable comparative study of methods of maize breeding has been made. Because the construction of a student hostel was delayed, the training course that was to have begun this year was postponed. There is serious need for formal agreement between governments on seed exchange, staff movements, and other matters to facilitate the excellent cooperation that has been started on a personal scientist-to-scientist basis.

In the second year’s work of the CIMMYT Regional Coordinator the two main activities were:

1. Incorporation of qualitative genes into composite breeding populations.
2. Assisting the different national maize improvement programs and fostering regional cooperation.

Qualitative genes

The second back cross for the introduction of several desirable genes into the Eastern African composite breeding populations was completed. The components of the very wide-based composites were chosen almost entirely for yield potential, and the following selection for improvement of the composites is based mainly on yield evaluation. This is
CIMMYT Regional Coordinators work closely with the leaders of national breeding and production programs. Here M. N. Harrison, coordinator for Eastern Africa, speaks with leading farmers and government officials at the Kitale Maize Research Station. Cooperative maize variety trials are now grown at more than 40 sites in 8 East African countries.

now being coupled with improvement of qualitative characters by the use of single major genes. The two main priorities are increasing protein quality, using opaque-2 and floury-2 genes; and reducing stalk height and increasing stalk strength, using the brachytic-2 gene. Two subsidiary aims are resistance to blight, *Helminthosporium turcium*, using the Ht gene, and facilitating hybrid seed production by converting the populations used as females to cytoplasmic male sterility. There are 10 composite breeding populations that perform well throughout the region.

The vast Bateke plateau, about a third of the Congo Republic, is a potentially important agricultural area. Methods of fertilizing and other cultural practices will have to be developed, along with suitable cereal crops. CIMMYT has supplied seed and advice, and government officials have expressed interest in a program. Two representatives attended the Third Eastern African Cereals Research Conference.
Regional cooperation

The two dominant themes in maize breeding progress in Eastern Africa are the ever wider successes with Latin American germ plasm and exploiting its use with the comprehensive breeding scheme developed at Kitale.

Races Montano and Comiteco, with late maturing tall plants and big ears, gave best crosses with local maize at Kitale, which has an altitude of 1900 meters and a cool, 8-month season. A wide range of other materials successful at Kitale has had little or no value elsewhere. In expanding the use of materials obtained through the Mexican and Colombian germ plasm banks, it was found that at lower elevations with shorter season, material better known in other countries also has application in Eastern Africa. Selections of Caribbean Flint, Eto, Corn Belt Dent, and Tuxpeño dominate the medium maturity Embu composites but they include also a wide range of crosses between Kitale late maturity and Katumani early maturity material. A new composite being started at Kenya's Mtwapa coastal station is based mainly on 10 white and 11 yellow complex crosses from the Central American tropical cooperative program. This material looks very promising at Ibadan, Nigeria. The maize breeders in Zambia and Malawi are now also evaluating wide ranges of Latin American germ plasm. The great wealth of breeding materials being found, including exotic by exotic crosses that outyield the best local maize, are best utilized through the formation of breeding populations.

Many composite breeding populations are being formed in Eastern Africa. Zambia Composite A, formed at Mount Makulu from more than 20 selected local inbred lines, outyielded the best open-pollinated varieties available. It was only 15 to 20% lower in preliminary yield trials than the outstanding good single cross, SR 52. Chitedze Composite A, from Malawi, also looks very promising. Kawanda Composite A, developed by Uganda maize breeders, promises to yield more than the recently-released improved varieties, Western Queen and White Star. Ilonga Composite A formed at Ilonga (450 m) outyields local maize/ at low altitudes in Tanzania by an average of 50%.

The Eastern Africa cooperative maize variety trials are now grown at more than 40 sites in 8 countries. They have identified improved varieties from other countries that are of value either for immediate release to farmers or as source material for breeding programs in each country. The outstanding result has been the establishment of the superiority of hybrids H 632 from Kitale and the Zambian single cross SR 52. These two hybrids outyield local farmers' maize by over 40% as an average of all locations throughout Eastern Africa. No daylength effect has been detected from Ethiopia down to Zambia and Malawi. The main factor is choosing the maturity of the variety to fit the length of rainfall period available. Resistance to the diseases Helminthosporium turcicum and Puccinia sorghi is needed at high altitudes, and to Puccinia polysora in some coastal areas. Altitude, presumably a temperature effect, is also involved.

Following formation of wide-based composites, the next stage in the Kitale comprehensive breeding scheme is yield improvement by the choice of the most effective selection method for the conditions of the station concerned. At Kitale, where 3 seasons are possible in 2 years, the testing of SI lines per se, a three-season cycle, has been chosen. To increase the progress per cycle, in addition to the SI line yield trial evaluation, opportunty for selection is provided in the nursery generations. In the first nursery generation, SI lines selected from the yield trial are recombined. A high planting density is used and selection is against those plants that go barren under stress. In the second nursery generation, selfing in the recombinations to provide the SI lines for the next yield trial, a moderate planting density is used and selection is for those plants that produce more than one ear. Agronomic characters—disease resistance, lower ear height, and stronger stalk—are selected in these nursery generations also. Experience gained at Kitale is being used to advise other maize breeders of the region as they begin selection in broad-based composites.

Progress in breeding is combined with agronomic research to provide the extension staff with simple recommendations that will triple or quadruple national average yields. The Kitale agronomy research program, started in 1963, has already made great strides. The 1967 Kenya Review of Agriculture reported the long-term average yield of maize grown on large scale farms between 1958 and 1965 as about 1,400 kg/ha. This contrasts with yields of 2,150 in 1966 (when about 50% of the acreage was hybrid) and 2,800 in 1967 (when nearly 100% was hybrid). The Kitale district average in 1968 was 3,400 kg/ha.

In the future, Kenya expects to have a consistent surplus. In fact, maize could change from a subsistence peasant food crop to a major raw material of a country that lacks mineral wealth. The potential is tremendous. Trial yields in Zambia and Kenya generally exceed those of the U.S. corn belt, and have been as high as 13,000 kg/ha. The joint team approach by breeders and agronomists is starting to affect more and more countries. Emphasis is also placed on quality seed production and extension methods (especially the use of package-deal demonstration plots) designed for small scale farmers. The
policy is a planned comprehensive approach that covers all aspects of maize production.

**Third Eastern Africa cereals research conference**

At the invitation of the governments of Zambia and Malawi, the third Eastern Africa Cereals Research conference was held in these countries March 10-15, 1969. Forty three cereal research scientists attended from 10 countries. The participants toured the main research stations of the host countries at Mount Makulu and Chitedze and seed production fields on commercial farms around Lusaka. The meeting terminated on the Lilongwe Land Development Scheme, a World Bank Project, in a densely populated peasant farming area where maize is the

main crop and yields have been doubled by applying results from the nearby Chitedze Research Station. Conference sessions covered breeding methods, agronomy research, grain legumes, extension methods and regional cooperation. They also reviewed the regional variety trials and compared the performance of varieties with their own trials back home. Zambia and Malawi both have formed broad-based

breeding composites involving Latin American germ plasm and have strong agronomy research linked with their breeding programs.

**UNITED ARAB REPUBLIC**

The collaborative maize project with the Ministry of Agriculture of the United Arab Republic made considerable progress during the year. Germ plasm collections from Central and South America, the Caribbean region, USA, and India were evaluated for their potential use in varietal improvement. A successful winter nursery was established in the upper Nile valley, and two generations in the year were grown to accelerate the breeding project. Two experiment stations for the National Maize Research Program were selected and experimental land at each site was allocated by the Ministry of Agriculture. Orders were placed for agricultural machinery for development of the experimental land. Insect and rat proof air-conditioned seed storage was provided at the designated maize stations.

**Germ plasm**

The resources and climate favor a revolution in maize production in UAR. But before this can be realized, high yielding disease and pest resistant varieties, and production techniques must be developed.

With this end in view, a comprehensive collection of maize germ plasm was grown and evaluated for its use in the breeding program.

The outstanding materials from the Middle American region were Mexican June, Jellicorse, and Yellow Tuxpan belonging to the Tuxpeño race; Sonora Groups 2, 7 and 51; Chihuahua Groups 13 and 41; Chapalote (Sinaloa); Llera III; and V-520C. The Caribbean materials, Compuesto Cubano and Antigua, showed good combining ability with Mexican and US germ plasm, and the compact plant type needed for this region. Combinations of US germ plasm with Central American and Caribbean appeared particularly outstanding. The better ones were Iowatigua, Carotigua, double top crosses between single crosses of US inbred lines and Compuesto Cubano and V-520C; and crosses between single crosses of Tuxpeño double cross hybrid 507 and the Corn Belt double cross AES 801. Local varieties Na-El-Gamal and American Early Dent (a selection from Boone County White) also combined well with Central American and US germ plasms. Thirty-eight white composite populations developed in India from American germ plasm were also grown for seed increase. A white selection of J1 appeared well adapted, comparable to its performance in India, Pakistan and Nepal.
Dr. Vasal from India sprays spores of Curvularia lunata on maize to be selected for resistance at Farm Suwon, center of research and training in Southeast Asia. Maize developed by CIMMYT and cooperating agencies performed better than conventional U.S. hybrids. Research made Thailand the world's third place corn exporter.

**SOUTHEAST ASIA**

Work in Southeast Asia is centered in Thailand in cooperation with the Ministry of Agriculture and Kasetsart University. The report for this area was prepared by the CIMMYT representative in the area.

**IACP Workshop**

Maize workers of Southeast Asia met in Bangkok October 6-12, 1968 for the Fifth Annual Inter-Asian Corn Improvement Workshop. Eighty-seven delegates from 12 Asian countries, Mexico, USA, and many local observers attended. At the workshop, it was decided to begin uniform yield trials in 12 countries in 1969 with released varieties submitted from 8 countries.

**Thailand**

The training program at the National Corn and Sorghum Research Center in Thailand continued on the same basis as 1967-68. The 1968-69 program included 8 Inter-Asian trainees from Pakistan, Malaysia, The Philippines, Afghanistan, and Thailand. Other Thais included 10 extension workers, 35 university students, and 2 research assistant trainees.

In uniform variety tests, selections from the collections Cupurico, Puerto Rico Group 1, and Veracruz 181-Antigua Group 2 performed well. Conventional U.S. hybrids yielded poorly in the main growing season, primarily because they were susceptible to disease; tropical hybrids performed reasonably well.

Modified ear-to-row selection in the variety Guatemala has continued to increase yield about 10% per cycle of selection after three cycles.

In an experiment designed to alter maturity (days to silking), after 2 cycles of mass selection maturity was shifted 2 days in either direction (early or late) in 3 different populations. Grain yield was maintained at the same level in the early group for all populations. Increases of 25 and 20% in the medium-maturing group and 21 and 14% in the late-maturing group for two of the populations were realized. Maturity was not altered as rapidly as expected, probably because of low selection intensity (about 25%). But these results suggest that yield levels can be maintained with slow shifts toward earlier maturity.

Estimates of genetic variance were calculated from advanced generations of the three populations, Cuba Group 1 x Cuba 40, Cuba Group 1 x Narino
330-Peru 330 and Cupurico x Flint Composite. Data were collected from one location for the first two populations and two locations for the latter. The two populations grown at one location indicated dominance of genes with little additive genetic variance for yield and low heritability estimates. The third population showed that additive genetic variance for yield was greater than dominance variance and the heritability estimate was quite high (42%). It is likely that these estimates are biased by genotype x environment interactions, especially the estimates from the first two populations.

Leaf spot caused by Curvularia lunata is one of the many diseases severely affecting corn in Thailand. The inheritance pattern of this disease was worked out using resistant (CM104) and susceptible lines (Antigua 2D source material). This disease evidently is governed by a polygenic system. Additive, dominance, and epistatic gene effects made significant contributions in the inheritance of this disease. Though additive genetic variation did not make the highest contribution, it was present in a significant and sizeable amount. It is suggested that various selection schemes that can exploit additive variance should raise the level of resistance of maize populations to this disease.

Cost of production surveys were made in three leading corn-producing districts in Thailand. The data were for the early, or March-July season. Total variable costs per hectare in the three districts averaged $43.75, $51.90, and $55.95.

Corn producing farms in Thailand are generally much larger than the national average size of 4.5 hectares. A strong relationship was found between yield and the sum of expenditures on seedbed preparation and weeding. Plowing was done by tractor, and all other operations were done by hand.

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Maize response to copper on peat soil in Malaysia. Check plot in the foreground received no copper while plot in back has had copper added. This research showed that maize can be grown on these peat soils.
Most of the corn was shelled by tractor-mounted shellers. Only 7 farmers out of the 62 in the survey used insecticides and only 2 out of 62 used fertilizers.

An analysis was made of the pattern and volume of maize exports over the past 12 years and the seasonal pattern of export price and volume. Exports have increased from nothing in 1954 to 1.5 million tons in 1968. The share going to Japan declined from over 80% in earlier years to 43% in 1968, while the share going to Taiwan increased to 27% in 1968. About 98% of the Thai corn exports go to Japan, Taiwan, Singapore, Hong Kong, and Malaysia. In 1966, Thailand was the world’s third largest exporter of corn, following the U.S. and Argentina.

**Malaysia**

The Malaysian government is increasing its efforts in maize production for crop diversification and for feed grains for the developing livestock industry.

One of the significant research accomplishments has been the demonstration that maize can be grown on the peat soils of Malaysia. The addition of copper, lime, nitrogen, phosphorus and potassium resulted in grain yields in excess of 6 tons/ha as compared to no yield when these requirements were not satisfied. Recognition of the copper requirement seemed to be the key to this success (see photo).

**Indonesia**

Indonesian maize plantings of about 3.5 million ha/year are one of the highest in Asia. In addition to Metro, the breeders have released several new varieties. Harapan, Bogor Composite 2, and Bogor Composite 4 have consistently outyielded Metro in certain areas and are being distributed.

**Afghanistan**

Maize is the second most important grain crop in Afghanistan. The production research program is concerned with the identification and improvement of varieties and culture. Some success has been demonstrated with the Surecropper variety in the Helman Valley. Selection is underway in J1 and two broad base composites of local and introduced germ plasm by staff that received training in Mexico and Thailand.

**Philippines**

A major step has been taken to produce more maize through the intensified corn production program; (in 1966, 2,167,000 ha were in maize). An important phase of this program is the training of technicians and specialists in the demonstration of good cultural practices. In 1968-69, 165 corn production technicians from 41 provinces received intensive training for 4 weeks. A total of 322 have been trained since the program began. Intensive 4-month training was given to 23 corn specialists. One thousand provincial technicians, farmers, and businessmen participated in 3-day seminars held in 8 important corn producing provinces; and 31 fertility trials and 25 variety trials were conducted for demonstration and training. Some 165 farmers cooperated in seed production of new varieties on 935 hectares.

**Downy mildew in Asia**

Downy mildew is potentially and sometimes actually the most serious disease of maize in Asia, particularly in the lowland tropics. The disease limits maize production in Taiwan, the Philippines, and perhaps Indonesia. Downy mildew has been important in India for years and was first reported in Thailand in 1968. No doubt, it is or soon will be important in other countries with similar environments.

The training of corn production technicians is boosting yields in the Philippines. Here Dr. Carangal, maize breeder, observes experimental results at Los Baños.
Several kinds of downy mildew reduce yields of Asian maize producers. Maize from the Taiwan and Philippine programs is expected to be a source of resistance for mildew diseases. This plant has been attacked by the species Sclerospora sacchari.

There is much confusion as to the species present in the different countries. The main organisms are reported to be Sclerospora philippinensis in the Philippines, S. sacchari in Taiwan, S. maydis (or S. sorghi) in Indonesia, S. sorghi (??) in Thailand and most of the above plus Sclerospora rayssiae in India. Sources of resistance to some species tend to have resistance to other species, particularly to S. philippinensis and S. sacchari.

An international approach is being made to the study of the organism and breeding for resistance. Procedures underway or proposed include an international workshop, a uniform downy mildew resistant nursery, development of artificial epiphytotic techniques, search for resistance, inheritance-of-resistance studies, and chemical control.

Two broad base composites have been established with the cooperation of the Taiwan and Philippine maize programs. One of the composites resulted from the recombination of 40 lines that showed resistance in Taiwan in 1967; most of the germplasm is from Taiwan and the Philippines. A second composite was made by bulk pollinating resistant S<sub>2</sub> plants from a large collection of varieties and composites sent from CIMMYT. It is hoped that these composites will serve as an initial source of resistance for countries needing downy mildew resistance.

India

A new hybrid, Ganga 5, was released this past year by the All-India Coordinated Maize Improvement Project. This new hybrid is an early-maturing, high-yielding yellow flint. It is resistant to brown stripe downy mildew (Scleropthora rayssiae var. zeae), a serious disease of the northern plains. Ganga 5 should replace Ganga 3 where the disease is a problem and increase the 600,000 ha of high yielding maize grown in India.

The effort to incorporate high lysine genes into elite materials is proceeding satisfactorily. The opaque-2 and floury-2 genes have been incorporated into a number of inbred lines and composite varieties. These materials are being tested for yield, protein quality and quantity, and other attributes with the goal of raising the nutritional status of people in parts of India where maize is an important food crop.

Other breeding programs are being pursued to increase yield and resistance to diseases and insects. Plant type is being emphasized more and the germplasm collection is being screened for dwarf and compact types, erect leaf types, and the multi-eared character. Populations with these morphological attributes are being developed in the genetic background of composites with high yield potential and resistance to diseases and pests.

CIMMYT cooperation with national programs is of mutual benefit. This year the Indian program released a new high yielding hybrid, Ganga 5, which is resistant to Scleropthora rayssiae brown stripe downy mildew disease.
Entomologists inspecting stalks for corn borer damage at the Pusa experiment station, New Delhi, India. While obtaining adequate borer control with insecticides, CIMMYT research goes forward on breeding resistant varieties.

Agronomy. The goal of agronomic research in India is to enable cultivators to achieve sustained, profitable, high yields of maize. To attain this objective, coordinated agronomic experiments are conducted each season to study the response of released composites and hybrids to fertilizer, plant population, planting dates, and micronutrients. Other experiments provide information about the proper techniques for applying fertilizer, develop chemical weed control measures, and study the effects of excess water and drought on growth and yield. In addition, agronomic evaluation of experimental germ plasm including erect leaf materials, dwarfs, and multi-eared germ plasms are either under way or planned.

All the six composite varieties released in India were compared with the recommended hybrid and local varieties at four nitrogen levels in one coordinated experiment. Results from 11 research centers show that the best-adapted composite yielded only
slightly less than the best adapted hybrid. Both the composite and the hybrid yield substantially better than the local variety. One of the composites, Vijay (derived from the older composite, J1), was widely adapted. It had the highest yield at 8 of the 11 locations and did well at the other 3. The development of these outstanding open-pollinated composites simplifies seed production and should lead to much more land in high yielding maize.

In another experiment, an erect-leaf composite derived from the composite variety Sona was compared with the normal-leaf type at populations of 25,000 to 100,000 plants/ha. As expected, the normal-leaf type increased in yield as plant population increased to 75,000 plants per hectare. The maximum yield was 5.9 tons/ha. In contrast, the erect-leaf type continued to increase in yield up to 100,000 plants/ha (maximum yield 7.2 tons/ha). Selection programs are under way to develop erect-leaf composites for the cultivators.

Entomology. The most important insects attacking maize in India are two stem borers, *Chilo partellus* (Swinh.) and *Sesamia inferens* (Walk.). These borers can reduce yields 20 to 40%. Both insecticides and resistant varieties are being developed to reduce borer infestation and injury.

In field tests, two to four applications of Lindane, Endrin, Malathion, Carbaryl, Azodrin, or Endosulfan as sprays or granular formulations effectively controlled both borer species.

Since borer infestations are sporadic and not uniformly distributed, artificial infestation of maize material is necessary to evaluate it for borer resistance. Considerable effort is being placed on methods of mass rearing these borers in the laboratory for field release.

The composite *A1 x Antigua Group 1* showed some resistance to *C. partellus* in preliminary screening. Full-sib family crosses are being used to increase the level of resistance in the composite. Other sources of resistance are also being sought.

Pathology. Work has continued on the development of disease-resistant germ plasm pools from several of the outstanding composites. Best success has been in selecting for resistance to *Helminthosporium* and brown stripe downy mildew from the selected composites Sona, Kisan, Jawahar, Vijay and the unreleased *A2* and *D1* composites. These materials will be tested at 8 locations in 1969 to compare gains made for disease resistance and to determine whether yields or other agronomic characters have been significantly changed.

Two inheritance studies were completed during the year. One study showed that resistance to maize mosaic, a strain of the sugar cane mosaic virus, is governed by a single recessive gene in which a blended inheritance or incomplete dominance for susceptibility is present.

The other study was on the inheritance of resistance to *Helminthosporium maydis*. Both additive and nonadditive gene effects are involved, but additive effects make the major contribution to resistance. The continuous nature of variation for reaction suggested that inheritance of resistance to *H. maydis* is controlled by several genes, a few with major, but most with minor effects. Some recessive genes convey resistance, but for each recessive gene, about two genes act in the partial dominance range.

Maize pathologists in India now believe that the leaf diseases, brown stripe downy mildew (*Sclerotinia sorghi* var. *zea*) and maize mosaic, are under practical control because several resistant hybrids and composites have been released. Research attention will now focus on the stalk and ear rots that are very damaging throughout the country.
Pakistan

Total maize production decreased from 778,000 metric tons in the 1967 normal crop season to 620,000 tons in 1968 on 612,000 hectares, largely because the monsoon rains failed. This is still much more than the average yield of 450,000-475,000 tons in previous years.

The impact of the J-1 composite has been tremendous, but only half of the maize area in West Pakistan is sown to yellow varieties. Therefore, a white synthetic composed of a cross between a local variety and a white single cross from Kansas is being increased rapidly for planting where the people prefer white maize.

Experimental plot yields of J-1, after four cycles of selection at the Central Maize Research Station with fertility levels of 220 kg N and 110 kg P\textsubscript{2}O\textsubscript{5}/ha, have been pushed up to 7.6 metric tons/ha at harvested plant populations of 70,000 plants/ha.

Many single crosses and double crosses being tested under such conditions surpass J-1 in yield. Unfortunately, seed production and distribution and a price that permits economic ventures are developing rather slowly.

Introductions from the Inter-Asian corn program in Thailand and from CIMMYT in Mexico have proven superior in yield to J-1 in the experiment station trials.

A highly successful 1-week training program in sorghum and millet production for extension agents was held at the Central Research Station in June 1968 and will be repeated in June 1969.

A supervised maize production is being organized throughout West Pakistan for the 1969 season. Fifty demonstration plots set out in the Central Region in 1968 proved extremely successful; 20% of the farmers produced over 7,000 kg/ha under supervision of project personnel. This program is being extended to 22,000 hectares throughout West Pakistan in 1969.

An attempt is being made to extend the work conducted in West Pakistan to the eastern province. Shipments of seed have been made to the East Pakistan Agricultural University at Mymensingh and to the Comilla Academy for Rural Development.

CENTRAL RESEARCH PROGRAM

CIMMYT's central research program has headquarters at Mexico City and experimental facilities in various parts of Mexico at environments that range from temperate to tropical. Additional physical facilities for the central research team are gradually being developed. Laboratory space for the protein quality and cytology activities as well as a cold storage room for seeds are provided at the National School of Agriculture, Chapingo. During the year, a 32-hectare farm at Poza Rica, Veracruz, was obtained for growing materials adapted to the low tropics (40 m altitude). A 43-hectare farm at Tlaltizapan, Morelos was acquired for winter nursery plantings. This farm is at 1359 m elevation.

When these farms are developed and equipped, they will provide a much needed addition to the maize production program; however more land is needed for tropical plantings. At both farms, an adequate supply of good quality water is available. Control of land facilities will permit studies of better land management and culture practices for maximum maize production.

BREEDING

The development of superior maize populations involves the intelligent use of the genetic variability available. "Superior" has come to mean high yielding varieties that respond to increased fertility, are relatively insensitive to changes in daylength, and relatively resistant to common crop hazards. Such varieties will be biologically efficient and widely adapted. The procedures needed to develop such varieties are not clearly identified at the present time. Various ideas are being put to test. Experimental data are needed to evaluate their relative effectiveness. As new approaches suggest themselves, it is hoped that they may be tested without delay.

Steps are underway to develop composites including broad genetic variability. The collections and varieties available are expected to differ with respect to the favorable genes and gene combinations which they carry. The formation of broad-based composites (gene pools) and their proper manipulation should provide the best basic materials for developing the type of superior varieties needed for increased food production. A Caribbean composite has been formed with all of the collections from that area that were in the germ plasm bank. It is now being used in a pest nursery selection program for the development of a high level of resistance to insects and diseases common to maize in the lowland tropics. Other selection methods are also being used with this material.

A composite of some 600 Tuxpeño collections (adapted to 0-1000 meters) has undergone a second cycle of synthesis. Variation in this productive
An experiment station for the lowland tropics is being carved out of this 32-hectare piece of land near Poza Rica, Veracruz. Another farm for winter nursery plantings was acquired at Tlaltizapán, Morelos, at 1,358 meters elevation.

The well drilling is at El Batán, future home of CIMMYT headquarters. The sensitivity of maize to environment requires that research be done in climates similar to those where new varieties and practices will be used.

tropical race is tremendous and the composite being formed should offer excellent selection opportunities when the synthesis has been completed. The composite will be used in the development of a cooperative "area-improvement" scheme among collaborators in the tropics where the material is adapted. The scheme of area improvement was described in the 1967-68 report.

**Effect of plant density on expected gain from selection**

Hybrids have made an important contribution in raising the production of maize per hectare. Increased productive potential using the hybrid method has been progressively more difficult to obtain. More recently, breeders throughout the world have obtained encouraging results by recurrent selection procedures. In contrast to the hybrid method where the goal is to detect and multiply the best genotypes (lines) found in the source populations and use them to produce hybrids, with recurrent selection, the goal is to continuously improve populations in which possibilities exist for creating superior new genotypes.

These populations can be used directly by
farmers in some areas or as sources of new lines for hybrid production where this is feasible.

Since recurrent selection is a useful approach for improving the agronomic value of corn, there is interest in studying selection techniques that maximize gains. The role of environment in selection is important. Results obtained in 1967 and 1968 suggest that selection under low plant densities will sort out different genotypes from those that would be selected under high plant densities (page 40, 1967-68 CIMMYT Report).

Preliminary estimates of the expected changes in yield, ear height, days to flowering and ears per plant that would result from mass selection under high and low rates of planting, were obtained during the past year. A design I mating system (153 male groups with 2 females per male) was used in Composite E (formed from 9 early Mexican races). The 306 full-sib families were divided into 17 blocks of 18 each (9 male groups) and grown in separate experiments at densities of 24,000 and 72,000 plants per hectare in 1968. Means of the several traits measured are given in Table M2.

Of the highest yielding full-sib families selected (one from each block) at 24,000 plants/ha, only one was common in the selected highest yielding group under 72,000 plants/ha. If the highest half-sib family had been selected at each population density in each block, six would have been common. Quite different genotypes would have been selected, therefore, depending on the plant density used.

Estimates of additive and nonadditive genetic variances and their standard errors, total genotypic, inter and intra-plot environmental, total phenotypic variances, and heritabilities were calculated and are presented in Table M3.

The additive genetic variance in all traits except ear height was reduced with increased plant density. Nonadditive genetic variance for yield under 72,000 plants/ha was approximately ½ of that under 24,000 plants/ha. Total genetic variance for yield under the high plant density was about ¼ of that under the low density planting. The same trend was observed for the other traits except days to flower. Drastic reduction in genetic variances were obtained for tillers and ears per plant. Striking similarity between changes in genetic and inter-plot environmental variances were observed for all traits when plant density was changed. Intra-plot environmental variance for yield under 72,000 plant/ha was about ½ that with 24,000 plants/ha. A similarity was observed in the reductions of genetic and environmental variances when rate of planting

<table>
<thead>
<tr>
<th>Plants per ha</th>
<th>Days to flower</th>
<th>Ear height cm</th>
<th>Plant height cm</th>
<th>Yield per plant</th>
<th>Tillers per plant</th>
<th>Ears per plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>24,000</td>
<td>78.6</td>
<td>95</td>
<td>199</td>
<td>151</td>
<td>.82</td>
<td>1.62</td>
</tr>
<tr>
<td>72,000</td>
<td>78.9</td>
<td>113</td>
<td>214</td>
<td>80</td>
<td>.05</td>
<td>1.00</td>
</tr>
</tbody>
</table>

The key to success in increasing genetic potential through mass selection is equal competition between plants. Hand planting with careful spacing helps to assure that each plant will have an equal chance to perform. San Rafael, Veracruz.
TABLE M3. Estimates of additive genetic ($\sigma_a^2$) non-additive genetic ($\sigma_d^2$) and their standard errors, total genotypic ($\sigma_g^2$) inter ($\sigma_{Ig}^2$) and intra-plot ($\sigma_{ig}^2$) environmental and total phenotypic ($\sigma_p^2$) variances and heritabilities ($h^2$%) on an individual plant basis for six agronomic traits measured under 24,000 and 72,000 plants/ha in Composite E, San Martín, 1968.

<table>
<thead>
<tr>
<th>Agronomic trait</th>
<th>1,000 plants per ha</th>
<th>$\sigma_a^2$</th>
<th>$\sigma_d^2$</th>
<th>$\sigma_g^2$</th>
<th>$\sigma_{Ig}^2$</th>
<th>$\sigma_{ig}^2$</th>
<th>$\sigma_p^2$</th>
<th>$h^2$%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield</td>
<td>24</td>
<td>.00092 ± .00038</td>
<td>.00064 ± .00045</td>
<td>.00156</td>
<td>.00043</td>
<td>.00376</td>
<td>.04992</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>72</td>
<td>.00102 ± .00007</td>
<td>.00024 ± .00008</td>
<td>.00036</td>
<td>.00009</td>
<td>.00101</td>
<td>.01270</td>
<td>1</td>
</tr>
<tr>
<td>Days to flower</td>
<td>24</td>
<td>6.75416 ± 2.57363</td>
<td>4.03432 ± 2.69022</td>
<td>10.78848</td>
<td>2.25709</td>
<td>15.28640</td>
<td>55</td>
<td></td>
</tr>
<tr>
<td></td>
<td>72</td>
<td>4.78316 ± 2.74021</td>
<td>8.56276 ± 4.00260</td>
<td>13.34589</td>
<td>2.25709</td>
<td>15.60298</td>
<td>31</td>
<td></td>
</tr>
<tr>
<td>Ears per plant</td>
<td>24</td>
<td>.25832 ± .07507</td>
<td>.00776 ± .00832</td>
<td>.00780</td>
<td>.02228</td>
<td>.00475</td>
<td>.015312</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>72</td>
<td>.01168 ± .00574</td>
<td>.00668 ± .00832</td>
<td>.00832</td>
<td>.01836</td>
<td>.00475</td>
<td>.00268</td>
<td>43</td>
</tr>
<tr>
<td>Ear height</td>
<td>24</td>
<td>.01452 ± .00577</td>
<td>.00776 ± .00832</td>
<td>.00780</td>
<td>.02228</td>
<td>.00475</td>
<td>.02703</td>
<td>54</td>
</tr>
<tr>
<td></td>
<td>72</td>
<td>.01784 ± .00534</td>
<td>.00260 ± .00832</td>
<td>.00636</td>
<td>.01524</td>
<td>.00394</td>
<td>.01918</td>
<td>93</td>
</tr>
<tr>
<td>Plant height</td>
<td>24</td>
<td>.02140 ± .00765</td>
<td>.00660 ± .00832</td>
<td>.01000</td>
<td>.02240</td>
<td>.00588</td>
<td>.03328</td>
<td>64</td>
</tr>
<tr>
<td></td>
<td>72</td>
<td>-.00200 ± .00337</td>
<td>.02204 ± .00832</td>
<td>.00612</td>
<td>.02004</td>
<td>.00541</td>
<td>.02545</td>
<td>**</td>
</tr>
<tr>
<td>Tillers per plant</td>
<td>24</td>
<td>.26368 ± .08847</td>
<td>.02236 ± .15312</td>
<td>.11344</td>
<td>.28604</td>
<td>.07176</td>
<td>.35780</td>
<td>74</td>
</tr>
<tr>
<td></td>
<td>72</td>
<td>.00232 ± .00129</td>
<td>-.00012 ± .00122</td>
<td>.00196</td>
<td>.00220</td>
<td>.00303</td>
<td>.00523</td>
<td>44</td>
</tr>
</tbody>
</table>

* Omitted because of heritability larger than one.
** Omitted because of negative value of additive variance.

was high. Of interest are the changes in heritabilities in varying plant densities, since heritability is finally the function of genetic as well as environmental variances. Heritability for yield under the high planting density was estimated as about half that under 24,000 plants/ha. The same trend was observed for days to flower and tillers per plant, but heritability for ear height was higher under the high density planting.

It appears that ear height is less subject to environmental influence when estimated under thick than under low plant densities. Thus, selection for low eared plants might be more effective under high rates of planting than in low density plantings.

The effects of plant density on the phenotypic, genotypic, and genetic interrelationships between combinations of the six agronomic traits studied were compared. The correlation coefficients are presented in Table M4.

In many selection programs, undesirable indirect responses pose a serious problem for breeders. In attempts to reduce such responses by simultaneous selection for several traits, selection in the main trait is somewhat reduced. Our results suggest that in some cases, undesirable indirect responses can be reduced by changing the environment in which selection is carried out. For example: the genetic correlations between days to flower and ear height are + .55 and - .52 for the 24,000 and 72,000 plants/ha experiments, respectively. Accordingly, it

TABLE M4. Phenotypic (upper), genotypic (middle) and genetic (lower) correlation coefficients among six traits estimated in the corn Composite E under 24 (above diagonal) and 72 (below diagonal) thousand plants/ha. San Martín, 1968.

<table>
<thead>
<tr>
<th>Traits correlated</th>
<th>Yield</th>
<th>Days to flower</th>
<th>Ears per plant</th>
<th>Ear height</th>
<th>Plant height</th>
<th>Tillers per plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield</td>
<td>-.01</td>
<td>.77</td>
<td>.24</td>
<td>.16</td>
<td>.50</td>
<td>.17</td>
</tr>
<tr>
<td></td>
<td>.17</td>
<td>.90</td>
<td>.50</td>
<td>.45</td>
<td>.54</td>
<td></td>
</tr>
<tr>
<td>Days to flower</td>
<td>-.20</td>
<td>-.01</td>
<td>.31</td>
<td>.17</td>
<td>.08</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-.28</td>
<td>.04</td>
<td>.18</td>
<td>.03</td>
<td>.11</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-.15</td>
<td>.00</td>
<td>.55</td>
<td>.24</td>
<td>.06</td>
<td></td>
</tr>
<tr>
<td>Ears per plant</td>
<td>.62</td>
<td>-.06</td>
<td>.23</td>
<td>.09</td>
<td>.65</td>
<td></td>
</tr>
<tr>
<td></td>
<td>.65</td>
<td>.01</td>
<td>.14</td>
<td>.09</td>
<td>.59</td>
<td></td>
</tr>
<tr>
<td></td>
<td>.65</td>
<td>-.18</td>
<td>.34</td>
<td>.20</td>
<td>.74</td>
<td></td>
</tr>
<tr>
<td>Ear height</td>
<td>.17</td>
<td>.36</td>
<td>.20</td>
<td>.55</td>
<td>.07</td>
<td></td>
</tr>
<tr>
<td></td>
<td>.10</td>
<td>.41</td>
<td>.01</td>
<td>.71</td>
<td>.12</td>
<td></td>
</tr>
<tr>
<td></td>
<td>.23</td>
<td>-.52</td>
<td>.36</td>
<td>.55</td>
<td>.01</td>
<td></td>
</tr>
<tr>
<td></td>
<td>.15</td>
<td>.22</td>
<td>.03</td>
<td>.52</td>
<td>.09</td>
<td></td>
</tr>
<tr>
<td>Plant height</td>
<td>.05</td>
<td>.24</td>
<td>.07</td>
<td>.83</td>
<td>-.05</td>
<td></td>
</tr>
<tr>
<td></td>
<td>.24</td>
<td>.25</td>
<td>.01</td>
<td>.42</td>
<td>.18</td>
<td></td>
</tr>
<tr>
<td>Tillers per plant</td>
<td>.16</td>
<td>.04</td>
<td>.18</td>
<td>-.08</td>
<td>-.01</td>
<td></td>
</tr>
<tr>
<td></td>
<td>.51</td>
<td>.03</td>
<td>.67</td>
<td>-.33</td>
<td>-.22</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-.08</td>
<td>.27</td>
<td>-.14</td>
<td>-.09</td>
<td>.14</td>
<td></td>
</tr>
</tbody>
</table>
would make a difference in the average ear height of the product whether selection for earliness were made in high or low density plantings.

Corn breeders generally have observed an increase in days to flower when selecting for high yields; however, most selection programs for high yield are made under rather low plant densities. This increase in days to flowering is in agreement with the genetic correlation estimated between yield and days to flower in Composite E under 24,000 plants/ha in this study. The negative value of the corresponding estimate under 72,000 plants/ha indicates that the undesirable correlated response in days to flower might be eliminated by selection under higher plant densities. Indirect gain from selection depends on the genetic correlations, the heritabilities, and the phenotypic standard deviations. The latter apparently are affected by varying plant densities also. The expected direct and indirect gains from mass selection for high yield and prolificacy were calculated (Table M5).

The expected gain from direct selection for yield was higher on a per plant basis with 24,000 plants/ha than with 72,000 plants/ha. This is in agreement with the reasoning many corn breeders follow with respect to the space available and maximum expression of genetic potential of the plants. However, on a per hectare basis, gains are expected to be equal. The data indicate also that undesirable correlated changes might be drastically reduced when selection is made in the appropriate environment. For example, selection for high yields is expected to increase the days to flower when selection is in low density plantings. In contrast, no change or perhaps a reduction in days to flower might occur

When selection for yield is made in high density plantings.

A similar situation is seen in the correlated response in ear height when selecting for high yields. Late plants are usually more productive than early plants with low rates of planting, perhaps because they have more time to grow and have less competition. But if plant competition is severe, fast growing (early) genotypes may shade the later plants and otherwise compete favorably with them so that later plants can not produce as much as the early ones.

Unfortunately, a negative estimate of dominance variance was obtained for the trait ears/plant when the rate of planting was 24,000 plants/ha, so no estimates of gain from selection were possible for selection for prolificacy.

**Indirect selection for lodging resistance**

The program in the Bajio area of Mexico to increase lodging resistance was described in the 1967-68 report. Of 500 S1 lines out of Puebla Group 1 being evaluated for productivity in 1967, the highest yielding 200 were sampled for measurement of stalk strength characteristics. Two measures were used to select for stalk strength, weight of stalk section at the full internode above the soil surface, and rind thickness. Two subpopulations were formed by selecting the 20 high and 20 low S1 lines on the basis of weight of section and two other populations from the 20 high and 20 low for rind thickness.

The four groups of selected lines were intercrossed during the summer season at Roque, Gto. and the resulting composites grown in a preliminary evaluation trial during the winter season at Tepalcinto, Mor. The trial consisted of 3 population densities: (40,000, 55,000 and 70,000 plants/ha) with 5 replications. The difference in stalk lodging was greatest between the two populations where selection was based upon differences in rind thickness. The populations will be regrown during 1969 in the area where they are adapted.

To obtain additional information on the effects of mass selection, a series of populations is under study in the CIMMYT lowland tropical program. Among the materials are:

1. V-520C, a single farmer variety of the race Tuxpeño.
2. Tuxpeño Crema I, consisting of eight high yielding collections, Veracruz 48, 143, 174, Michoacan 137 and 174, V-520C, Colima Group 1 and Mix 1.
3. Mix 1 x Col. Group 1, consisting of two varieties.

---

**TABLE M5.** Estimates of expected direct and indirect gains from mass selection for high yield and prolificacy were calculated (Table M5).**

<table>
<thead>
<tr>
<th>Trait selected for and plant density</th>
<th>Expected change in Trait(s)</th>
<th>Expected change in Trait(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Trait selected for and plant density</strong></td>
<td><strong>Expected change in Trait(s)</strong></td>
<td><strong>Expected change in Trait(s)</strong></td>
</tr>
<tr>
<td><strong>Yield g/plant</strong></td>
<td><strong>Days to flower</strong></td>
<td><strong>Ears per plant</strong></td>
</tr>
<tr>
<td>24</td>
<td>.003</td>
<td>.105</td>
</tr>
<tr>
<td>72</td>
<td>.001</td>
<td>-.052</td>
</tr>
<tr>
<td><strong>Ears per plant</strong></td>
<td><strong>72</strong></td>
<td>.008</td>
</tr>
</tbody>
</table>

* Omitted either because of negative estimates of additive genetic variance of one of the traits or heritabilities larger than 1 caused by negative estimates of dominance variance.
Plants with upward growing leaves like these appear to intercept more light and may thus have higher yield potential. In an Indian experiment testing populations up to 100,000 plants per hectare, an erect-leaf composite of the variety Sona yielded 1.3 tons/ha more than the normal leaf type.

4. ETO Blanco, a single variety developed in Medellin, Colombia.
5. (Mix 1 x Col. Group 1) x ETO Blanco, representing a combination of adapted and relatively unadapted material.

These materials vary in number of cycles of selection reached at this stage from three cycles in one case to eight in another. Preliminary yield evaluations suggest that progress is being achieved in all populations. All varieties in the study have performed well as varieties themselves and in crosses with other materials. Some of them are already in production in certain lowland tropical areas.

Parallel to the yield selection outlined, the Tuxpeño Crema I (broad base) is being subjected to selection for prolificacy, for shorter plant and ear height, and to two cycles versus one cycle per year of mass selection for yield.

Leaf angles

From among 1000 selfs made in Antigua Group 2, a series of S1 lines were selected that show decidedly contrasting leaf angles of the upper leaves. These are being intercrossed to study behavior of these characters in crosses and to attempt to relate them to yield performance.

Photoperiod response

Maize varieties from low latitudes (short days) become taller, later, and less productive when planted at higher latitudes (long days). The reduction in yield is due to the delay in floral initiation resulting from change in daylength. Flowering may begin so late in the season that the development of grain is stopped by frost long before maximum growth has occurred. When maize varieties adapted to the long days of the higher latitudes are planted nearer the equator, they become earlier, but the change is less drastic than in the move away from the equator. These are light reactions, primarily. Temperature reactions may also occur. Maize for low elevations (sea level) in the tropics does not do well when moved to the higher elevations in the same latitude and vice versa. These climatic responses greatly restrict the area of adaptation of maize varieties and hybrids. Development of widely adapted varieties would do much to alleviate the world food problem.

Preliminary information was obtained during the year on differential reaction to daylength and nitrogen levels. Seven races of maize (two collections of each) were planted at monthly intervals at Roque, Gto. (April, May and June) during the period of increasing daylengths and again at Tepalcingo, Mor. (October, November and December) when daylengths were decreasing (Table M6). Two fertility levels of nitrogen were used, 80 and 160 kg/ha. Each variety was replicated twice in each fertility level at each planting date. Measurements were made of yields, stover, days to flower and ear height on 10 competitive plants in each plot. Days to flower, ear height and the grain/stover ratio were chosen as indicators of stability to changing daylengths. The grain/stover ratio is a measure of plant efficiency that seems to be a worthwhile indicator of stability to changing daylengths, as well as fertility level response. The results from the materials planted at Tepalcingo, Mor. have not yet been analyzed completely. The experiment is being repeated again during the current season.

In both locations, the plantings suffered from moisture stress, mainly after the flowering period. Stunt virus and bird damage were additional disturbing factors at Tepalcingo. Mean values averaged over the 14 collections for each date of planting and for both fertility levels are in Table M6.

Neutrality to daylength should result in about the same period of time from planting to flowering whenever or wherever the crop is planted, so long as growing conditions are suitable for the crop. None of the varieties responded in this way. Pepitilla exhibited the greatest change in days to flower at Roque. It required 115 days in the April planting (daylength 12 hr, 39 min) and 88 days in
the June planting (13 hr, 11 min daylength). Tabloncillo, on the other hand, flowered after 73.5 days in the April and after 71 days in the June planting.

The differences were less pronounced at Tepalcingo but the trend was for a longer period to flower as the daylength at planting became shorter. In the last 3 dates of planting (Tepalcingo), daylength at planting time decreased a total of 46 minutes. Plant height as indicated by ear height responded similarly in all varieties used over the different planting periods. Differences among dates of planting occurred but the patterns of differences are believed to reflect irregularities in irrigation rather than reactions to daylength. Temperature differences may also have contributed to the variation in response among the different planting periods.

Grain/stover ratio was calculated as the ratio of shelled grain/stover on a per plant basis. The mean values for the various dates of planting in order of increased length at planting under the two fertility levels used are shown in Table M6. The analysis of variance of the plot means for the three dates of planting at Roque showed significant differences among dates but no difference between nitrogen levels. The variances associated with differences among the races and varieties within races, as well as their interactions with dates of planting, were significant statistically. None of the races included gave a very consistent grain/stover ratio over the several plantings used.

The range in values for the grain/stover ratio in the individual collections at Roque where plant development was considered to be more nearly normal was from .374 to .738. On the basis of these values, the materials included do not appear to be highly efficient in the production of grain. At least the values fall far short of some of the better rice varieties that exhibit ratios up to 1.25. Mass selection in maize using the grain/stover ratio as a selection index is underway.

In an attempt to combine the possible sources of different genes that presumably condition photo-periodic responses, a pool of germ plasm representing the extremes of day length adaptation is under formation.

Included in this pool are:
1. a sweet corn from Alaska.
2. seven collections of New England flints from Canada and the northern U.S.
3. corn belt dent from Wisconsin, Iowa, and Nebraska.
4. varieties from Kentucky and Mississippi.
5. Nine collections of Tuxpeño and Conico corns from Veracruz and San Luis Potosí, Mexico.
6. one collection each of the Mexican races

<table>
<thead>
<tr>
<th>Planting date</th>
<th>Daylength at planting hr:min</th>
<th>Mean temp. °C</th>
<th>N applied kg/ha</th>
<th>Days to flower</th>
<th>Ear height meters</th>
<th>Grain/stover</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEPALCINGO</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dec. 2</td>
<td>10:45</td>
<td>20.3</td>
<td>80</td>
<td>81.4</td>
<td>.65</td>
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<tr>
<td></td>
<td></td>
<td>160</td>
<td>80.6</td>
<td>.65</td>
<td>.49</td>
<td></td>
</tr>
<tr>
<td>Nov. 1</td>
<td>11:02</td>
<td>20.9</td>
<td>80</td>
<td>77.2</td>
<td>.85</td>
<td>.51</td>
</tr>
<tr>
<td></td>
<td></td>
<td>160</td>
<td>77.6</td>
<td>.84</td>
<td>.51</td>
<td></td>
</tr>
<tr>
<td>Oct. 2</td>
<td>11:31</td>
<td>23.7</td>
<td>80</td>
<td>73.4</td>
<td>.64</td>
<td>.47</td>
</tr>
<tr>
<td></td>
<td></td>
<td>160</td>
<td>72.6</td>
<td>.60</td>
<td>.43</td>
<td></td>
</tr>
<tr>
<td>ROQUE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ap. 21</td>
<td>12:39</td>
<td>16.6</td>
<td>80</td>
<td>84.7</td>
<td>1.48</td>
<td>.57</td>
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<td></td>
<td></td>
<td>160</td>
<td>84.7</td>
<td>1.60</td>
<td>.62</td>
<td></td>
</tr>
<tr>
<td>May 21</td>
<td>12:57</td>
<td>18.5</td>
<td>80</td>
<td>77.4</td>
<td>1.70</td>
<td>.53</td>
</tr>
<tr>
<td></td>
<td></td>
<td>160</td>
<td>77.1</td>
<td>1.69</td>
<td>.36</td>
<td></td>
</tr>
<tr>
<td>June 21</td>
<td>13:11</td>
<td>18.5</td>
<td>80</td>
<td>74.2</td>
<td>1.26</td>
<td>.57</td>
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<td></td>
<td></td>
<td>160</td>
<td>74.1</td>
<td>1.30</td>
<td>.57</td>
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<tr>
<td>Means</td>
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<td></td>
<td>80</td>
<td>78.1</td>
<td>1.10</td>
<td>.53</td>
</tr>
<tr>
<td></td>
<td></td>
<td>160</td>
<td>77.8</td>
<td>1.11</td>
<td>.53</td>
<td></td>
</tr>
</tbody>
</table>

* Daylength: Sunrise to sunset.

Celaya, Chalqueño, Comiteco, Zapalote Chico, Harinoso de 8, Cacahuacintle, and maiz ancho.
7. a composite of Cuban flint and corns from Antigua in the Caribbean.
8. a popcorn from Pakistan.
9. Eto Blanco from Colombia.
10. Calca, Choclero and Cuzco from Peru.
11. Argentine flint from Argentina.

This pool is being thoroughly mixed and will be made available for study by interested research workers in other areas.

**Reduction of plant height in the humid tropics**

The enormous size of tropical corn plants raises a series of questions about the feasibility of increasing grain yield appreciably while maintaining ability to remain erect. The advantage of shorter plants is obvious in avoiding heavy lodging and associated yield losses when soil fertility is high.

Several lines of approach are being taken to reduce plant height. Brachytic 2 has been introduced into several Tuxpeño backgrounds. The resultant dwarf populations have been composited in one brachytic 2 variety that is itself now under modified ear-to-row mass selection for yield. Initial performance of the new dwarf is promising. Other genetic dwarfs, including brachytic 1, brachytic 3,
d 1 short, d 1 tall, pigmy, tallo cuadrado, and another ear are being studied. Direct recurrent selection for shorter plant height in Tuxpeño is being used as well as selection in segregating populations resulting from the cross of Tuxpeño by Antigua corns.

Flint vs. dent

Corn varieties with dent grain are widely believed to yield more than varieties with flint grain. Most comparisons of such types have been made using unrelated varieties of different origin. To study the relationship in more detail, two yellow endosperm varieties with strongly contrasting textures were selected. The dent variety was formed from a composite of kernels selected from more than 50 Tuxpeño collections. The flint variety is a composite of Cuba 11J, PD(MS) 6, and ETO Amarillo. The dent variety, the flint variety and the cross of the two were then randomly mated for five generations. After the mixing, the intercross of the flint by dent is being separated into a flint component and a dent component. First evaluations of the recovered flint and dent selections will be made in 1969, and will compare the two new varieties with each other and the original parental populations.

PATHOLOGY

Corn stunt virus has been increasing in severity in recent years in Mexico, Central, and South America. Many of the wild grasses around Veracruz show symptoms similar to those of maize affected with the stunt virus.

Several grasses (Echinochloa colonum L. and Digitaria ischaemum Schreb.) having these symptoms were collected in the area. Healthy, nonviruliferous leafhoppers (Dalbulus maidis) were allowed to feed on these grasses. After 14 days and at 4 day intervals thereafter, leafhoppers from each of the sampled grasses were transferred to protected seedlings of a stunt-susceptible inbred line, T4, for transfer of any virus they might have picked up from the grasses. The inoculated seedlings were transplanted in the field after the leafhoppers had been feeding for 4 days.

Preliminary results of these inoculations indicated the presence of virus types in addition to the stunt virus. The rapid change in the causal agents and the potential number of different types is of interest. In much of the tropics, plants and insects grow the year around. Therefore, it seems mandatory to use heterozygous and heterogeneous maize.

The inoculated maize was grown in peat pots so transplanting would not disturb the roots. The two rows on the left are a susceptible variety. The taller one depended on natural infection. The row on the far left was inoculated and accurately shows the damaging effects of stunt virus.

One problem in testing for disease resistance is to be sure the plants are equally exposed to the pathogen. The two rows on the right are the same disease resistant variety. The row on the far right depended on natural field infection. The plants in the next row were inoculated in the greenhouse by leafhoppers carrying stunt virus and then transplanted into the field.
populations that can change over time as the numerous pathogens change.

Selection for resistance to ear rots mainly caused by *Diplodia maydis* has been based upon natural infections. Many plants selected as being resistant were in fact susceptible but somehow escaped infection. To reduce the number of escapes in the selection program, all ears in the selection nurseries are being inoculated by spraying a spore suspension of *D. maydis* on the silks about 10 days after pollination. The appearance of the disease on progeny rows of susceptible materials was more consistent and intense than when natural infection was relied upon.

During mass selection of apparently disease-free ears, disease often goes unnoticed. In this way, susceptible plants are retained in the selected samples. In a sample of 285 selected “healthy” ears, a germination test was made with 25 seeds from each selected ear. Only 77 (27%) of the ears produced completely healthy, vigorous, seedlings apparently free of the vigorous mycelial growth of the fungus. Whether absence of mycelial growth shows resistance remains to be seen. Selection efforts should reflect more progress if inoculum applied to the ears permits better identification of resistant types.

**ENTOMOLOGY**

**Maize insect pests of world importance**

Early in 1968, a questionnaire was sent to 60 scientists throughout the developing world to identify the major insect pests of maize. Such information could be valuable in the development of integrated control procedures, particularly the use of insect resistant germ plasm, biological control, and selective use of insecticides.

Only the generic designations are reported here, because species names often were not provided in the 21 questionnaires returned. The information received thus far is preliminary, but it provides a general idea of the most important maize insect pests (Table M7). In general, the borer complex comprises the most important group among field pests. However, armyworms, root insects, earworms, aphids or insect vectors of viruses can limit crop production in a given area.

Cramer (1967) estimated that insects are responsible for losses of 44 million tons, equivalent to 12% of the world’s maize harvest; weed and disease losses waste another 77 million tons.

Percentage losses larger than those estimated by Cramer have been observed in the insecticide trials conducted at Tepalcingo, Morelos.

<table>
<thead>
<tr>
<th>TABLE M7. Maize insect pests of importance in the world as reported by 21 respondents.*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Borer</strong></td>
</tr>
<tr>
<td><em>Busseola</em></td>
</tr>
<tr>
<td><em>Coniesta</em></td>
</tr>
<tr>
<td><em>Chilo</em></td>
</tr>
<tr>
<td><em>Ostrinia</em></td>
</tr>
<tr>
<td><em>Sesamia</em></td>
</tr>
</tbody>
</table>

**AFRICA**

**AMERICAS**

**ASIA**

* Heliothis earworms were a major pest on all continents. Besides *Heliothis*, borers, armyworms, and adult rootworms also injure the developing ear. In addition, the most commonly reported stored-grain pests were in the genera *Sitophilus*, *Sitotroga*, *Tribolium*, *Rhyzopertha*, *Dinoderus*, and *Ephesia*.

**Insect control with insecticides**

**Field pests.** Preliminary results with granular Telodrin and Sevin were reported last year. At Tepalcingo, Morelos, Mexico, Sevin was applied at 250 to 400 g/ha active ingredient. Telodrin dosages were 90 to 180 g/ha. Telodrin gave slightly better control of armyworm and borers, but yields were higher with Sevin. Sevin plot yields were 3.1 to 3.4 times those of the check. Telodrin treated plots yielded 2.2 to 2.6 times as much as the untreated checks. Differences among dosages of either insecticide were not statistically significant.

Five tests have been completed thus far to determine the effectiveness of two applications of granular insecticides at different stages of plant growth. Applications were made 2 to 5 weeks after plant emergence to control the fall armyworm and early attacks of the stem borer. Other applications were made 6 to 9 weeks after plant emergence to control the southwestern corn borer and late attacks of the fall armyworm.

These tests are conducted at different times of the year to expose the plants to different insect...
TABLE M8. Effect of timing of granular 1.5% Telodrin applications, 12 kg/ha per application, on fall armyworm and corn borer damage and yield at Tepalcingo, Morelos, 1968-69. Average of five replications.

<table>
<thead>
<tr>
<th>Time of treatment weeks after plant emergence</th>
<th>Planting date for each test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25 Nov.</td>
</tr>
<tr>
<td>2 weeks and 6 weeks later</td>
<td></td>
</tr>
<tr>
<td>3 weeks and 7 weeks later</td>
<td></td>
</tr>
<tr>
<td>4 weeks and 8 weeks later</td>
<td></td>
</tr>
<tr>
<td>5 weeks and 9 weeks later</td>
<td></td>
</tr>
<tr>
<td>Check</td>
<td></td>
</tr>
</tbody>
</table>

**FALL ARMYWORM**

<table>
<thead>
<tr>
<th>% plant survival</th>
<th>% undamaged plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 weeks and 6 weeks later</td>
<td>87 97 96 91 100</td>
</tr>
<tr>
<td>3 weeks and 7 weeks later</td>
<td>79 96 93 97 99</td>
</tr>
<tr>
<td>4 weeks and 8 weeks later</td>
<td>69 98 91 99 99</td>
</tr>
<tr>
<td>5 weeks and 9 weeks later</td>
<td>69 96 86 93 94</td>
</tr>
<tr>
<td>Check</td>
<td>56 88 69 80 13</td>
</tr>
<tr>
<td>LSD 5%</td>
<td>9 N.S. 8 3 7</td>
</tr>
</tbody>
</table>

**SOUTHWESTERN CORN BORER**

<table>
<thead>
<tr>
<th></th>
<th>Average borer-injured internodes in 10 plants b</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 weeks and 6 weeks later</td>
<td>2 10 25 1 0</td>
</tr>
<tr>
<td>3 weeks and 7 weeks later</td>
<td>0 7 14 1 0</td>
</tr>
<tr>
<td>4 weeks and 8 weeks later</td>
<td>1 5 7 1 0</td>
</tr>
<tr>
<td>5 weeks and 9 weeks later</td>
<td>9 37 41 4 0</td>
</tr>
<tr>
<td>Check</td>
<td>9 3 6 8 1</td>
</tr>
<tr>
<td>LSD 5%</td>
<td></td>
</tr>
<tr>
<td>Average yield as percent of check</td>
<td></td>
</tr>
<tr>
<td>2 weeks and 6 weeks later</td>
<td>146 145 219 130 240</td>
</tr>
<tr>
<td>3 weeks and 7 weeks later</td>
<td>136 152 249 123 216</td>
</tr>
<tr>
<td>4 weeks and 8 weeks later</td>
<td>145 151 208 136 212</td>
</tr>
<tr>
<td>5 weeks and 9 weeks later</td>
<td>157 139 198 161 209</td>
</tr>
<tr>
<td>Check</td>
<td>100 100 100 100 100</td>
</tr>
<tr>
<td>LSD 5%</td>
<td>30 34 17 49 69</td>
</tr>
</tbody>
</table>

* Fall armyworm, Spodoptera frugiperda (E. J. Smith), infestations were estimated 73, 63, 30, 47, and 63 days after plant emergence, respectively.

* Southwestern corn borer, Zeadiatraea grandiosaella, infestations were estimated at harvest time.

Stalk girdling by larvae of Zeadiatraea grandiosaella. The pest usually girdles stalks close to the ground, and many of the plants lodge.

Population densities. Except in the test planted in January, the percentage of plants undamaged by armyworm has been significantly increased in the treated plots. The insecticide applications made 2 or 3 weeks after plant emergence have provided the most effective control.

Infestations of the stem borer have also been significantly reduced in the treated plots. Maximum reduction in those tests where infestations were high have been observed in the plots treated 7 or 8 weeks after plant emergence (Table M8).

Yields have been increased significantly in all tests by the insecticide treatments except in the August planting, when both armyworm and borer infestation were low. Increases in yield ranged from 23% to 149% more than the untreated check (Table M8).

Yield reductions of untreated plots (checks) in the November, August, and December tests may be attributed mainly to fall armyworm; while in the January planting, yield reductions were caused almost entirely by the southwestern corn borer. In the March planting, both insects reduced yields somewhat.

Stored grain pests. Malathion has been used extensively to protect stored grains from heavy and continuous attack by mixed populations of stored-grain insects. However, little is known about the persistence of this material when treated grain is moved from one location to another with a different climate.

We studied the effect of three dosages of Malathion as a grain protectant for rice, maize and wheat against the corn weevil *Sitophilus zeamais* Mots. in two different environments: Chapingo,
Seed for two tests was prepared and treated in Chapingo. One test was transferred to Tepalcingo before the first infestation was made.

The appropriate amount of insecticide was put in quart jars containing 1000 g of grain and the jars were shaken by hand about 5 minutes. Dosages were 5, 10, and 15 ppm by weight. The total volume of insecticide + water, was 2.5 cc/500 g of seed to adjust the moisture content of the grain to 12%. Controls were shaken for an equal time with 2 cc of water.

The samples were infested with 50 corn weevils 1 week old, 5 days after the grain was treated and reinfested thereafter with the same number of weevils every 20 or 21 days. The insects were removed from each sample of grain 48 hours after the infestation was made, and the number of dead insects determined. Temperature and humidity were not controlled.

At Tepalcingo, rice, maize and wheat differed strikingly in the length of time the treatment was effective (Table M9). Wheat was protected for a much shorter time than the other two grains, and rice was protected most effectively.

The work was partially supported by Cyanamid de México, S. A., de C. V.

**TABLE M9.** 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.

<table>
<thead>
<tr>
<th>Days after fumigation (age of fumigant)</th>
<th>Rice</th>
<th>Maize</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>ppm</td>
<td>ppm</td>
<td>ppm</td>
</tr>
<tr>
<td>2</td>
<td>98%</td>
<td>99%</td>
<td>92%</td>
</tr>
<tr>
<td>21</td>
<td>100</td>
<td>100</td>
<td>94</td>
</tr>
<tr>
<td>41</td>
<td>99</td>
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<td>70</td>
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<td>62</td>
<td>99</td>
<td>95</td>
<td>40</td>
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<tr>
<td>83</td>
<td>99</td>
<td>95</td>
<td>51</td>
</tr>
<tr>
<td>104</td>
<td>100</td>
<td>97</td>
<td>57</td>
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<tr>
<td>133</td>
<td>100</td>
<td>96</td>
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<td>175</td>
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<td>197</td>
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<td>217</td>
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<td>94</td>
<td>50</td>
</tr>
<tr>
<td>259</td>
<td>98</td>
<td>83</td>
<td>27</td>
</tr>
<tr>
<td>280</td>
<td>100</td>
<td>99</td>
<td>86</td>
</tr>
</tbody>
</table>

Data reported are the averages of four replications.
TABLE M10. 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.

<table>
<thead>
<tr>
<th>Days after fumigation (age of fumigant)</th>
<th>Rice</th>
<th>Maize</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15 ppm</td>
<td>10 ppm</td>
<td>5 ppm</td>
</tr>
<tr>
<td>AT CHAPINGO</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>71%</td>
<td>49%</td>
<td>5%</td>
</tr>
<tr>
<td>21</td>
<td>79%</td>
<td>63%</td>
<td>44%</td>
</tr>
<tr>
<td>41</td>
<td>47%</td>
<td>23%</td>
<td>10%</td>
</tr>
<tr>
<td>62</td>
<td>17%</td>
<td>7%</td>
<td>1%</td>
</tr>
<tr>
<td>83</td>
<td>9%</td>
<td>2%</td>
<td>0%</td>
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<tr>
<td>104</td>
<td>14%</td>
<td>6%</td>
<td>0%</td>
</tr>
<tr>
<td>125</td>
<td>10%</td>
<td>5%</td>
<td>0%</td>
</tr>
<tr>
<td>145</td>
<td>92%</td>
<td>45%</td>
<td>6%</td>
</tr>
<tr>
<td>166</td>
<td>25%</td>
<td>17%</td>
<td>9%</td>
</tr>
<tr>
<td>187</td>
<td>16%</td>
<td>9%</td>
<td>2%</td>
</tr>
<tr>
<td>AT TEPALCINGO</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>145</td>
<td>100%</td>
<td>100%</td>
<td>98%</td>
</tr>
<tr>
<td>166</td>
<td>100%</td>
<td>99%</td>
<td>96%</td>
</tr>
<tr>
<td>187</td>
<td>100%</td>
<td>95%</td>
<td>84%</td>
</tr>
<tr>
<td>207</td>
<td>100%</td>
<td>87%</td>
<td>51%</td>
</tr>
<tr>
<td>228</td>
<td>100%</td>
<td>99%</td>
<td>89%</td>
</tr>
<tr>
<td>249</td>
<td>99%</td>
<td>70%</td>
<td>28%</td>
</tr>
<tr>
<td>270</td>
<td>100%</td>
<td>100%</td>
<td>95%</td>
</tr>
</tbody>
</table>

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.

**Thrips resistance**

From a group of 200 entries grown in 1967 and 1968 at Tepalcingo, Morelos, to measure susceptibility or resistance to thrips damage, the 60 more resistant varieties were allowed to interpollinate by detasseling the most susceptible ones. The resulting population was termed Thrips Resistant Synthetic (Tep. 67-68). Using a laboratory technique developed for artificial thrips infestation of seedlings, the Thrips Resistant Synthetic and 17 other varieties were evaluated at Roque, Guanajuato, in 1968 for reaction to this insect. The result are in Table M11. Progress in development of materials less damaged by thrips is evident. Even though all plants died in this severe test, the best might have survived typical field infestation. Simple mass selection and selection based upon S1 line evaluation are being used to further increase the level of resistance in the "thrips resistant" population. Evidence suggests the resistance trait may be recessive; thus, use of S1 line evaluation is indicated as the appropriate procedure since plants within S1 lines can be selected for rapid advance in level of resistance.

**Stem borer resistance**

Search for resistance to stem borers was continued by planting 57 maize varieties at 5 locations in Mexico: Tepalcingo, Morelos; Coatzila, Veracruz; Chontalpa, Tabasco; Apodaca, Nuevo Leon; and Rio Bravo, Tamaulipas. *Zeadiatraea grandiosella* (Dyar) was the only species at Tepalcingo. *Z. lineolata* (Walker) was the only species present in Coatzila and Chontalpa. A complex of *Z. lineolata*, *Z. grandiosella* and Diaatraea saccharalis (Fab.) was present at

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*The following stations provided valuable cooperation: Tepalcingo, ProNaSa; Rio Bravo, Centro de Investigaciones Agrícolas de Tamaulipas, INIA; Apodaca, Escuela de Agricultura, ITESM; Coatzila, CIASE, INIA; Chontalpa, Centro de Investigaciones y Extensión Agropecuaria de la Chontalpa, SRH-SAG, INIA."
These 5-cm sections of corn stalk were cut at the second full internode above the soil surface, dried, weighed, and then the rind thickness was measured. This part of the search for resistance to borers did not succeed. The research has now turned to physiological differences that may repel borers.

TABLE M11. Survival of seedlings of 18 maize populations artificially infested with 20 thrips Frank‐kliniella williamsi Hood per plant. Roque, Gto., 1968; averages for each of 4 tests with 10 replications.

<table>
<thead>
<tr>
<th>Identity</th>
<th>Mean number of days the plants survived after being infested when 5 days old</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Test I</td>
</tr>
<tr>
<td>Antigua Group 2</td>
<td>17.8</td>
</tr>
<tr>
<td>Michoacan Group 30</td>
<td>19.1</td>
</tr>
<tr>
<td>Sonora Group 13-A</td>
<td>19.6</td>
</tr>
<tr>
<td>Queretaro Group 8</td>
<td>19.8</td>
</tr>
<tr>
<td>Sonora Group 9</td>
<td>20.0</td>
</tr>
<tr>
<td>Sonora Group 5</td>
<td>20.3</td>
</tr>
<tr>
<td>Oaxaca Group 14</td>
<td>20.3</td>
</tr>
<tr>
<td>Nayarit Group 3</td>
<td>20.5</td>
</tr>
<tr>
<td>Jalisco Group 46</td>
<td>23.8</td>
</tr>
<tr>
<td>Celaya x Puebla</td>
<td>24.0</td>
</tr>
<tr>
<td>Jalisco Group 39</td>
<td>24.4</td>
</tr>
<tr>
<td>Antigua Group 2 x Puebla Group 1</td>
<td>25.0</td>
</tr>
<tr>
<td>Oaxaca Group 40</td>
<td>26.8</td>
</tr>
<tr>
<td>H-366 (Hybrid)</td>
<td>27.3</td>
</tr>
<tr>
<td>Puebla Group 1</td>
<td>29.5</td>
</tr>
<tr>
<td>Thrips Res. Synt. (Tep. 67-68)</td>
<td>21.5</td>
</tr>
<tr>
<td>Cortazar Synthetic V</td>
<td></td>
</tr>
<tr>
<td>Celaya x Tehuacan</td>
<td></td>
</tr>
<tr>
<td>LSD 5%</td>
<td>5.1</td>
</tr>
</tbody>
</table>

Apodaca and Río Bravo with *lineolata* predominant. This is the first report of *grandiosella* in Apodaca and Río Bravo and the first report of the 3 species from the same locality.

The significant influence of size of plant and maturity on the amount of borer damage within as well as among varieties makes it important to consider these characteristics when selecting for resistance. Results at the five localities showed the need to question the level of resistance of very short and early plants and varieties with low levels of actual damage as well as the large and late varieties with low relative damage. Adjustments need to be made for variability in damage among plants and varieties that is associated with plant characteristics other than resistance in order to identify truly resistant genotypes.

Most varieties reacted similarly at the various locations and the interaction variety x localities was not significant in the compounded analyses of the number of damaged internodes per plant.

Since the amount of genetic variation in the source population will largely determine the potential gain by breeding, the best varieties with which to start a breeding program to increase levels of borers resistance should combine high levels of resistance and high genetic variability in relation to resistance. According to this, the best varieties among those tested were: Antigua group 2, (T₂ x WF9) x T₂, Tuxpantigüa, República Dominicana group 2, San
Croix group 1, Santa Lucia group 2, Antigua group 1, Haití group 1, Guadalupe group 1A, Puerto Rico group 2, Puerto Rico group 3, Puerto Rico group 1 and Haiti group 3.

The low values for the estimated heritability of resistance indicated that the potential gain in resistance between generations will be relatively low unless some measures are taken to reduce the environmental component of variance. The most important factor contributing to the environmental variance was probably the uneven or "contagious" distribution of the pest. Accordingly, the best possible measure to increase the levels of heritability would be to infect artificially the materials to be tested.

The efficiency of the experiments increased with the levels of damage, indicating that screening under natural conditions should be done during the season of highest infestation. The similar efficiency of the two methods used to measure damage; actual damage (number of damaged internodes per plant) and relative damage (percentage of damaged internodes), suggests the choice of the former since it is simpler.

A comparison between the levels of borer damage in early and advanced generations of varieties developed in the absence of selection for resistance indicated that there is apparently a trend in most varieties for an increase in susceptibility when selection for this factor is not considered in the breeding program.

**Stored grain insects**

The studies of stored grain insects, reported in the two previous annual reports, have been continued with "free choice" and "no choice" tests. Kernels from 216 Brazilian and 71 Colombian maize varieties have been tested for their reaction to *Sitophilus zeamais* Mots. and *Sitotroga cerealella* Oliv. In *S. zeamais* there was considerable difference among varieties in numbers of emerged weevils from the first generation, insects attracted to the kernels, and kernels damaged. The weight of the weevils was quite uniform with only a few cases of significant differences between varieties.

Taking into consideration the results from both the free choice and no-choice tests, only in five Brazilian varieties was the weevil emergence significantly smaller than the over all average (B-59, B-122 and B-114 of the cateto type; B-7 of the cateto dent type; and B-212 of the orange flint type).

Among the Colombian materials, 8 varieties had significantly less emergence of weevil in the no-choice tests (C-5, Pira blanco; C-9, Pira naranja; C-11, Nariño 369; C-19, Magdalena 443; C-23, Magdalena 466; C-124, Diacol V. 254; C-128, Eto x Peru (Blanco); and C-132, a mixture of the best white varieties).

The correlation between number of weevils attracted and number of damaged kernels in the free-choice tests with the Brazilian varieties, was significant at the 5% level ($r = 0.23$). Perhaps the varieties included in these trials were different in their attractiveness for oviposition, nutritive value, or for a combination of these two factors. The correlation between number of weevils attracted in the free-choice tests and weevils emerged in the no-choice tests, ($r = 0.34$) was significant at the 1% level. This indicates that those varieties that are more attractive are also more suitable for the development of the insects. Another significant correlation in the no-choice tests ($r = 0.42$) was between number of kernels damaged and weevils emerged. This probably indicates that the stimulus for feeding also stimulates oviposition.

In 18 experiments with *S. cerealella*, only in three were significant differences found between collections in moth emergence. The collections in which significantly less moths emerged were: B-217, a cateto; B-67, a cateto flint; B-258, Hiebory King; B-90, a dent; B-243 and B-237, a Brazilian yellow dent.

In a study with 20 Colombian maize collections, it was found that larger kernels produced heavier moths and insects developed slower. The variations observed in texture, protein, amylose, fats and sugar content did not affect the number of emerged moths in 19 of the 20 Colombian varieties. Failure to detect differences in insect emergence was no doubt due to relatively minor differences in these components. Influence of seed size of 12 Brazilian collections on weevil and moth development was similar to that observed in the Colombian materials.

**Infestation by stored grain insects in the field**

During the latter part of the crop growing season in 1968, collecting trips were made to Cotaxtla Veracruz; Chontalpa, Tabasco; Río Bravo, Tamaulipas; Tepalcingo, Morelos; and El Batán, Mexico. The objective was to determine the extent to which stored grain insects infested ripening grain prior to harvest.

The collected material was taken to the laboratory for study. The ears were separated into four groups based upon husk extension beyond the tip of the ear. The following classes of husk extension were used: 0-20; 21-50; 51-80; and 81-120 mm. Two locations had substantial numbers of insects, Cotaxtla and Chontalpa. The results are presented in Table M12. It is clear that in tropical climates, a heavy infestation of *S. zeamais* and *Cathartus* spp. occurs while the crop is still in the field. Long tight husks reduce the field infestation but do not completely eliminate this source of early infestation.

<table>
<thead>
<tr>
<th>Length of husk mm</th>
<th>No. of ears</th>
<th>Av. no. of insects per ear</th>
<th>% infested ears</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td><em>S. zeamais</em></td>
<td><em>Cathartus</em> spp.</td>
</tr>
<tr>
<td>Cotaxtla, Veracruz</td>
<td></td>
<td>S. z.</td>
<td>C. spp.</td>
</tr>
<tr>
<td>0-20</td>
<td>15</td>
<td>79</td>
<td>10</td>
</tr>
<tr>
<td>21-50</td>
<td>36</td>
<td>20</td>
<td>6</td>
</tr>
<tr>
<td>51-80</td>
<td>33</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>81-120</td>
<td>17</td>
<td>5</td>
<td>7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Length of husk mm</th>
<th>No. of ears</th>
<th>Av. no. of insects per ear</th>
<th>% infested ears</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td><em>S. zeamais</em></td>
<td><em>Cathartus</em> spp.</td>
</tr>
<tr>
<td>Chontalpa, Tabasco</td>
<td></td>
<td>S. z.</td>
<td>C. spp.</td>
</tr>
<tr>
<td>0-20</td>
<td>20</td>
<td>30</td>
<td>12</td>
</tr>
<tr>
<td>21-50</td>
<td>36</td>
<td>17</td>
<td>8</td>
</tr>
<tr>
<td>51-80</td>
<td>10</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>81-120</td>
<td>0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Effect of opaque-2 on grain moth**

Normal and opaque-2 seeds from a lowland tropical composite segregating for the high lysine mutant were used to study the behaviour of the Angoumois grain moth, *Sitotroga cerealella* Olivier, on these grain types. The treatments consisted of whole and degermed kernels. Little difference was noted on whole kernel sets of either type, although weight of emerged moths was slightly greater on the opaque-2 seeds. Removal of the embryo, which normally is well balanced nutritionally, markedly reduced the numbers and weights of insects. The difference was larger in normal than in opaque-2 seeds (Table M13).

**TABLE M13.** Adults emerged and average weight of *Sitotroga cerealella* (Olivier) reared on normal and opaque kernels of a lowland tropical composite with and without an embryo. Samples infested with 60 eggs and replicated 5 times, Chapingo, 1969.

<table>
<thead>
<tr>
<th>Corn kernels</th>
<th>Av no. of insects emerged</th>
<th>Av. weight per insect emerged, mg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Opaque (whole kernel)</td>
<td>100</td>
<td>58.5</td>
</tr>
<tr>
<td>Opaque (without embryo)</td>
<td>33</td>
<td>49.3</td>
</tr>
<tr>
<td>Normal (whole kernel)</td>
<td>127</td>
<td>56</td>
</tr>
<tr>
<td>Normal (without embryo)</td>
<td>12</td>
<td>35.6</td>
</tr>
</tbody>
</table>

**PROTEIN IMPROVEMENT**

Improved cereals offer one of the most practical ways of increasing the world food supply. More and better protein in maize is particularly desired and within reach.

The improvement and study of protein quantity and quality in maize includes breeding, genetics, cultural practices, and evaluation of nutritional value. The nutritional value of maize would be much higher if its content of the essential amino acids were increased. The high lysine mutants opaque-2 and floury-2 offer one way to raise the nutritional value.

Originally, the program was directed toward the incorporation of opaque-2 and floury-2 into a wide range of maize races available in Mexico. Later, it seemed more appropriate to develop composites with more genetic variability (and having the above mutants present) and adapted to the low, intermediate, and high altitudes of the tropical and semitropical regions. The composite for the low elevations was formed from such races as Tuxpeño, Salvadorino, Cuban Flint, Antigua 2D, Eto Blanco and Blanco de Junio (Composite K). For intermediate elevations, the composite was from mass-selected Puebla Group 1 and Celaya (Composite J); and for the high elevations various selected strains of the Chalqueño race (Composite I).

In all cases, the opaque-2 and/or floury-2 gene was introduced and the materials advanced through two or three generations of backcrossing. Each of the composites was planted in isolation in 1968 and selections made for healthy, vigorous, apparently high yielding plants. The selection intensity was about 5%. The selected ears that exhibited seeds of the mutant character permitted the choosing of these seeds for the following cycle of selection. The frequency of the “high lysine” mutants for the 1969 planting is such that homozygous populations may be available within two generations. Meanwhile, continued selection for agronomic traits of value should result in progressively more promising materials for distribution to farmers. The genetic variability in these populations provides a ready source of desirable materials for rapid selection and adaptation to other tropical and semitropical areas around the world. Seed for this purpose already has been distributed rather widely.

A genetic program is underway to increase the quantity of protein at the same time the protein quality is being improved through use of the high lysine mutants. Crosses between Illinois high protein stocks and some Mexican high altitude races into which opaque-2 had been introduced were the basic materials for this selection program. Maize combining higher total protein and improved quality should be of interest for feeding trials.
Evidence has been obtained of possible advantages of floury-2 over the opaque-2 gene in improving protein quantity and quality. Both mutants are being transferred into tropical materials (Tuxpeño, Cuban flint and ETO). After 2 or 3 backcrosses followed by self-fertilization, samples of 50 ears of each type that showed segregation for the mutant characters (opaque or floury) were chosen. The normal and mutant seeds from each of these ears were analyzed for protein and for tryptophan. The tryptophan level correlates highly with lysine and can be measured much faster. The average results are in Table M14.

Since the background genotype used for both mutants is similar, there is no reason to expect the protein percentage in the normal seeds to be different. Yet the normal seeds in ears segregating for floury-2 averaged 1.45 percentage points (12.5%) higher than normal seeds in ears segregating for opaque-2. Furthermore, the homozygous opaque-2 seeds have only 85.7% as much protein as normal seeds from the same ears (1.67 percentage points lower). Floury-2 seeds had 4.1% more protein (.54 percentage points) than normals from the same ears. The end result is that the percent tryptophan on a sample basis is essentially equal for the 2 mutants. Dominance of floury-2 in some combinations prevents identification of the floury-2 homozygotes. Therefore, the samples analyzed may have lower tryptophan values than would be obtained with homozygous genotypes. To the degree that the values for floury-2 shown in Table M14 are depressed by the inability to detect the homozygous floury-2 seeds, the floury-2 would be the better mutant for improving protein quality in maize. This is aside from the fact that a better overall balance of the essential amino acids results from its use.

### Search for new protein mutants

Using the procedure described in the 1967-68 report, the search for new protein mutants was continued. Ten individuals kernels from each of 30 S₁ ears of Olotillo, Salvadoreño, Querétaro 50, and Pepitilla were analyzed. Protein and tryptophan contents varied considerably. The most promising sample analyzed was in Pepitilla; one family exceeded 1.25% tryptophan in the protein.

The Sᵢ families of Puebla Group 1, which gave relatively high values in the previous season, were grown and S₂ ears produced. The individual ears obtained were analyzed to determine whether homozygous high tryptophan strains existed. The hoped-for extreme tryptophan values did not occur. However, the evidence suggests that quantitative improvement might be obtained through use of the system. Consequently, the procedure is being used to determine whether protein quality can be improved in the population by selection based upon larger numbers of genes having less, but additive, effects in contrast with improvement through use of a major mutant such as floury-2.

### Protein production as related to cultural practices

A study of the interaction of germplasm complexes with varying levels of fertility and planting densities was also used to study effects of these treatments on protein production. Six or seven adapted varieties were planted at each of four locations representing low, intermediate, and high elevations in Mexico. Population densities were 30,000 and 60,000 plants/ha at three fertility levels. Varietal differences in protein and tryptophan were small, but the effect of varying nitrogen levels was rather marked, (Table M15). Grain yields increased sharply and protein values increased slightly with increases in nitrogen fertility. Total protein per hectare rose substantially with increased nitrogen fertilizer. Tryptophan production also increased substantially, although the response varied with location.

Population density affected the recovery of added nitrogen. At both densities, the first increment of nitrogen had the most pronounced effect. The yield increase from the second increment was greater at 60,000 plants/ha than at 30,000.

### Protein values in floury corns of the Andes

Since maize has been important in the diets of people in the Andes for centuries, some have thought that these varieties probably have high nutritional quality. Ing. E. Hernández X. spent several months of 1968 collecting strains of maize in the high elevations in Colombia, Ecuador and Peru. Much of the maize at the higher elevations is floury. Samples

<table>
<thead>
<tr>
<th>Class</th>
<th>% protein (P)</th>
<th>% tryptophan in the protein (T)</th>
<th>% tryptophan in sample (P x T)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>11.59</td>
<td>0.38</td>
<td>0.044</td>
</tr>
<tr>
<td>Opaque-2</td>
<td>9.92</td>
<td>0.81</td>
<td>0.080</td>
</tr>
<tr>
<td>Normal</td>
<td>13.04</td>
<td>0.34</td>
<td>0.044</td>
</tr>
<tr>
<td>Floury-2</td>
<td>13.58</td>
<td>0.57</td>
<td>0.077</td>
</tr>
</tbody>
</table>
The endosperm removed by the drill is treated with hexane to remove fats that might interfere with analysis. Then it is pulverized in the micromill (right). The sample is weighed and hydrolyzed with an enzyme. After a colorimetric reaction, the solution is put in a photocolorimeter to determine the tryptophan content. In corn, lysine can be predicted from its correlation with tryptophan. About 120 samples can be handled in one day.

The search for better protein quality, particularly the content of the essential amino acids lysine and tryptophan is now going forward at the level of the individual kernel. At the CIMMYT laboratory, the tryptophan content of a single kernel can be determined without destroying the seed. This is important, because each kernel on an ear can have a different heredity. Even if only one kernel has the much-wanted high lysine, it may result in an important new variety.

Drilling removes a 40 to 50 milligram sample of endosperm for analysis. The seed will still grow if planted.

This technicon equipment measures colorimetrically the nitrogen content of the sample. It is one of the fastest ways to do it — about 150 samples can be analyzed in one day.
The results of technicon analysis appear as a graph. Each peak is a measurement from which nitrogen can be calculated, using a standard curve, and protein inferred, using a given factor. With this protein value and a separate determination of tryptophan and lysine content in the sample, the percentage of these essential amino acids in the protein is calculated.

The Kjehldahl test for nitrogen is the most common and most time consuming (60-70 samples a day). The percentage of nitrogen multiplied by 6.25 gives the protein content.
TABLE M15. Average yields of grain, protein, and tryptophan for six or seven varieties at La Soledad, Veracruz; Puebla, Puebla; El Batán, México; and Roque, Gro. Varieties were grown at three fertilization levels and two population densities, 1968.

<table>
<thead>
<tr>
<th>Item</th>
<th>30,000 plants/ha</th>
<th></th>
<th></th>
<th>60,000 plants/ha</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low N</td>
<td>Medium N</td>
<td>High N</td>
<td>Low N</td>
<td>Medium N</td>
</tr>
<tr>
<td>Yield (tons/ha)</td>
<td>3.3</td>
<td>5.7</td>
<td>6.6</td>
<td>3.4</td>
<td>6.2</td>
</tr>
<tr>
<td>Difference</td>
<td>+ 2.4</td>
<td>+ 0.9</td>
<td></td>
<td>+ 2.8</td>
<td>+ 1.4</td>
</tr>
<tr>
<td>Protein (kg/ha)</td>
<td>234</td>
<td>430</td>
<td>542</td>
<td>227</td>
<td>421</td>
</tr>
<tr>
<td>Difference</td>
<td>+ 196</td>
<td>+ 112</td>
<td></td>
<td>+ 194</td>
<td>+ 173</td>
</tr>
<tr>
<td>Tryptophan (kg/ha)</td>
<td>1.17</td>
<td>2.01</td>
<td>2.38</td>
<td>1.09</td>
<td>1.98</td>
</tr>
<tr>
<td>Difference</td>
<td>+ .84</td>
<td>+ .37</td>
<td></td>
<td>+ .89</td>
<td>+ .60</td>
</tr>
</tbody>
</table>

from 30 flougy collections were analyzed. The results were negative; high lysine mutants were not found. Total protein was generally very low, probably due in part to poor soil fertility. The total protein ranged from 4.44% to 9.31%. Tryptophan as percent of the sample was also low, ranging from 0.026 to 0.44%. Thus, it appears that high quality protein is not a common characteristic of corns in these areas. These results agree with protein analyses of the Peruvian races made recently by Dr. D. E. Alexander of Illinois.

MAIZE GERM PLASM BANK

The inventory of the 1,926 maize populations stored in the refrigerated room at the National School of Agriculture, Chapingo, Mexico, was completed. Information on origin and location in the bank has been punched in IBM cards and a preliminary list printed. The work of filling seed requests and of listing populations that need to be propagated has been greatly simplified and an inventory of the seed supply of each population is maintained.

Maize bank seed storage at Chapingo, Mexico. Scattered through these drawers are the genes that have increased the world's food supply by millions of tons. Ancestors for other great corns of the future are probably already here.
Agronomic information, disease and insect reaction, and chemical composition data on the populations inventoried were collected and prepared for punching in IBM cards. This will allow the identification and location of collections possessing specific traits.

Seventy-six requests for a total of 1,136 collections were filled and shipped to 31 countries during the 12 months covered by this report. The number of shipments and collections sent are shown in Table M16.

As in previous years, over 50% of all shipments and collections were distributed in the American Hemisphere. The USA continued to request the most shipments (31.5%), and collections (31.6%).

A total of 1,519 new corn accessions collected in Colombia, Ecuador, Mexico, and Peru were inventoried and put in refrigerated storage. Seed of each of these new accessions was also prepared for next year’s planting to allow study and increase as needed.

Some 3,636 maize populations collected in Argentina, Brazil, British Virgin Islands, Bolivia, Colombia, Cuba, Guyana, Mexico, Paraguay, and Uruguay prior to 1954, under the sponsorship of the Committee on Preservation of Indigenous Strains of Maize, were planted and propagated by hand pollination in Tepalcingo, Morelos, Mexico, during the winter of 1968-69. The propagation field covered 11 hectares and close to 100,000 pollinations were made.


<table>
<thead>
<tr>
<th>Destination</th>
<th>No. shipments</th>
<th>No. collections</th>
</tr>
</thead>
<tbody>
<tr>
<td>AFRICA</td>
<td>13 (17%)</td>
<td>264 (23%)</td>
</tr>
<tr>
<td>Cameroon, Ethiopia, Ghana, Ivory Coast, Liberia, Nigeria, Sierra Leone, Togo, UAR, Zambia.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AMERICA</td>
<td>51 (62%)</td>
<td>677 (60%)</td>
</tr>
<tr>
<td>Argentina, Bolivia, Brazil, Colombia, Costa Rica, Chile, Haiti, Mexico, Panama, Paraguay, Peru, Surinam, USA.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ASIA</td>
<td>7 (9%)</td>
<td>182 (16%)</td>
</tr>
<tr>
<td>India, Lebanon, Nepal, Pakistan, Philippines.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EUROPE</td>
<td>4 (5%)</td>
<td>10 (1%)</td>
</tr>
<tr>
<td>France, Sweden.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OCEANIA</td>
<td>1 (1%)</td>
<td>3 (2.6%)</td>
</tr>
<tr>
<td>Fiji.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>76</strong></td>
<td><strong>1,136</strong></td>
</tr>
</tbody>
</table>

Percentages do not equal 100 because of rounding.

It may look like mishmash, but this assortment of materials being grown for the germ plasm bank contains the essential variability on which the breeder can draw for the characteristics he needs in a new variety. He may find resistance to a disease in one kind of maize, strong stalks in another, and combine those with an otherwise desirable line to make a better variety.

GENETICS AND CYTOLOGY

Studies on chromosome morphology and its use in determining relationships among germ plasm complexes throughout Latin America were continued. Further work on B chromosomes confirmed the manner of their transmission as outlined in the previous report.

A method for counting somatic chromosomes

Normal corn plants have 10 chromosome pairs, but some have accessory chromosomes referred to as "B chromosomes." One step in studying B chromosomes was to develop a faster way to detect them. Determining the number of B chromosomes by analyzing microsporocytes or somatic cells undergoing division is slow. Seed must be planted in the field and the microsporocytes collected when the young tassels develop, months later.
The use of somatic cells of the root tips eliminates the disadvantages mentioned above. However, it was necessary to find an effective method for handling a great number of root tips easily. A method was developed that combines those of Tjic and Levan (1950) and Fabergé (1945). The former used 8 hydroxyquinoline instead of colchicine in somatic chromosome analysis and Fabergé used the snail stomach cytase as a hydrolyzing reagent instead of HCl.

Cytase was obtained by collecting snails, Helix aspersa, near Chapingo and removing the stomach by dissection. Some cells in metaphase obtained with this cytological method are shown in the figure.

A single root tip from each seedling is used. Every root tip analyzed represents a plant and the chromosome counts from many plants can be made with a minimum of space for germination of seeds and storage of root tips.

Normal corn has 10 pairs of chromosomes, as in the upper picture. Some maize has an extra one, called the B chromosome. The arrow below points to a B chromosome. It has now been shown that the B chromosome affects the time it takes for maize to flower. Other important influences of the B chromosome remain to be discovered.

Influence of B chromosomes on four plant characters

Certain variations in morphologic or physiologic characters were found to be related to variation in number of B chromosomes.

A variety with 0 to 11 B chromosomes (Nayarit 39, of the race Reventador) was planted at Tepalcingo during the winter of 1967-68. Microsporocytes were collected from tillers of 200 plants and the number of B chromosomes determined. On the same plants, data were recorded for four characters: days to male and female flowering, plant height, and number of tillers. The simple phenotypic correlation coefficients were calculated among several traits. The number of B chromosomes was correlated with days to male flowering and plant height (significant at 5% level). As the number of B chromosomes increased, male flowering was later and plants were shorter.

Days to male flowering, which appears to be affected by the presence of B chromosomes, has a high correlation with plant height (significant at the 1% level). Days to female flowering was not correlated with plant height.

Influence of B chromosomes on pollen grain size and variability

Pollen was collected from 25 plants with different numbers of B chromosomes and 100 grains were measured on each plant.

No statistically significant relationship was found between number of B chromosomes in the plant and average pollen grain size within a range of 0 to 11 B chromosomes. There was no change in the variability of the pollen grain size. We now have evidence that B chromosomes influence flowering. Other ways they may influence the physiology of maize will be studied.

Genetic marker bank

Work continued on the transfer of genetic marker stocks into several tropical backgrounds for future use in the identification and localization of genes of value in the breeding program. Translocation stocks from the maize genetic bank at the University of Illinois are also being transferred to tropical background for future use.

Further work on the genes for “tallo cuadrado” (square stalk) and “tallos gemelos” (twin stalks) is of interest. For example, a cuadrado x normal cross gives an easier means of lowering plant height, because the shorter plant characteristic is partially dominant. The gemelos gene offers one way to increase yield through growing at least two ears per plant.

The tallo cuadrado, a square-stalk mutant, has re-
vealed the more complex nature of its inheritance. A cross was made between tallo cuadrado and the variety Puebla Group 1 and advanced to the F2.

All F1 plants were normal, indicating the recessive nature of the tallo cuadrado gene(s). A noticeable reduction in plant height implied partial dominance for the reduced height of the mutant(s).

Three distinct F2 phenotypes were found: normal, tallo cuadrado, and a new one that was called "tallos gemelos" (twin stalks), since two identical plants developed from a single seed.

All tillers produced by tallo cuadrado plants in the F2 generation were normal.

In F3 tallo cuadrado material, two plants started as tallo cuadrado phenotypes, but when 10-15 cm in height, each formed two normal stalks. The behavior of these materials can be explained by assuming that two apical meristems with varying degrees of independence are involved and that tillers develop from one of the meristems.

Some tallos gemelos plants grow two stalks from a single seed. Others begin with one stalk which then bifurcates.

The character tallos gemelos can be explained assuming that these phenotypes are basically tallo cuadrado but than an additional factor causes independent development of the two apical meristems early in seedling development. The fact that some plants bifurcate strongly supports the postulate of two meristems. Anatomical studies should clarify this point. The postulated explanation of the inheritance of these plant characters is:

1. The segregation in the F2 implies that three pairs of recessive, complementary, and independent genes control the development of these characters.
2. The presence of two recessive genes, tc1 and tc2, in a homozygous condition is necessary for the expression of tallo cuadrado.
3. The character tallos gemelos is expressed only when tc1, tc2, and a third gene, tg, are together in a homozygous state.

The character tallos gemelos appeared in material from Argentina which was segregating for the character tallo cuadrado. Probably the genes for both characters came together in the Argentine stock. To verify the postulates, additional crosses have been made.

Should the postulations be substantiated, tallos gemelos can be introduced into any maize population so each plant will produce at least 2 ears. The maximum number of ears produced per plant

**Bifurcated form of tallos gemelos, or twin stalk maize. This trait may provide one way to increase yield.**
The first-discovered and more common form of tallos gemelos forms two stalks near the ground. Will depend upon its capacity for developing tillers that form ears. Thus, more effective control of prolificacy seems possible. Study of root development in these plants and ontogenetic studies should disclose more about the genetic control of plant development in maize.

Chromosome knob morphology

Chromosome morphology studies give clues to the ancestry of maize races. One kind of morphology study is made to determine knobbed positions and sizes on chromosomes of various races.

Recent collections of the Pepitilla race and several collections from the USA were analyzed cytologically. The 24 Pepitilla collections averaged 9.6 knobs (range 6.0 - 12.0) and appear quite consistent in collections from the several regions. Large sized knobs were found in 21.2% of the cases, medium sized in 62.0%, small in 4.5% and 8.1% had none.

Cytological analyses were made of some North American varieties. Collections from southern areas of the USA had higher total knob numbers (2.0 to 9.3) than did those of the north central areas (1.0 to 4.0) (Table M17). These limited data suggest that maize in the USA is basically a product of at least four knob complexes, Mesa Central knobless, Eastern Mexico, Zapalote, and Southern Guatemala complexes.

Teosinte

Collections of teosinte are made whenever the opportunities permit, usually during excursions made for collecting maize varieties. Some important locations have not yet been visited. Collections made in 1968 revealed some interesting differences in seed sizes. Twelve collections from the Balsas region in Mexico (Guerrero and Michoacan) showed an average seed size ranging from 4.44 to 7.66 g/100 seeds. A sample of 12 collections from the Chalco region (Mexico) ranged in seed size from 9.74 to 16.74 g/100 seeds.

The relationship between Teosinte and maize and the value of Teosinte in modifying certain characteristics of maize will be investigated.

TABLE M17. Mean number of knobbed positions, range, and percent frequency of knob sizes of maize collections from different regions of the United States. Homozygosity and heterozygosity of the knobs are considered. All the knob forming positions of the ten chromosomes are pooled.

<table>
<thead>
<tr>
<th>Regions</th>
<th>No. of collections</th>
<th>Mean knob number range</th>
<th>Mean knob number</th>
<th>Percent frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Oklahoma</td>
<td>16</td>
<td>2.0 - 8.0</td>
<td>6.8</td>
<td>88.1</td>
</tr>
<tr>
<td>Arizona</td>
<td>3</td>
<td>3.0 - 7.0</td>
<td>5.6</td>
<td>73.8</td>
</tr>
<tr>
<td>Texas-Louisiana-Mississippi</td>
<td>5</td>
<td>4.0 - 8.5</td>
<td>6.6</td>
<td>77.5</td>
</tr>
<tr>
<td>Virginia-N.C.-Georgia</td>
<td>6</td>
<td>6.0 - 9.3</td>
<td>7.2</td>
<td>75.6</td>
</tr>
<tr>
<td>N. Dakota-S. Dakota-Nebraska-Towa-Idaho</td>
<td>5</td>
<td>1.0 - 4.0</td>
<td>2.8</td>
<td>91.4</td>
</tr>
</tbody>
</table>
Maíz Ancho

A study was made to determine the origin of Maíz Ancho, the new type of maize found in 1967. The investigation compared Maíz Ancho and races growing in the same general areas, Bolita, Pepitilla, Tabloncillo and Chalqueño. The four listed varieties (races) and their F₁ intercrosses were grown together with 13 of the Maíz Ancho collections. Self-pollinated progenies were used to gain information on the types of plants that segregated out, since these may lead to suggestions relative to possible parentage.

The parentage of Maíz Ancho apparently is Bolita and Tabloncillo or a cross of one of the parental races of each of these. The merits of Maíz Ancho for use in breeding are under study.

TRAINING

During the current year, the maize program worked with 10 in-service trainees. The future scientists who participated in the program are listed below. All were trained in breeding except Mr. Torres, who was in entomology.

<table>
<thead>
<tr>
<th>Name</th>
<th>Country</th>
<th>Months of Training</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carlos N. Pérez Rodas</td>
<td>Guatemala</td>
<td>9</td>
</tr>
<tr>
<td>Bosso N’Guetta</td>
<td>Ivory Coast</td>
<td>6</td>
</tr>
<tr>
<td>Manuel Sandoval Olmedo</td>
<td>El Salvador</td>
<td>12</td>
</tr>
<tr>
<td>Roberto Arguello</td>
<td>Nicaragua</td>
<td>12</td>
</tr>
<tr>
<td>Carlos J. U. Torres</td>
<td>Argentina</td>
<td>6</td>
</tr>
<tr>
<td>Magdi Salama</td>
<td>United Arab Republic</td>
<td>12</td>
</tr>
<tr>
<td>Youssef Katta</td>
<td>United Arab Republic</td>
<td>12</td>
</tr>
<tr>
<td>Mahmoud Ibrahim</td>
<td>United Arab Republic</td>
<td>12</td>
</tr>
<tr>
<td>Ahmed Abdelfattah</td>
<td>United Arab Republic</td>
<td>12</td>
</tr>
<tr>
<td>Roushdy Abdallah</td>
<td>United Arab Republic</td>
<td>12</td>
</tr>
</tbody>
</table>
New varieties and production methods are among the research results that have made it possible for India and Pakistan to follow Mexico's skyrocketing wheat yields. Several other nations are also approaching yield takeoffs.
THE CIMMYT WHEAT PROGRAM is dedicated to increasing world wheat production. To achieve this, it operates in two interrelated fields. First, it conducts research to develop better varieties, to enhance knowledge of disease and insect control, to improve agronomic practices, and to improve wheat quality, from both an industrial and a nutritional standpoint. Second, it participates directly in drawing up and executing plans for accelerated national wheat production programs in India and Pakistan, and within the past year, in Tunisia and Morocco. Indirectly, CIMMYT is involved through such other agencies as U.S. AID, FAO, etc. in similar production programs in Afghanistan, Turkey, Lebanon and Nepal. Several of these production programs have reached the pay-off stage within the past 2 years and others are fast approaching it. Several other countries are interested in obtaining CIMMYT assistance for launching production programs.

The first section of this report summarizes progress made and obstacles met during the past year in the national production programs with which CIMMYT is collaborating. The second section gives more detail on production and research programs by country.

Since the national wheat production programs in Pakistan and India are the most advanced, this report draws heavily on experience in these two programs, to illustrate certain principles and results obtained.

NATIONAL PRODUCTION PROGRAMS

In the spring of 1967, after an extensive trip through the wheat areas of Pakistan and India, the late Grant Cannon wrote an article for the Farm Quarterly entitled “On the Eve of Abundance”. In it he correctly predicted the revolution in wheat production that is now sweeping the subcontinent.

During the past 2 years, the “green revolution” has ripened into golden harvests across vast areas of Asia, and is beginning to spread to parts of Africa. The focal points of the wheat production revolution are Pakistan, India, and Turkey, but its impact will soon be felt in several other countries.

CIMMYT-Mexican wheat varieties have been the catalysts in this revolution. It is estimated that more than 7,457,000 hectares (18,642,500 acres) of CIMMYT-Mexican dwarf wheats or their derivatives (reselections) are now being grown in Asian and North African countries (Table W1). In addition, a considerable but unknown area grows these wheats in South Africa, Rhodesia, Kenya, Guatemala, southwestern USA, and Europe. The total known area sown to Mexican varieties in foreign countries is more than ten times that sown to wheat in Mexico, where the varieties were developed.

For the second consecutive year, production records are being broken in both Pakistan and India. The bountiful harvests of 1968 were produced under conditions nearly ideal for wheat production. Winter rains were adequate and timely spaced over vast areas of the subcontinent. Temperatures were favorable for plant development throughout the growing season, and remained low and favorable for grain formation throughout the ripening period.

Pakistan produced about 7 million metric tons, 2.4 million tons more than the previous all-time high of 1968, and became self-sufficient in wheat. India harvested between 17 and 18 million tons, or 5 to 5½ million tons more than had ever been harvested before. Although there was ample ev-

<table>
<thead>
<tr>
<th>Country</th>
<th>Area sown, 1,000 hectares</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pakistan</td>
<td>2,630</td>
</tr>
<tr>
<td>India</td>
<td>4,451</td>
</tr>
<tr>
<td>Turkey</td>
<td>728</td>
</tr>
<tr>
<td>Afghanistan</td>
<td>150</td>
</tr>
<tr>
<td>Tunisia</td>
<td>12</td>
</tr>
<tr>
<td>Iran</td>
<td>9</td>
</tr>
<tr>
<td>Morocco</td>
<td>5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>7,985</strong></td>
</tr>
</tbody>
</table>
idence that the 1968 success was largely due to the widespread impact of the Mexican dwarf wheats grown under a new technology, many in both countries attributed the bumper harvest to unusually favorable weather.

The current 1969 harvest should convince all skeptics that the green revolution has deep, strong roots. The current season has been very unfavorable for wheat production in both countries, yet record crops are being harvested. The monsoon was cut short with below normal precipitation, and winter was virtually without rain, especially in India. March, when the grain was filling, averaged 5 to 8°F above normal in both countries. Nevertheless, we estimate that the Pakistan harvest will reach 8 million metric tons, a million tons or 14% more than last year. The Indian crop is estimated at 18½ to 19½ million tons, or about 8% more than a year ago.

These production records have been achieved despite a reduction in the area sown to wheat because of the shortage of moisture on the barani (rain-fed) lands in both countries. The expansion of the irrigated area sown to Mexican dwarfs coupled with more widespread use of fertilizers has more than compensated for the reduction in total area sown.

It is estimated that dwarf wheat was sown on 2.6 million ha in Pakistan, and 4.4 million ha in India during the current season. These are increases over last year of 116 and 76%, respectively, in area sown to the high-yielding dwarf varieties.

Turkey, too, has had phenomenal results with the Mexican wheat dwarf varieties. During the 1967-68 season, 170,000 ha were sown with these varieties and an average yield of 4.1 ton/ha was harvested. As a result, 800,000 ha are planted to these varieties during the current crop season, representing most of the area suitable for the cultivation of spring wheats along the Mediterranean and Aegean coasts. The harvest is under way, but no data are yet available.

The area grown to Mexican semi-dwarfs in Afghanistan continues to expand. An estimated 150,000 ha were sown during the present crop season.

Iran for the first time planted a sizeable area to semi-dwarfs. Approximately 9,000 ha of Penjamo 62 and Pitic 62 are being harvested from seed imported from Turkey. Results are highly favorable. Iran is now arranging importation of 300 tons of Inia 66 from Mexico for the 1969 sowing season.

Tunisia is harvesting 12,000 ha of Inia 66, Tobari 66, Jaral 66 and Sonora 63. Although the rainfall this season was considerably below normal, results have been highly favorable. There will be a large increase in area sown to Mexican semi-dwarfs during the next season.

Morocco planted about 5,000 ha to dwarf wheats. The rainfall was more than double the longtime average, and diseases like Septoria and stem and leaf rusts were very severe on both introduced semi-dwarfs and local indigenous varieties.

Commercial areas of undetermined size were grown to the semi-dwarfs in Iraq, Syria, Jordan, Lebanon, Israel, Kenya, Sudan, Rhodesia and South Africa.

Varieties grown

The varietal makeup of the vast area sown to Mexican semi-dwarfs in the Near and Middle East countries is similar to that of 1968. The varieties in order of commercial importance are derivatives of the Mexican cross II 8156, Lerma Rojo 64, Penjamo 62, Inia 66, Tobari 66, Sonora 64, Pitic 62 and Norteño 67. There has been a very great increase during the 1968-69 season in the Heads of Sonalika, one of the new Indian varieties formed from Mexican materials. This high yielding, disease resistant variety will be extensively planted next year. It has large white grain of good quality. The light color is preferred in India.
area sown to derivatives of II-8156, i.e. the white grain derivatives Mexipak 65, Kalyansona, Siete Cerros and Espigas; and the red grain types PV-18, Indus 65, Super X. While they outyield all other varieties, the choice is dangerous because there are races of all three rusts in the Near and Middle East capable of attacking this group. Nevertheless, the only areas where diseases of significance were noted on these varieties during the current season were in Morocco, where septoria leaf and glume blotch severely damaged Siete Cerros, and some areas in Turkey and Lebanon where stripe rust damaged Super X and Siete Cerros.

Lerma Rojo 64, Penjamo 62, Inia 66, Tobari 66, Piti 62 and Norteño 67 provided adequate protection from diseases in all areas where they were grown commercially.

Under the severe Septoria epidemic in Morocco, Tobari 66 and Penjamo 62 gave the best protection. It has become evident that Tobari 66, although slightly lower and somewhat more unstable in yield than the other semi-dwarfs, has a unique spectrum of disease resistance. It has a high degree of resistance throughout the Near and Middle East, North Africa, Europe and North America to the prevalent races of the three rusts as well as to Septoria tritici and mildew.

During the 1968-69 season, the All-India Coordinated Wheat Program took a great stride toward diversifying the types of resistance of their commercial varieties through the further multiplication of the three new varieties, Somalika, Chhoti Lerma, and Safed Lerma. All of these varieties are derived from selections made in India from introduced segregating Mexican materials. They have different types of rust resistance from that of the first Mexican introductions. There will be about 400,000; 350,000, and 30,000 tons of Somalika, Safed Lerma, and Chhoti Lerma seed, respectively. This is enough to sow more than 10 million ha in the 1969 fall plantings. Pakistan is also increasing three new varieties, Mangla 69, Inia 66, Norteño 67, Khushar, Mexipak 69 and Nayab 70, but their seed multiplication program has not moved as aggressively as that of India.

CIMMYT is making every effort to encourage the rapid multiplication and distribution of new high-yielding varieties selected by the national programs, in order to diversify the types of disease resistance in the commercial dwarf varieties of the Near and Middle East. CIMMYT has identified several sister lines from the Mexican cross II-23384 [(CIANO x Sonora 64-Klein Rendidor) x 8156], that significantly outyielded the II-8156 derivatives in Sonora, Mexico, during 1968-69. In Mexico, these lines are resistant to all prevalent races of stem, leaf and stripe rust. On the other hand, all 8,156 derivatives have always shown susceptibility to one or more races of all three rusts. The 23,584 derivatives, generically called "CIMMYT-Bluebird", are in preliminary multiplication at Chapingo. Lots of several kilos each will be shipped to Near and Middle East countries for evaluation during 1969-70.

Expansion of irrigation with tube-wells

The spectacular yields obtained from the cultivation of dwarf wheat during the past 2 years has stimulated the drilling of private tube-wells. Although this development began as early as 1964 and 1965 in Pakistan, before the impact of dwarf wheats, there has been a spectacular increase in 1967 and 1968, under the impulse and fever of the intensive cultivation of dwarf wheats. The fever
has caught on in India, especially during the past 2 years. It is estimated that in each of the past two years, 200,000 privately financed tube-wells were sunk. This program in India has brought 3.2 million ha of land under controlled irrigation, much of it producing wheat during the *rabi* (winter) season. Little information is available on the effective recharge of the aquifers of the Gangetic and Indus basins. This type of research is urgently needed to balance extraction with recharge.

**Second generation problems**

Despite a continuation of the second generation problems of inadequate warehouse facilities, and obsolete and inadequate transport, which first became evident during the record-breaking wheat harvest of 1968, substantial improvements have been made in handling the current harvest. The difficulties of warehousing, however, remain acute, especially in West Pakistan, where more than 700,000 tons of wheat were carried over from last year’s crop. The difficulties were further compounded by a 50% increase in rice production during the 1968 fall harvest. Warehouse construction continues at a rapid pace in both countries, but the storage problem will not be solved without a continuing long-range plan for expanding storage capacity. The storage problem in Mexico today fully supports this view.

Similarly, the problem of transportation will continue. The railroads in India are transporting the crop much more expeditiously than last year, but are short of equipment. Pakistan railroad transport has become even more overextended than last year. There is an extreme shortage of railroad cars, certainly caused in part by the need to transport the large rice crop as well as the larger wheat crop.

Pakistan best illustrates the nature of the new problems that arise from the successful revolution in wheat, rice and maize production.

Pakistan became self-sufficient in production of all cereal grains during 1968, even though it is still deficient in edible oils and proteins. Although there is still a deficit of rice in East Pakistan, both rice and wheat grown in West Pakistan are more than enough to cover this shortage. Consequently, Pakistan now has the production capacity to become a large exporter of both rice and wheat if it can solve the second-generation problems. Some of these include:

1. The development of a satisfactory grading system.
2. A network of suitable grain warehouses.
3. Improvement of its transportation system.
4. Improvement of Karachi port facilities.

Although India has not yet achieved self-sufficiency in food grains it has moved rapidly toward self-sufficiency in wheat production, and will likely reach this goal within the next two years. The total wheat required by India for self-sufficiency depends in a large part on rice production and its availability, since wheat, to a degree, is substituted for rice.

Even though India has not yet made any spectacular increase in rice production, an expanding area is being sown to improved rice varieties and heavily fertilized. As a result, a large increase in rice production is expected within the next 2 years.

**Pricing policy and its implementation**

The government of India, and to a lesser extent, that of Pakistan, has been able to stabilize wheat prices during the peak harvest season for the second consecutive year. Timely government purchases of large quantities of grain in the principal centers of production have stabilized prices. Prices received by Indian farmers in most cases have been close to those established as the floor, or procurement price, or above.

**Impact on gross national product**

The record-breaking wheat harvests of the past 2 years have greatly increased the GNP of both Pakistan and India (Table W2). During 1968, the GNP from wheat was increased by $236 million U.S. in Pakistan and $585 million in India, over that of the record crop of 1965. The current 1969 harvest will add an estimated $294 and $739 million to the GNP of the two countries. The total increase in GNP from wheat in Pakistan for the 2-year period totals $530 million, and for India $1,325 million. The combined increase in GNP for both countries resulting from increased wheat production would therefore be $1,033 million for the 1969 harvest. It is estimated that the wheat production increase in Turkey in 1968 added $80 million to that country’s GNP.

Increased production of maize and rice in the subcontinent is also adding smaller but significant increases to the GNP, especially in West Pakistan.

**Multiplier effects on wheat production**

The revolution in wheat production in both Pakistan and India has had two multiplier effects on production. First, the experience of farmers, government officials, and scientists with the successful transplanting of the high-yielding Mexican wheats and the new production technology has influenced the rate of adoption of new technology in other crops. Once the farmer gains experience, confidence and success with the first crop, he anxiously searches for ways to adopt the new technol-
TABLE W2. The impact of the green revolution on wheat production and GNP in Pakistan and India during 1968 and 1969.

<table>
<thead>
<tr>
<th></th>
<th>Millions of metric tons harvested</th>
<th>Increase in production over 1965, millions of metric tons</th>
<th>Grain price $/ton</th>
<th>Increase in GNP, millions of dollars</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
<td>Total,</td>
<td></td>
</tr>
<tr>
<td>Pakistan</td>
<td>4.6</td>
<td>7.0</td>
<td>8.0</td>
<td>2.4</td>
</tr>
<tr>
<td>India</td>
<td>12.3</td>
<td>18.0</td>
<td>19.5</td>
<td>5.7</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>16.9</td>
<td>25.0</td>
<td>27.5</td>
<td>8.1</td>
</tr>
</tbody>
</table>

1. Grain floor prices: India, Rs 76/100 kg or Rs 76/ton; Pakistan, 1968 = Rs 17/maund (Rs 455.6/ton); Pakistan, 1969 = Rs 15/maund (Rs 402/ton). Rs 7.40 = $1.00 U.S.

* Corrected to remove the effect of the value of the fertilizer input (15%), as suggested by Professor Addvor Aresvik.

The rate of adoption of dwarf rice varieties and synthetics following the breakthrough on wheat in West Pakistan clearly illustrates this principle. The overall impact has rapidly transformed the country from a nation with chronic food deficits to one of surpluses.

The breakthrough in wheat and rice production ushered in a second multiplier effect — multiple cropping and its influence on total food production. Double cropping is not new in the irrigated lands of the subtropics. In the past, however, grain yields of both crops in such a system were extremely low, primarily because of low soil fertility. The introduction of the early-maturing, high-yielding, fertilizer-responsive wheat, rice and maize varieties, new production technology, and cheap fertilizer, drastically altered this picture. Large numbers of farmers are now changing their management in order to produce high yields of two or more crops each year on the same land.

Where formerly scientists concentrated on maximum production in one crop, the new objective is to grow the most grain per hectare per year. Many farmers now harvest 10 to 15 tons/ha of grain per year, using such double cropping patterns as wheat during the winter, followed by a summer crop of rice or maize. These yields are in contrast to a total production of 3 tons of grain per hectare for the two crops before the new technology and varieties were introduced. A few especially talented farmers are effectively using triple cropping systems involving wheat-maize-mustard, wheat-moong-beans-rice, or wheat-rice-potatoes, to greatly expand total production per hectare per year.

The impact on world food outlook

The new yield level of wheat, rice, and maize in several food-deficit countries combined with greatly increased efficiency in multiple cropping systems has drastically changed the outlook for world food production for the next two or three decades. It is now clear that these developments can provide a brief period for bringing population growth into balance with the rapidly expanding demands for more jobs, schools, housing, medical and recreational facilities, as well as that indispensable item — food.

Changes in attitudes

One of the most significant basic changes in both Pakistan and India during the past two years as a result of upward shift in wheat production has been in attitudes. Enthusiasm has displaced despair, which only 2 short years ago permeated the social fabric of the two countries. The farmers' new enthusiasm is infecting government officials, scientists and educators. The pressure is now on the planners to come to grips with the numerous second-generation problems.

In retrospect, many of the fears and predictions of disaster that were voiced against the launching of the accelerated national wheat production programs in both Pakistan and India have failed to materialize.

It was said that the short-strawed varieties would immediately result in a shortage of bhoosa (finely ground straw) for animal feed. This was a myth. The price of bhoosa has collapsed in many areas of Pakistan because of overproduction of straw in the past year. Some areas have so much bhoosa that wheat straw is being burned following the harvest.

Others predicted that red grained dwarfs would never be accepted by the consumer. They were wrong. The original breakthrough in production was made with the semi-dwarf red grained varieties Lerma Rojo 64, Penjamo 62, Sonora 64, PV 18,
Success in boosting wheat yields has created second generation problems. Rail, storage, and marketing facilities are hard pressed to handle the torrent of grain in both India and Pakistan. Photos taken near Delhi.
and Indus 66. Nevertheless, there is a real market preference for the white or amber grained varieties amounting to a premium of 10-20%. This is reflected in the present shift to such varieties as Mexipak 65, Kalyansona, Sonalika, Safed Lerma, Chhoti Lerma and Sharbati Sonora as seed stocks become readily available.

The nitrogen of the red grain, semi-dwarf varieties saved 3 years in achieving the breakthrough in production, since white grain types were not available in Mexico when the original introductions were made.

Those who criticized the governments of India and Pakistan for spending $3 million $5 million respectively, of scarce foreign exchange for the importation of large quantities of Mexican semi-dwarf wheat seed have been proven wrong.

The enormous increases in GNP that have directly resulted from these moves (Table W2) vindicate the two governments’ actions in full. Probably never in the history of agriculture has such an investment had such a large pay-off in such a short time.

Finally, the fears voiced by many critics that the nonreceptivity of the traditional farmer to new varieties and new technology would doom the accelerated wheat production program have been quietly laid to rest in the ashes of the flaming success of the two past harvests.

CIMMYT is proud to have been privileged to play a minor role in the launching and execution of the Indian and Pakistani accelerated wheat production programs that have revolutionized food production in these two countries.

INDIA

The “green revolution” in wheat has become an acknowledged fact. Even the unfavorable growing weather this year did not stop the advance.

Figure W1 shows the remarkable rise in wheat production and average yield per hectare over the past 2 years with the advent of the dwarf varieties. In the 1968-69 crop year, the success of the wheat program was on trial, since the rainfall during the monsoon ended prematurely and the winter rains were nearly absent. Sowings on the rainfed lands were decreased because too little moisture was available for germination.

Under these conditions why did production increase? The answer is a greater area of high yielding varieties, wider use of fertilizer, and increased development of ground water through tube-well drilling. It is estimated that just under 4.4 million hectares were sown to high yielding varieties of wheat compared with last year’s 2.4 million. In the state of Punjab, 1.1 million of the 1.6 million ha of wheat are said to be dwarf varieties. This compares with last year’s 240,000 ha.

Reliable and current statistics on tube-wells are not available. Most of these new wells are powered by stationary diesel units and tractors. Karnal district of Haryana state reports 10,000 additional tube-wells. Punjab estimates 12,000 new tube wells this year and plans to sink 200,000 in the next 5 years. Madhya Pradesh plans 10,000 for the same period. Fertilizer supplies have been reasonably adequate and its use has markedly increased.

There have been many problems, but the enthusiasm of government officials, scientists, and farmers is overcoming these obstacles as they arise. As the other crops, particularly rice, reach the same stage as wheat, India’s cereal problem should be solved for the next two decades. The move to multiple cropping could well change the entire picture and extend this time into the foreseeable future. Family planning and population control are still problems of first importance.
Procurement price support

The central government has established a procurement price of Rs 76.00/quintal throughout the areas where grain is being procured. Stocks are being purchased both by the states and the Food Corporation of India. Mexican red-grained varieties are included under the procurement price and represent a large proportion of stocks now being bought. Farmers tend to market all the red-grain to make sure it is sold at the procurement price, and withhold their indigenous or dwarf amber wheats in the hope of higher prices later in the year. Amber wheats are now selling at a premium of 10-20%. The machinery of procurement seems to be well-stabilized and stocks are being handled expeditiously. The effectiveness of the government pricing policy is illustrated by the May prices reported in the *Times of India* for the Hapur U.P. market (Fig. W2). Superior grades fluctuated above the procurement price but the base price was held.

In the past year, price support provided real stability in the market. It has encouraged farmers to develop more ground water and invest in fertilizers. It has led to confidence on the part of money-lending institutions and borrowers alike. This is reflected in increased borrowings for mechanization and water development. It has provided confidence, brought security, and expanded wheat production.

Fertilizers

Demand for fertilizers is rising rapidly. During 1968-69, the country's production capacity for N and P₂O₅ rose from 715,750 and 416,860 tons to 1,011,750 and 433,590 tons respectively.* These are increases of 41.2% in N and 4.0% in P₂O₅ in one year. Not all plants are producing at capacity, so the actual production figures estimated for 1968-69 are 655,000 and 320,000 tons for the two materials, respectively. Imports in 1968-69 of both nutrients, valued at $245 million U.S., continue to exceed the internal production. Estimated consumption for 1968-69 was 1,200,000 tons of N, 450,000 tons of P₂O₅, and 180,000 tons of K₂O. It is estimated, however, that India's requirements by 1973-74 will be 4.8 million tons of N and 2.4 million tons of P₂O₅. This represents a nearly five-fold increase over the present production capacity for both plant nutrients, if India is to meet her own requirements. This also assumes full capacity of production. By 1972-73, the capacity of present plants, plants under construction, and those licensed, proposed or under consideration could be 3.35 million tons of N and 1.3 million tons of P₂O₅.

* These and succeeding figures taken from *Developments in Fertilizer Production in India*, by C. Sahai, Statistician for the Fertilizer Association of India.

The food grain target for 1973-74 has been set at 130 million tons. The annual increases over these 5 years are therefore about 6 million. If returns are 15:1 for N used, 400,000 tons of additional N would be required each year for food grains alone; if 10:1, 600,000 tons. It is apparent that great effort will be required to advance the fertilizer supply to meet these needs.

Storage, transport and food zones

New storage facilities have been built in district towns and grain markets. New deliveries of wheat after purchase are being put into storage or moved out in orderly fashion to the deficit areas. The main harvest sales are still to come and are expected to be heaviest during early June. The transport facilities will be strained, but the organization has been functioning smoothly. In 1968, 58,000 rail carloads and innumerable trucks were used in transporting grain in a 60-day period in May, June and July. Prior to last year, 70,000 carloads were the most used in a *full* year. When the expected full market rush comes in June, temporary storage will probably be needed, as last year, but officials feel
that grain can be kept out of the weather. There
will be fewer fat rats!

In April, the Government of India enlarged the
previous food zones. There are now only five:
1. In the north, all of the states of the Ganges
Valley and Madhya Pradesh;
2. Maharashtra, Orissa and Goa;
3. Gujarat, Daman, Diu and Nagar Haveli;
4. All states south of the Maharashtra-Orissa
zone;
5. Assam and the Union Territories of that
area.

This arrangement allows a much freer movement
of grain. It will provide faster truck transportation
from state to state and will tend to equalize the
price over a much wider area. The procurement
price is set for the enlarged zones, but farmers
and traders are allowed to sell on the open market
throughout the zone.

Farm mechanization

Tractor production and sales have continued to
grow. In 1966-67, many tractors being produced
were not sold. In 1967-68, all inventories were
liquidated and a waiting list established. Ministry
of Agriculture officials estimate the 1968-69 tractor
demand at 60,000. By 1973-74 it is expected to
reach at least 90,000 units per year. Yearly pro­
duction is now about 20,000 units. This has led
to a 3-year waiting list at some factories. An in­
creasing volume and selection of ancillary tractor
equipment is also being produced and sold with the
tractors.

Mechanical threshing has become very popular.
An additional 10,000 threshers are reported to
have been sold this year in the State of Punjab
alone. Most threshing by bullock trampling has
stopped in the area. Where the change to improved
wheat was undertaken later, or has not yet taken
place, bullock threshing is still the rule.

Hired services for plowing, cultivating and
threshing have become common in some areas. This
practice will probably increase and spread rapidly.

Varietal performance and development

White and amber-seeded dwarf varieties con­tin­
ued taking over the area of the red-seeded varieties
Lerma Rojo 64, Sonora 64 and PV18. However, a
comparatively large area is still in the red vari­
eties. Kalyansona continues to be the most pop­
ular variety of northwestern India, but farmers
are increasingly moving toward Sonalika for its large
grain and market acceptability. The fall of 1969
should see ample white and amber seed to meet
the growers’ needs.

Soaring wheat yields encouraged mechanization
to replace such old ways as this hand win­
nowing.
Machines have replaced this threshing by bullock trampling in most of Punjab State.

RendiJor) 8156) is the outstanding one among all others. Representatives of this cross will be put forward in the program's widespread tests in the coming year. Many other combinations appear very promising. Wheat breeders are becoming interested in the upright leaf characteristics, which are theoretically important, particularly in dense growing, three-gene dwarfs.

Agronomic research

Research on varieties under irrigation was continued and expanded to include new approaches. Since depth of seeding had been investigated over 3 years with essentially the same results, this test was discontinued. Three varieties were grown under 6 rates of N from 0-200 kg. A trial on planting dates, seeding rates and varieties was continued, as was the trial on optimum time of first irrigation with three varieties. A second test to show the critical stages of irrigation will determine which irrigations are most essential to yield. There has been considerable controversy on the advantages of applying fertilizer at one time, in split doses, and whether part might be applied as a foliar spray. An experiment was designed with six different treatments at three rates of N to determine which treatment will return the most.

The need for application of \( P_2O_5 \) in farmers' fields is considered widespread. A test was conducted for the second time on farms at 5 rates of \( P_2O_5 \), from 0 to 80 kg/ha, and one treatment combining 60 kg of \( P_2O_5 \) with 40 kg of \( K_2O \). Wheat has responded to \( P_2O_5 \) in most locations, but seldom to \( K_2O \).

Because of the recent interest in three-gene dwarfs, a trial was designed to test the effect of N levels, row spacing, and seed rate on yield. Four levels of N from 0 to 300 kg/ha were included, with spacing at 15 and 25 cm and seed rates of 100 and 150 kg/ha. When a successful three-gene dwarf is finally identified, this pioneer work will provide a package of practices under which it can be most successfully grown.

It has long been recognized that better agronomic practices could increase yields on dry land. A good deal of work has already been done by a number of institutions. Recently, performance of wheats under dry land conditions has become particularly important. As the yields of wheat under irrigation have moved upward, the farm income from dry land farming has decreased. Prices have come down and yields have not increased.

For the first time this year, the coordinated agronomic program has turned its attention to dry land farming. Three trials were grown. In the first trial, three nitrogen rates were combined with four methods of application on one variety. Application methods included broadcast, broadcast and foliar, shallow placement, and deep placement. In a second trial, five rates of N were applied to three to five varieties. In the third, three varieties were sown at three rates in three row-spacings. These dry land trials are expected to develop principles that can be applied generally in the very large growing area that still depends on rain.

The agronomic research on irrigated culture has been excellent indeed. The program is dynamic and has changed with changing needs. While water is the limiting factor, it is hoped that these trials will demonstrate methods that will add appreciably to the dry land farmers' incomes.

Pathology and entomology

This was essentially a nonrust year in India, undoubtedly due in part to the widespread cultivation of resistant varieties and the consequent limiting of inoculum. The survey for rust was intensified. The Rockefeller and Ford Foundations supplied transportation and temporary pathology staff to help the regular program officers maintain close surveillance throughout north and central India. Trips by a number of program officers sufficed to report on rust development in the south.

Leaf rust appeared during December and was established in the northern part of the Ganges Plain by early January. Cold weather, however, suppressed its development and there was little
damage. Yellow rust first appeared in mid-February, at isolated locations in the north. It was effectively held in check by resistant varieties. Stem rust was virtually absent.

In the western and southern parts of Mysore State, both leaf and stem rust were firmly established by mid-January, but had not yet moved into the northern part of the state or central India. It was significant that the prevalent races severely attacked Kalyansona and somewhat less severely, Sonalika. Fortunately, Lerma Rojo 64, Safed Lemra and S-331 (Chhoti Lerma) were resistant. Sonora 64 was resistant to stem rust, but susceptible to leaf rust. The area sown to irrigated, highly fertilized wheat in Mysore is rapidly expanding and is expected to occupy 300,000 ha next season. It is imperative that only resistant varieties be grown, since this area appears to be the primary source of stem rust infection. The rapid build-up of races virulent on Kalyansona and Sonalika, the main varieties of the Ganges Plain, combined with favorable conditions for early northward spread and early high-temperatures in the north could spell disaster to the wheat crop. Maintaining resistant varieties in this region may indeed be a good method of nearly eliminating the danger from stem rust in the country.

Loose smut has been greatly reduced in the Punjab. Formerly, the state was noted for the high infection in its fields. The immunity of Kalyansona to present races has brought about this reduction. Sonalika, however, appears to have more loose smut this year than formerly. This has become a problem in seed production.

The attack of *Alternaria* was very light. Black point was nearly absent. This is in contrast with last year’s heavy attacks by the organism responsible for these diseases.

The importance of plant pathology cannot be over-emphasized. Without constant surveillance the “green revolution” can become a “black counter-revolution”. The discipline is in urgent need of strengthening, both in numbers of personnel and facilities. Some steps are being taken to improve the situation, but in the meantime very effort must be made to monitor the disease situation. Those few individuals available to work on wheat pathology form a thin line.

Insect attacks have always been considered unimportant on wheat in India. The hairy caterpillar, which first appeared last year, again became important in isolated areas. Fields grown next to those where mustard is grown as an oil crop are attacked when the mustard is harvested. Since mustard is an early maturing crop, wheat can be severely defoliated. Reports are increasing that shoot fly on wheat can be severe. It was noted this year in particular on very late sown wheat and many of the late tillers showed the typical dead heart. Pyrilla, a sucking insect common on sugarcane, became epidemic this year. Rather large concentrations of the insect could be seen on wheat for several meters out from the edge of the sugarcane field. It was evident that they were not moving into the wheat, but were there by accident. Large-scale aerial spraying to protect the sugarcane was employed with good results.

**Quality**

In the past few years, most Indian wheat work has been concerned with increase in quantity, with little emphasis on nutritive quality. The primary need was the closing of the food gap. Quality of cereals in this country is even more important than in the more affluent societies. Unlike the latter, most Indians cannot supplement their diets with animal proteins. About half are vegetarians who can use milk or milk products as a supplement, but this source of protein is becoming very scarce. Further, a large sector of the population is forced to rely on cereals as their main food source for economic reasons. In fact, on an average, about 60% of the protein in the diet comes from cereals. Therefore, quality (the presence of well-balanced amino acids and high digestible protein) is of major importance. Now that quantity in wheat has in part been achieved, more attention must be turned to quality.

An amino acid laboratory has been installed at Delhi and supports the cereal programs. The program is in close contact with the Nebraska center. Many of the existing varieties have been classified for lysine content. It is anticipated that once varieties identified for high lysine enter the breeding programs, this laboratory will identify lines for high lysine for several centers.

Pelshenke and Alveograph tests are also being used. In previous years, a good deal of work was undertaken to perfect techniques. Now the tests are being applied to breeding lines on an organized basis. Unfortunately, staff and facilities are not sufficient to service all the breeding programs and it is urgent that these tests be extended to some of the other centers.

Tests have been worked out that are considered to give a good indication of *chapati* quality. Since the *chapati* is still the main form in which wheat is eaten, these tests will continue to receive major attention. Interest in using wheat as loaf bread is growing in the urban centers. Several bakeries have been started in cooperation with the Australian and Canadian governments. Thus far, only imported wheats have been used for bread. There is no
reason why indigenous wheats cannot be developed for supplying these bakeries. Consequently, lines showing high Pelshenke values and well-balanced doughs (Alveograph) will be tested for bread making potential. The requirements for bread differ from those for the chapati, the best wheats for which have a Pelshenke value in the mid-range of 100-140 minutes.

Physiology
Physiologic studies in wheat are being continued. Most of the work is concerned with developing principles of plant form or physiologic activity that would lead to higher production under dry conditions. Interesting root studies have been conducted. Hypotheses about plant structures better adapted to these conditions have been developed. The work will undoubtedly expand as more physiologists are employed at the new state agricultural universities and other institutions.

Seed production
In 1967-68, production of seed wheat became big business. The amber varieties were in short supply and farmers and state procurement officers made purchases as soon as the seed was processed at production centers. Prices were much above the market price for grain. Farmers learned that seed is not grain, but is a much more valuable commodity. Sufficient stocks of the new amber-seeded varieties were distributed to enable the sowing of large acreages in the country, in particular northwestern India. The picture has changed somewhat for the present year, as seed is much more widely available. There is, however, a considerable market to be filled as the amber-seeded varieties are taken up on an expanding scale in northeastern and southern parts of the country. However, there is no question that the activity in seed circles has diminished, and more of the sales will be made in the pre-sowing season rather than after harvest. This is to be expected and will continue until new varieties with superior characteristics are released. Meanwhile, some of the seed producers have achieved the high standards of production in a very short period.

Extension
The extension service in India has now taken over the further spread of dwarf wheat production and the requisite agronomic practices. Many are doing a very creditable job of improving the production over large areas, but the greatest developments are in the areas surrounding the universities and other agricultural institutions. Improved wheat production is only gradually moving into eastern Uttar Pradesh and Bihar, which have much irrigation potential, and into parts of Peninsular India.

It is very heartening to note the rapid spread of dwarf wheats in Mysore State under the Tungabhadra Irrigation Project. In 1967-68, only 12,000 acres were grown; in 1968-69, 60,000; and in 1969-70, the acreage is expected to reach 300,000. This represents a very significant extension effort by the state officer and the Tennessee U.S. AID team located at Bangalore. A similar development could and should be made in northern Andhra Pradesh.

Extension is also developing the multiple cropping program through demonstrations of its feasibility. This program has had its greatest success in Punjab State.

PAKISTAN
For the second consecutive year, Pakistan is harvesting a record-breaking wheat crop. The changes in production, yield, and area sown to wheat are shown in Figure W3.

The spread of new high yielding dwarfs
The area sown to the so-called Mexican dwarf varieties increased greatly during the 1968-69 crop season. It is estimated that about 2.6 million ha were grown. They represented about 45% of the total area sown to wheat, and 65 to 70% of the production. About 54% of the irrigated wheat area was sown to dwarf varieties, whereas only
18% of the rain-fed wheat area was sown to Mexican dwarfs.

An estimate of the global distribution of Mexican and local varieties and their contribution to the total production of the current crop is shown in Table W3.

There has not only been a rapid shift toward the use of Mexican dwarf wheat varieties within the past year, but also a rapid shift in the area sown to the different dwarf varieties. The increase in the area sown to the white-grain Mexipak 65 variety during the 1968-69 season was spectacular. This is attributable to a price differential of 15 to 20% in favor of the white grain over the red grain types on the free markets in some of the larger cities, especially from December to April.

This shift to the white grain varieties is not uniform in all parts of the country. The red grain varieties Lerma Rojo 64, Penjamo 62 and Indus 66 remain very popular in many areas of the northern region, as well as in some districts of the central and southern regions. Moreover, the variety Inia 66, which was introduced into Pakistan on a small scale in 1967, has been rapidly increasing in sown area because of its high yield and large hard grain, despite its red color.

It is highly desirable to continue to encourage the cultivation of Lerma Rojo 64, Penjamo 62 and Inia 66 wherever they are acceptable, since each has a different type of resistance to stem and leaf rust from that in Mexipak 65 and Indus 66, which are identical. It is undesirable to encourage the exclusive use of a single variety or several varieties with the same type of resistance because of the danger of loss from rust epidemics or other diseases. This point cannot be over-emphasized.

**Varietal performance**

In spite of the government's efforts to obtain detailed data about variety shifts and area covered by each of the new dwarf wheats, this was impossible.

Seed was distributed on a large scale from farmer to farmer, making it difficult to assess accurately the relative distribution of all of the newly released Mexican wheat varieties. In recent years a wheat crop survey had been made by the research staff during February and March. Because of difficulties of travel during this period, this activity was omitted for the 1969 crop.

As this report is being written, the threshing is still in full swing. Only tentative estimates of the varietal distribution are therefore available (Table W4). More accurate data will be reported in the Annual Technical Report issued every year by the Accelerated Wheat Improvement Program of West Pakistan.

Most of the farmers who had grown Mexipak sold their crop as seed to neighbors. The Agricultural Development Corporation, a semi-autonomous body in charge of seed multiplication and distribution, was unable to buy for redistribution any significant amount of Mexipak 65 seed, in spite of utilizing all means of procurement. Premium prices were offered, and sometimes pressures were applied to force farmers to sell them part of their seed.
Mexipak 65 was well scattered throughout the country. Its yield performance, in spite of the adverse weather during March and early April, remained consistently higher than most of the other wheat varieties. Indus 66, the red-grained sister of Mexipak, was the only variety that on the average outyielded Mexipak 65. In some cases it outyielded Mexipak by about 10 to 15%.

Although both Mexipak 65 and Indus 66 are known to be susceptible to some Pakistani races of leaf rust, there was only very light infection anywhere in the country. Diseases were not severe enough to affect yields anywhere in the country during the 1968-69 crop cycle. High temperatures during March and early April adversely influenced yields of both Mexipak 65 and Indus 66. Had it not been for this adverse factor, the large area sown to Mexipak 65 and Indus 66 probably would have added an extra 1.5 million tons of wheat to the 1969 harvest.

Penjamo 62 covered roughly 5% of the total wheat acreage. Its yield remained high, only 10-15% lower than Indus 66 or Mexipak 65. Penjamo 62, in spite of its red color, remains fairly popular among farmers in the Swat State and it also well liked by many farmers in the Sind and in some areas in Sheikhpura District.

No disease attacks were reported on Penjamo 62. It remains resistant to all the prevalent Pakistani races of leaf, stem, and stripe rusts.

The rusticity of Penjamo 62 appears to be the reason for the preference of some farmers for cultivating this variety, even when prices about 20% higher are being offered for white-grained varieties.

Inia 66 was the fourth most important dwarf

This combine demonstration in Pakistan is part of the attack on new problems of harvesting the greater production.

TABLE W4. Estimated distribution of Mexican dwarf varieties in West Pakistan during the 1968-69 season.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Millions of acres</th>
<th>Percent of total acres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mexipak 65</td>
<td>5200</td>
<td>80</td>
</tr>
<tr>
<td>Indus 66</td>
<td>650</td>
<td>10</td>
</tr>
<tr>
<td>Penjamo 62</td>
<td>325</td>
<td>5</td>
</tr>
<tr>
<td>Inia 66</td>
<td>130</td>
<td>2</td>
</tr>
<tr>
<td>Others (Lerma Rojo 64, Sonora 64 &amp; Norteño 67)</td>
<td>195</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>6500</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>
variety grown last season. When Inia 66 and Mexipak 65 are planted early (October 15-Nov. 15), Mexipak 65 outyields Inia 65 by about 20%. When they are planted during mid-season, the two varieties yield equally, and when planted late (November 20-December 31) after paddy, cotton or maize, Inia 66 consistently outyields Mexipak 65. Owing to its relatively short growing cycle, Inia 66 may become widely grown, especially among the progressive farmers who are increasing their cropping intensity.

Inia 66 was found to be highly tolerant to water logging, resistant to Pakistan stem and stripe rust races, and fairly resistant to leaf rust.

Lerma Rojo 64 and Sonora 64 have been declining in cultivated area. The newer white grain variety, Norteño 67, is growing in popularity. Farmers are buying seed on the black market at double the price of seed of the other dwarf varieties. Because of its long white grain and its short cycle, Norteño 67 may become widely grown in Pakistan.

About 8 million acres were planted to local tall varieties during 1968-69. The most important tall strawed varieties were C-273, Dirk, C-271 and H-68. Their relative preponderance is estimated in Table W5.

The greatest acreage of C-273 was concentrated in the central region. Dirk was equally distributed in the central and northern regions. C-271 was mainly found in the central region, while all of the H-68 was planted in the Sind. C-591 and C-228 were the predominant wheat varieties in rain-fed areas.

### Wheat research

The breeding program to develop superior new wheat varieties continues to make good progress. The number of crosses made has been increased yearly to get greater variability into the breeding materials, and thereby increase the chances of selecting better plant types with higher yields and more resistance to all diseases prevalent in the country.

Most of the advanced lines have been tested for disease reaction in the greenhouse at the Murree Cereal Disease Laboratory and under induced epidemic conditions at Khagan Valley during the summer.

On the basis of yield performance in the Institutes' yield trials and in the province-wide network of micro-plot variety trials, lines have been selected for multiplication. Several are being considered as possible varieties for release to the farmers during the next year of two.

The most promising lines are now in the stage of preliminary multiplication. The range of adaptability, yield performance, and disease resistance in future trials will determine which ones will be named and distributed as commercial varieties.

One of the most promising groups of lines in early stages of yield evaluation are some triple dwarfs selected from the Mexican cross II-23584 = [(Ciano x Sonora 64-Klein Rendidor) x 8156]. The best of these will be included in a series of agronomic tests during 1969-70 season.

### Teamwork approach

The research in Pakistan continues to be well coordinated among the research staff of the three different agricultural research institutes.

The team approach to wheat improvement is taking root throughout west Pakistan. Research workers from three institutes jointly plan the breeding program, seed preparation, planting, and harvest. The data from all trials are prepared and published in a single annual report.

A single summer nursery is planted each year in the northern hills to screen the breeding materials from all three institutes for rust resistance, and to speed the varietal development program.

### Staff development

The Accelerated Wheat Improvement Program in Pakistan has actively promoted the training of scientists and officials during the past 5 years. The number of individuals and type of training provided are in Table W7.

The Government of Pakistan recognizes the diploma given by CIMMYT in Mexico as a basis for promotion and salary advances for all the wheat research staff in Pakistan.

Most of the 16 "trainees" sent for observation tours were government officials directly or indirectly engaged at policy level in aspects of wheat research and production. Among this group were top officials of the Ministries of Agriculture of both the central and provincial governments, as well as members of both planning commissions.

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### TABLE W5. Estimated acreage of local tall varieties during the 1968-69 season.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Millions of acres</th>
<th>% of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-273</td>
<td>3200</td>
<td>40</td>
</tr>
<tr>
<td>Dirk</td>
<td>3200</td>
<td>40</td>
</tr>
<tr>
<td>C-271</td>
<td>800</td>
<td>10</td>
</tr>
<tr>
<td>H-69</td>
<td>400</td>
<td>5</td>
</tr>
<tr>
<td>Others (C-591, C-228)</td>
<td>400</td>
<td>5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>8000</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>
The fear that never materialized. A shortage of bhoosa (chopped straw) was predicted as a result of the introduction of dwarf wheats. Actually, bhoosa is now so abundant in many areas that there is no market for it. The farmer is showing Drs. R. Glenn Anderson and S. Qureshi his carry-over from last year.

Price supports

The government lowered the support price (floor) on wheat from Rs 17/maund ($98.20 U.S. per metric ton) to Rs 15/maund ($86.60/ton) during April, 1969. The government has tried to maintain the floor price, but there are reports that many farmers were forced to sell their wheat for Rs 12 or 13 instead of for the official price.

Government policy had already reduced farm income by lowering the fertilizer subsidy from 50% to 35% in July, 1968. Fiscal policy will largely influence wheat production in the 1969-70 season.

Fertilizer use and prices

The widespread use of high-yielding fertilizer-responsive dwarf wheat and rice varieties has revolutionized the use of fertilizer in Pakistan over the past three years. An estimated 315,000 tons of nutrients were used during the 1968-69 crop cycle. Of this total an estimated 115,000 tons of nutrients were applied to the wheat crop. Thus, for the second consecutive year, the fertilizer applied to the wheat crop increased 50%. Only about 25% of all fertilizer used is from domestic production. The import requirements for fertilizer will continue to exceed the expansion of fertilizer production capacity.

Pakistani farmers are now convinced of the value of nitrogen and have been rapidly increasing...
the consumption of nitrogenous fertilizers. Many are not yet convinced of the value of phosphate and consequently have been slow to use enough. More than half of the farmers who use fertilizer apply only nitrogen. Those who do use phosphate almost without exception apply much less than is needed for optimum economic yields. The current recommended fertilizer for wheat under full irrigation is 120-60-0. Nevertheless, the proportions of nitrogen to phosphorus used on the 1967-68 and 1968-69 wheat crops were 14:1 and 6:1 respectively. The under use of phosphate is one of the main things preventing higher yields on hundreds of thousands of farms where nitrogenous fertilizers are being applied.

During the past season, the Government of Pakistan imported considerable diammonium phosphate to circumvent this extension problem. This approach was highly successful, and accounts in a large part for increasing the proportion of phosphate consumption, compared to that of nitrogen. Continued expansion of imports of diammonium phosphate and other mixed fertilizers high in phosphate would correct this production bottleneck.

**MEXICO: JOINT CIMMYT-INIA PROGRAM**

**Commercial production**

Mexico is currently completing a record-breaking harvest. Despite a considerable reduction in the area sown to wheat, production is expected to reach a new high. The State of Sonora, for example, recently reported a harvest 1,080,000 tons from 281,000 hectares. The average yield of 3,843 kg/ha is an all-time record. It is estimated that the national average yield will reach 3,000 kg/ha (Figure W4). Yields throughout the entire Northwest (Sonora, Sinaloa and Baja California) as well as northern Mexico will probably reach an all-time high.

Only in the Bajio are yields lower than usual. Two things are responsible: poor handling of irrigations during the unseasonably warm March and early April, and inadequate fertilization, especially nitrogen. Farmers have not modified their fertilizer application to meet the changing cropping pattern in the region. Wheat is increasingly sown after a summer crop of grain sorghum, and soil nutrients are heavily depleted. The former practice was to plant wheat after maize, where residual fertility is expected.

Diseases had little effect on yield in any of the wheat-producing areas. Stem rust (*Puccinia graminis tritici*) was in a few areas, but only in trace or low levels of intensity, even on susceptible varieties. Although leaf rust (*Puccinia recondita*) became widespread on late plantings in the northwest, it did no appreciable damage.

Inia 66 was the most extensively grown variety during the current season, probably representing 75% of the area grown to wheat. It is characterized by high yield potential (being exceeded only by Siete Cerros or Super X), and good resistance to stem rust, adequate resistance to stripe rust (*Puccinia glumarum*), but susceptibility to leaf rust. Despite its susceptibility to leaf rust, it maintained its characteristically high grain test weight and good yield, even from extremely late plantings where leaf rust infection was heavy. Inia 66 has the highest grain test weight of all Mexican varieties, past or present. This year, virtually all commercial production of this variety had test weights of 81 to 83 kg/ha.

This year in the absence of stem rust, the susceptible varieties Siete Cerros, Super X and Penjamo 62 again yielded spectacularly. Because of their susceptibility to stem rust, these varieties are recommended only for the drier climates of northern Mexico. Tobari 66, Noroeste 66, Nortefño 67, Ciano 67 and Azteca 67 performed satisfactorily but were consistently outyielded by Inia 66, Siete Cerros, Super X and Penjamo 62. Moreover, Tobari 66, Ciano 66 and Azteca 67 show instability of yield.

A new high-yielding soft wheat variety is needed urgently to replace Lerma Rojo 64, which has been rapidly displaced by such strong gluten varieties as Inia 66, Ciano 67, Azteca 67, Tobari 66 and

![W4. Cultivated area, production, and yield of wheat in Mexico, 1925-69.](image-url)
Second generation problems do not disappear quickly. Mexico has at least tripled its warehouse capacity. But warehouses were more than half-filled with soybeans and maize when the 1969 wheat harvest began. Fortunately, Sonora’s dry season extends at least 2 months beyond the harvest, unlike Pakistan and India, where the monsoon rains follow soon after the harvest.

Noroeste 66. Norteno 67 has an unusual balance between good dough strength and extensibility. It would be very desirable, therefore, for blending with stronger wheats to produce different types of flour. Because Norteno 67 tends to shatter in the field, it will not likely occupy a large commercial acreage.

**Development of new bread wheat varieties**

The diverse Mexican bread wheat gene pool is constantly being modified to improve it further. Twice each year, more than 1,000 new crosses are made in an attempt to incorporate new valuable characters into the pool. This enhances the pos-
sibility of selecting varieties superior to the best ones now being grown in the spring wheat areas of the world.

The CIMMYT staff has a unique advantage for guiding the modification and improvement of the Mexican gene pool, because of its close personal contact with spring wheat breeding programs and problems in India, Pakistan, Egypt, Kenya, Tunisia, Australia, Argentina, Brazil, Chile, Ecuador, Colombia, Canada and Mexico. Through these contacts, CIMMYT scientists draw on the strength of each of the programs in the aforementioned countries. Each program is attempting to overcome the principal factors that limit wheat production in the area where the program is located. Using the high yielding, fertilizer-responsive, light-insensitive Mexican dwarf wheat varieties as a breeding base, the country programs are incorporating into them the outstanding characteristics or strengths needed to meet the specific problems of their regions. As these stocks pass back to CIMMYT and are again recrossed, it should become possible to make further significant, rapid progress in spring wheat varietal improvement for use in many parts of the world.

Attempts are being made to improve the gene pool from the following standpoints:

1. higher yield
2. improved phenotype, including shorter and stronger straw and adequate strength of glumes
3. a broader spectrum of resistance to the three rusts
4. resistance to *Septoria* (leaf and glume blotch), to *Fusarium* (scab) and to *Erysiphe* (powdery mildew), none of which occur or are important in Mexico
5. improvements in milling and baking quality
6. improvement in nutritional quality through breeding and selection for higher total protein and improved balance in the essential amino acids.

Many different techniques are being used to incorporate this variability into the Mexican gene pool, including the use of single, backcross, three-way, and multiple crosses. In recent years, double crosses between two outstanding *F1* single crosses of different genetic background have been used frequently. Outstanding *F2* plants from exceptionally outstanding *F1* plants, indexed for their strength and weakness, have been crossed with other outstanding lines and varieties with good success.

This vast and diverse Mexican gene pool is sampled and sent to collaborators in other parts of the world twice each year. Materials sent to collaborators include one or more of the following groups, depending upon the facilities and experience of the recipient scientists:

1. Unselected *F2* bulk seed from the Toluca summer nursery, and from the CIANO winter nursery.
2. Modified *F2* bulk populations from the 20 most outstanding *F2* populations grown in the Toluca summer nursery. After individual plants have been selected from the Mexican program, all diseased and tall plants are removed and all of the remaining plants are harvested together to form the selected or modified *F2* bulk. These populations are extremely valuable in other parts of the world, since they have been screened for resistance to the diverse virulence gene pool present in North American races of stem rust (*P. graminis tritici*) and stripe rust (*P. glumarum*). With this background of selection they are likely to yield a high percentage of plants with resistance to both rusts in the recipient country.
3. Two screening nurseries, one made up from lines harvested in the Toluca summer nursery and the other from lines from the CIANO winter nursery, are sent to collaborators in many countries. These include lines that are being entered in yield tests in Mexico and represent various stages of selection from the *F2* to *F6*.

Seed of outstanding individual plants that have been reselected from these or other populations in collaborating countries under different selection pressures are returned to Mexico for recrossing into the Mexican gene pool whenever possible.

This phase of the program interchange needs further strengthening. The importance of this international cooperation and its desirable effect on long-range wheat breeding cannot be overemphasized.

**1968-69 performance of genetic material at CIANO**

During the past season in CIANO, 800 experimental lines, varying from *F4* to *F7* were grown in replicated yield trials in which the main commercial varieties were used as checks. Only lines with adequate resistance to the rusts and to lodging and shattering were harvested for grain yields. Further, only those lines that yielded as much as the highest yielding commercial check variety included in the same experiment were submitted to the laboratory for preliminary tests of grain test weight, grain protein, Alveogram, and Mixogram analyses. Those passing these tests are being evaluated for milling and baking properties.

In the aforementioned tests, 53 outstanding lines were identified, yielding from 6,302 to 9,313 kg/ha. Although some of these lines are still
segregating or are heterogeneous, all have been included in the CIANO 1969 screening nursery being distributed to collaborators in other countries. The best 10 lines, considering grain yield, plant and grain characteristics, disease resistance and quality, are being multiplied in small plots this summer at the CIMMYT experiment station of El Batán, near Chapingo. These 10 lines are included in Table W8. (To simplify this table, information on the other 43 lines is omitted. However, tables with the information on all the 53 promising lines are available upon request at the CIMMYT Wheat Program.)

Several of the most outstanding lines entering preliminary multiplication are derived from the Mexican cross II 23584 [(CIANO x Sonora 64-Klein Rendidor) x Siete Cerros]. A number of these, on the basis of one season's yield tests, appear to have a higher yield potential than Siete Cerros or Super X. All have good resistance to prevalent races of the three rusts in Mexico. In this respect, they are far superior to Siete Cerros, Super X, Mexipak 65, Indus 66, Kalyansona and PV-18. Seven lines are shorter than Siete Cerros; three are classified in the triple dwarf height class. Five of the lines have white grain and two are red. Unfortunately, all of these lines appear to have dough that is somewhat tenacious; they will be better for use in chapatis than in pan type bread.

Seed from the preliminary multiplication plots will be sent to India, Pakistan, Turkey, Lebanon, Tunisia and Morocco for evaluation. It is quite probable that some of the selections from cross 23584 made either in Mexico, Pakistan, or India will be suitable for replacing Kalyansona, Mexipak, and Siete Cerros. The same cross has given rise to many promising selections in all three countries.

**Development of new durum varieties**

Durum wheats are extensively grown in Morocco, Algeria, Tunisia and Libya. Extensive areas are planted to durums in Turkey, Syria, and other Near East countries.

With the expansion of CIMMYT activities into

**TABLE W8.** The 10 most promising bread wheat lines identified in preliminary yield tests conducted in CIANO during the 1968-69 season.1

<table>
<thead>
<tr>
<th>Var. No.</th>
<th>Exp. No.</th>
<th>Variety or cross</th>
<th>Yield kg/ha</th>
<th>% of highest check</th>
<th>Grain kg/hl</th>
<th>Puccinia recondita</th>
<th>Alveogram P/G W</th>
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<tr>
<td>647 XXVI</td>
<td>CIANO x Son 64-KL rend./8156 II-23584-26Y-2M-2Y-0M</td>
<td>8708</td>
<td>.112</td>
<td>R</td>
<td>81.3</td>
<td>O-TrMS</td>
<td>4.2 333</td>
</tr>
<tr>
<td>675 XXVII</td>
<td>CIANO &quot;S&quot; x INIA &quot;S&quot; x II-23999-52T-1M-3Y 0M</td>
<td>8099</td>
<td>103</td>
<td>R</td>
<td>82.3</td>
<td>30MS</td>
<td>2.7</td>
</tr>
<tr>
<td>703 XXIX</td>
<td>Tob 66 x CIANO &quot;S&quot; II-25000-6M-2Y-0M</td>
<td>7037</td>
<td>98</td>
<td>R</td>
<td>83.0</td>
<td>TrS</td>
<td>2.7</td>
</tr>
<tr>
<td>710 XXIX</td>
<td>CIANO &quot;S&quot; x INIA &quot;S&quot; x II-23999-13T-1M-5Y-0M</td>
<td>7286</td>
<td>101</td>
<td>R</td>
<td>80.8</td>
<td>TrR-TrS</td>
<td>2.4</td>
</tr>
<tr>
<td>733 XXX</td>
<td>INIA &quot;S&quot; x Napo II-22402-6M-4Y-1M-1Y-0M</td>
<td>7020</td>
<td>110</td>
<td>R</td>
<td>81.1</td>
<td>30MS</td>
<td>2.1</td>
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<td>993 XL</td>
<td>CIANO x Son 64-KL rend./8156 II-23584-18M-10Y-3M-3Y-0M</td>
<td>7172</td>
<td>107</td>
<td>B</td>
<td>82.2</td>
<td>10S</td>
<td>3.4</td>
</tr>
<tr>
<td>1016 XLI</td>
<td>CIANO x Son 64-KL rend./8156 II-23584-26Y-2M-1Y-0M</td>
<td>9313</td>
<td>120</td>
<td>Seq.</td>
<td>81.4</td>
<td>TrMS-S</td>
<td>5.5</td>
</tr>
<tr>
<td>1032 XLII</td>
<td>CIANO x Son 64-KL rend./8156 II-23584-37Y-2M-2Y-0M</td>
<td>7453</td>
<td>106</td>
<td>B</td>
<td>82.7</td>
<td>O-TrS</td>
<td>4.1</td>
</tr>
<tr>
<td>1614 LXI</td>
<td>CIANO x Son 64-KL rend./8156 II-23584-6M-9R-2M-0Y</td>
<td>8186</td>
<td>106</td>
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<td>80.9</td>
<td>10MS-S</td>
<td>3.7</td>
</tr>
<tr>
<td>2621 CV</td>
<td>CIANO x Son 64-KL rend./8156 II-23584-15Y-6M-0Y</td>
<td>8890</td>
<td>123</td>
<td>B</td>
<td>83.3</td>
<td>O-TrMR</td>
<td>2.8</td>
</tr>
</tbody>
</table>

1 All of these lines are in preliminary multiplication in the summer of 1969; All lines shown here did not lodge. In all, 53 lines were selected; information about them is available from CIMMYT on request.
the Near East and North Africa, higher yielding, light-insensitive dwarf durums with more yield stability are urgently needed. Oviachic 65, the only dwarf durum variety in cultivation in Mexico, lacks both yield stability and light insensitivity. During the 1968-69 crop season, 42 advanced durum lines out of 88 tested, outyielded the bread wheat variety Inia 66. Of these, 14 yielded more than 8 tons/ha. The best 10 crosses are listed in Table W9.

Thirty eight of the top yielding lines from this year’s tests in CIANO are being put into an international screening nursery to assess their yield stability and range of adaptability to other environments.

**Table W9. The most promising durum wheat lines in yield tests at CIANO, 1968-69.**

<table>
<thead>
<tr>
<th>Variety No.</th>
<th>Pedigree</th>
<th>Yield kg/ha % of Inia 66</th>
</tr>
</thead>
<tbody>
<tr>
<td>V-03266</td>
<td>(LD 357E-Tc x D # 2-Tc²) Lak II-21279-6M-2R-11M-0Y</td>
<td>8458 123</td>
</tr>
<tr>
<td>V-03254</td>
<td>BYE-Tc² II-21276-3Y-6Y-1Y-0Y</td>
<td>8338 121</td>
</tr>
<tr>
<td>V-03253</td>
<td>BYE-Tc² II-21276-3Y-1Y-1Y-0Y</td>
<td>8333 121</td>
</tr>
<tr>
<td>V-03252</td>
<td>Anhinga “S” II-22234-9M-2Y-0Y</td>
<td>8302 120</td>
</tr>
<tr>
<td>V-065</td>
<td>Brant “S” II-24102-4R-3M-1Y-0M</td>
<td>8297 120</td>
</tr>
<tr>
<td>V-03</td>
<td>(TMe-Tc²/Z-B x W) (BYE-Tc²/Tace-Tc²) II-25609-6M-0Y-0Y</td>
<td>8261 120</td>
</tr>
<tr>
<td>V-066</td>
<td>Brant “S” II-24102-10Y-1M-2Y-0M</td>
<td>8244 120</td>
</tr>
<tr>
<td>V-03258</td>
<td>TMe-Tc²/Z-B x W II-21584-100M-103Y-100M-100Y-105C-0Y</td>
<td>8156 118</td>
</tr>
<tr>
<td>V-047</td>
<td>(LD 357E-Tc²) (TMe-Tc²/Z-B x W) II-23619-8M-1Y-2M-0Y</td>
<td>8125 118</td>
</tr>
<tr>
<td>V-067</td>
<td>(BYE-Tc x Stw 63/Z-B x W) (TMe-Tc²/Z-B x W) II-23055-45M-5Y-1M-1Y-0M</td>
<td>8063 117</td>
</tr>
<tr>
<td>V-045</td>
<td>(BYE-Tc x Stw 63/Z-B x W) (TMe-Tc²/Z-B x W) II-23055-56M-5Y-2M-0Y</td>
<td>8049 117</td>
</tr>
<tr>
<td>V-063</td>
<td>Albatros II-21570-91Y-6R-1M-0Y</td>
<td>8005 116</td>
</tr>
<tr>
<td></td>
<td>Oviachic 4 reps.</td>
<td>7170 112</td>
</tr>
<tr>
<td></td>
<td>Inia 66 16 reps.</td>
<td>6867 100</td>
</tr>
</tbody>
</table>
CIMMYT is organizing the First International Durum Yield Nursery, which will be sent to collaborators in countries interested in durum wheats. Five of the best yielders from the CIMMYT program in Mexico are included in this test.

Most of the available CIMMYT durums have excellent agronomic architecture. Many are light-insensitive, have fair fertility, good seed characteristics and resist diseases prevalent in Mexico. However, almost all of them are backcross derivatives built upon a very narrow genetic base. Hence, attempts are being made to widen the genetic base while retaining the plant characteristics. To attain this end, the USDA World Durum Wheat Collection was grown in CIANO and crosses were made between the Mexican dwarfs and the most promising lines. Crosses were also made with varieties from Canada, Chile, Italy, Portugal, Tunisia and the United States. Since most of the introduced varieties used as parents in these crosses have many defects, it is planned to grow very large F² populations. To increase the pace of the program during the coming season, we will also make many top crosses and double crosses involving superior F₁s. The success of these types of crosses depends upon the size of the F₁ and F₂ populations and the amount of selection pressure applied. With the widening of genetic base, and with the plant morphology already available, it is hoped that dwarf durums will soon be developed that combine high yield, yield stability, light insensitivity, wide adaptation and good disease resistance.

Durum wheats are also used as parents in the triticales breeding program. Therefore, improved yield and agronomic type and wider genetic diversity in durums also will be valuable for incorporating greater diversity into the triticale.

Increasing the spectrum of disease resistance

The relatively broad spectrum of rust resistance has been one reason for the successful transplant of Mexican dwarfs to many countries in Africa, Asia and the Americas. Nevertheless, there is an urgent need to both broaden the spectrum and to increase in depth the genes for resistance to the rusts and other diseases in the CIMMYT gene pool.

Within the past year, three plant pathologists have been added to the CIMMYT staff. Their main efforts are being devoted to increasing our background information on the genes for pathogenicity in the stem rust pathogen (P. graminis tritici) and leaf rust organism (P. recondita) in Mexico. This information will be used to introduce additional genes for resistance to these pathogens into the breeding program.

Although leaf and glume blotch caused by Septoria tritici occurs in Mexico and especially in the summer Toluca nursery, it seldom reaches epidemic proportions. Consequently, it is impossible to select for resistance effectively under Mexican conditions. Other diseases such as fusarium head blight (scab) and powdery mildew (Erisyphe sp.) are rare and never epidemic. In these cases too, it is impossible to bring heavy selection pressure to bear on populations segregating for resistance.

The introduction of Mexican dwarfs into many other parts of the world in the past two years has shown the need for incorporating resistance to Septoria, Fusarium, and Erisyphe into the Mexican gene pool. This will be attempted immediately by close collaboration with different national programs in countries where these diseases often are epidemic.

Septoria and Erisyphe screening nurseries will be established in collaboration with the national wheat programs in Tunisia, Morocco, and the new wheat improvement program in Brazil. Seed from lines with a high resistance to these diseases will be sent back to CIMMYT to upgrade the resistance of the gene pool.

Similarly, Pergamino, Argentina and a place in southern Brazil will be used as locations to identify unusual levels of resistance to Fusarium. Outstanding lines identified at these locations will also be returned to CIMMYT for incorporation into the gene pool.

If an effective liaison and flow of genetic material can be maintained between the screening nurseries and CIMMYT, and vice-versa, the breadth and spectrum of disease resistance in the CIMMYT gene pool will expand. Then the pool can provide even better genetic materials to the collaborating countries than now.

Breeding for improved nutritional quality

About 2 years ago, CIMMYT began a program in collaboration with the University of Nebraska to increase the nutritional value of wheat. This was a two-pronged attack to increase the total grain protein content, and to improve the essential amino acid balance.

A large number of single crosses between the high-yielding Mexican dwarfs and varieties with high grain protein content and others with high lysine content, have been of little value. Without exception, they have given few segregates with acceptable phenotypes, even when large F₂ populations have been grown.

Consequently, the approach is being revised. The single crosses are being remade, and double crosses between F₁s of these single crosses will be
made to increase the number of plants with acceptable phenotype. Only plants with acceptable phenotypes will be screened for total protein and lysine.

**Breeding high yielding semi-winter wheat**

In certain areas of the world, wheats with a semi-winter habit are better suited for cultivation than either highly frost-resistant, late-maturing winter habit varieties, or than frost-susceptible, spring habit varieties, or than frost-susceptible, spring habit varieties. Parts of the highlands of Turkey, Iran and Afghanistan need varieties of this type. Dr. A. J. Rupert, of the CIMMYT staff, based at the University of California in Davis, is organizing a breeding program to produce such varieties. The high-yielding dwarf spring wheat types, i.e. Mexican and Chilean, will be intercrossed with high-yielding, semi-winter varieties of French origin.

**Distribution of experimental seed**

One of CIMMYT’s main contributions to wheat and triticale research and production is through providing a continuing flow of experimental lines and varieties to collaborators throughout the world. The materials sent out by CIMMYT represent the Mexican bread wheat, durum wheat, and triticale gene pools, which are continuously upgraded through new crosses. Depending upon the facilities and scientific personnel available in the recipient countries, and availability of adequate quantities of seed, one or more of the following sets of materials are shipped to collaborators:

1. the international spring wheat (bread) yield nursery
2. the international durum yield nursery
3. the international triticale yield nursery
4. F₂ bulk bread wheats
5. F₂ bulk durum wheats
6. F₂ bulk triticales
7. F₃ bulk bread wheats — screened in F₂ generation for stem and stripe rust in the Toluca summer nursery
8. bread wheat screening nursery “A”, the F₃ to F₄ lines harvested in CIANO during the winter season.
9. bread wheat screening nursery “B”, the best F₃ to F₄ lines harvested in the Toluca summer nursery.

Many more samples of experimental seeds were shipped during 1968-69 than in the previous year. Experimental samples of seed were shipped to many collaborators in 61 countries in past years (Table W10).

Moreover, two new international yield nurseries, one for durum wheats and the other for triticales, are being prepared for world-wide distribution for the first time.

A new CIMMYT staff member will be responsible for the organization of the international yield nurseries, the screening nurseries, and for handling and interpreting all data relating to these nurseries.

**MEXICO: CIMMYT HYBRID WHEAT RESEARCH**

During the first four years of hybrid research, the main effort was on determining whether lines could be developed that would completely restore the fertility to cytoplasmic sterile lines carrying *Triticum timopheevi* cytoplasm. The successful development of such lines was necessary to determine the feasibility of commercial hybrids. During the past two years, nine restorer lines have been devel-

The high yielding variety Siete Cerros in Mexico, its home. Although it also yields well in the Near East and in Asia, it is susceptible to Septoria and certain rusts. It has been a valuable parent in breeding other lines.
TABLE W10. Seed shipments 1968-69.

<table>
<thead>
<tr>
<th>Countries</th>
<th>ISWYN(^1)</th>
<th>ISN(^1)</th>
<th>Comm.</th>
<th>vars.</th>
<th>Advanced</th>
<th>F(_1)</th>
<th>F(_2)</th>
<th>Durum</th>
<th>Tritic.</th>
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<td>Germany</td>
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<td>X</td>
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</table>

\(^1\) ISWYN = International Spring Wheat Yield Nursery; ISN = International Screening Nursery.

* Small set.

opied that can completely restore fertility to a number of cytoplasmic sterile lines, under certain environments.*

In the second cycle of restorer line development, restorers combining the following characteristics are being sought:

1. greater stability of restoring capabilities under a wider range of environments
2. shorter and stronger straw
3. broader spectrum of disease resistance, especially rust resistance
4. improved milling and baking properties

* Tables listing restorer lines and their pedigrees, and cytoplasmic sterile lines as well as their effect on restoration of fertility are available from CIMMYT Wheat Program on request.

These improvements are being sought by inter-crossing all of the promising restorers that were developed from single crosses in the first cycle of breeding. During each of the past two generations, about 1500 different test crosses of promising plants from these intercrossovers have been made and studied. Only plants showing a desirable combination of high fertility, good agronomic type and adequate disease resistance are used in these test crosses. As a result of this approach, many very promising restorer lines in the F\(_3\) to F\(_5\) appear to combine many of the aforementioned desirable characteristics. These lines promise hybrids in the future that will be far superior to the experimental hybrids tested so far.

A growing body of evidence from both Mexico and India indicates that there may be many reces-
sive "chromosomal sterility genes," independent of the cytoplasmic restorer genes, that influence fertility in conventional wheat varieties. Three of these recessive "sterility genes" have been isolated in a series of double dwarf lines derived from a Norin 10 x Mexican cross. There may be many others still unidentified. These partially fertile lines range in sterility from 98% down to about 5%, depending on whether three, two or single genes are involved. The degree of sterility expressed varies considerably in a given line, whether a single, double or triple recessive, under different environments. Is it possible that this set of chromosomal sterility genes interacting with the genes for restoration in the cytoplasmic sterile system account for much of the inadequately explained instability in restoration of the latter under a range of different environments?

**Basic considerations in developing restoration of fertility in hybrids**

There is increasing evidence of a great deal of specificity in restoration of fertility in experimental hybrids. Some restorers are effective in restoring fertility, either partially or completely, to only one sterile; others appear to be equally effective on several steriles. Sterile lines also differ markedly in the ease with which they are restored when crossed with a number of different restorers. For example, the sterile [(21931-Chap53 x An) x Y50]7 is considered to be very easily restored to fertility. The restorer Nad. 63 x (Lerma Raja 64 x Sonora 64 2) restore very little fertility to a number of other steriles, yet are completely effective on the aforementioned line.

It has become clear in the past two years that a group of several unrelated steriles must be used as the females in test crosses for evaluating the restoration capabilities of lines being developed as restorers. Unless this is done, potentially valuable restorer lines will be overlooked because of poor performance in test crosses. In 1964 and 1965, only Sonora 64 and Penjamo 62 steriles were used in testing the restoration capabilities of plants being evaluated as restorers. Several very promising Sonora 64 derivatives showing excellent anther development and normal pollen were used as "restorer or pollen parents". All test cross "F1 hybrids" were completely sterile. During the past two years, several very promising Sonora 64 restorers have been identified from this same material as the spectrum of sterile lines used as females in test crosses has been broadened.

The unfortunate selection of too narrow a spectrum of sterile lines for use in test crosses in the first two years set back development of the hybrid program several years.

An attempt is being made to evaluate the fertility-restoring ability of all lines being studied as potential restorers on a minimum of 10 different unselected steriles.

The steriles now in use as screening for restorers are: Ciano, Sonora 64, Noroeste 66, Inia 66, Tobiari 66, Lerma Rojo 64 x Sonora 64, (Tezanos Pinto Precoz x Sonora 64), [(21931-Chapingo 53 x Andes) Yaqui 50] and Jalarsib and 10 (Penjamo-Gabo x (Tezanos Pinto Precos-Knott 2).

**Distribution of restorers and steriles**

During the past year, CIMMYT distributed small samples of five first-cycle (single cross) restorer lines to research organizations, both public and private. These probably cannot be used directly to produce a commercial hybrid because of a number of defects, but are valuable research tools.

These restorers are:

1. Penjamo 62 H 169-65-1-J-1C-105Y,
2. Lerm Rojo 64A x 8156 (R) H 107-65-8Y-2M-1Y-OM,
3. (Lerma Rojo 64 x Sonora 64 2) H-2-65-2Y-2C-1Y-OM,
4. Lerm Rojo 64 2 H 78-64A-2C-1Y-1C-5Y-1C-0Y,
5. Nadadores 63 x (Lerma Rojo 64-Sonora 64) H 411-65-1Y-3C-102Y-0C.

Currently, a very large number of cytoplasmic sterile lines are in various stages of development. Several steriles including Nadadores 63, Sonora 64, Inia 66, Noroeste 66 and (Lerma Rojo 64 x Sonora 64) and Combiner have been increased to a point where they can be planted in large strips during the 1969-70 season for studies of problems in commercial hybrid seed production. Small samples of these steriles also have been distributed to research organizations.

Small samples of restorer lines and sterile lines are available for distribution upon written request.

**Triticale research**

The improvement of triticcales from the early days of research on this man-made species up until the spring of 1968 was stymied by several seemingly insurmountable obstacles. The two most important obstacles were partial sterility and shrunken endosperms.

Research at CIMMYT during 1968-69 has broken through both of these barriers. There are now ex-
Highly fertile triticales have been isolated by CIMMYT. This fertility has been checked through four generations in three very different environments in the past 1½ years and can be transmitted to progeny.

cellent opportunities for further improvement on all fronts.

In April, 1968, a number of F₁ hexaploid triticale plants, derived from a three-way cross between three hexaploid triticales, were found to have a high degree of fertility. The progeny from these original plants have since been grown and reselected twice in two widely different environments, and have given rise to homozygous, true breeding, highly fertile lines. The second generation was grown during the summer of 1968 under heavy rainfall at Toluca, which favors partial sterility in conventional wheat varieties, in hybrid wheat varieties, and in all previously studied triticales. The third generation of these lines was regrown at CIANO during 1968-69.

Many homozygous fertile lines are now available for yield evaluation and for distribution to collaborators. Seventeen of the best are described in Table W11.

Several of the highly fertile lines, all of which had shorter heads than many of the larger spiked, highly sterile types, were crossed with the latter in

Treatment of a wheat x rye seedling with colchicine. The alkaloid doubles the chromosome complement of the F₁, which will give rise to a partially fertile triticale.

<table>
<thead>
<tr>
<th>PC no.</th>
<th>Identity and cross number</th>
<th>Grain yield g/15 m²</th>
<th>Seed grade Y68-69</th>
<th>% lodging early at harvest</th>
<th>Leaf rust reaction</th>
<th>Seed grade MV68</th>
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<tr>
<td>PC-34</td>
<td>Bruin-34 X 653-4M-6Y-1M-0Y</td>
<td>8285</td>
<td>2*</td>
<td>0</td>
<td>10</td>
<td>Otr</td>
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<tr>
<td>PC-40</td>
<td>10 X 653-17M-6Y-2M-0Y</td>
<td>8035</td>
<td>2</td>
<td>10</td>
<td>40</td>
<td>5MR</td>
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<td>PC-46</td>
<td>10 X 653-17M-8Y-2M-0Y</td>
<td>9095</td>
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<td>0</td>
<td>10S</td>
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<td>PC-79</td>
<td>195-17Y-2M-3Y-1M-0Y</td>
<td>8680</td>
<td>3</td>
<td>0</td>
<td>10</td>
<td>30MS</td>
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<td>PC-90</td>
<td>Bronco-90 X 224-15Y-2M-1Y-1M-0Y</td>
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<td>2</td>
<td>0</td>
<td>0</td>
<td>5MS</td>
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<td>PC-101</td>
<td>273-4M-2M-1Y-1M-0Y</td>
<td>8125</td>
<td>2</td>
<td>0</td>
<td>30</td>
<td>5S</td>
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<tr>
<td>PC-103</td>
<td>4Y-2M-2M-3Y-1M-0Y</td>
<td>7455</td>
<td>2</td>
<td>10</td>
<td>10</td>
<td>80S</td>
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<td>PC-129</td>
<td>Armadillo X 308-17Y-4M-2Y-2M-0Y</td>
<td>7655</td>
<td>2</td>
<td>0</td>
<td>30</td>
<td>0</td>
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<td>9130</td>
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<td>5</td>
<td>30</td>
<td>30R</td>
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<td>40</td>
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<td>1</td>
<td>5</td>
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<td>0</td>
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<td>8350</td>
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<td>0</td>
<td>60</td>
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<td>PC-181</td>
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<tr>
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<td>9300</td>
<td>2</td>
<td>40</td>
<td>40</td>
<td>30S</td>
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<tr>
<td>PC-214</td>
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<td>9000</td>
<td>1</td>
<td>0</td>
<td>0</td>
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* Seed grade from 1 (best) to 4 (discard).

Toluca last summer. The F₁ plants from these crosses closely approached the fertile parent in fertility when grown in CIANO during the 1968-69 season. This indicates that the high degree of fertility is heritable and can be transferred.

Fortunately, many of the highly fertile lines also have fairly good seed, far better than most other partially sterile types. This is another very great secondary advantage. However, still other more or less fertile lines were found during May 1969 which had even plumper and better filled grain than the highly fertile types. One of these lines, probably not yet homozygous for this character, had grain test weights of 73.6 kg/hl (58.8 lb/bushel). Crosses between the highly fertile types and these outstanding grain types will be made during the summer of 1969.

Lines of triticales are now available with the following combinations of characteristics:

1. high floret fertility with fair to good endosperm (grain) types but with tall weak straw.
2. good to very good grain (endosperm) in tall, weak-straw types.
3. dwarf triticales with strong straw but highly sterile.
4. lines with daylength insensitivity but tall straw
5. tall, weak-strawed types with good rust resistance.

A program to intercross all of these types by first making a large number of F₁ single crosses and later many double crosses between F₁ triticales is under way. Growing large F₂ populations of these future crosses and then subjecting them to strong selection pressure for all of the factors that currently limit the productiveness of triticales will almost certainly result in very rapid genetic improvement.

During the past year, a great deal of useful comparative basic information was obtained on the variability in floret fertility and seed weight and plumpness in triticales, durum wheat, and bread wheats, Table W12.

Detailed basic studies have also been made to determine the relative compatibilities involving reciprocal crosses in all combinations, between wheats, ryes, and triticales, Table W13. This information will be extremely useful for increasing the efficiency in further crossing designed to increase the variability in triticales.

During the past year, many new triticales have been made at both the octoploid and hexaploid levels. Much greater success was encountered by crossing bread wheats and ryes to subsequently form new octoploid triticales than with the formation of new hexaploid triticales, Table W14. However, improvements in embryo culture techniques, combined with improvements in handling the subsequent colchicine treatments are now at least in part circumventing the former difficulties in the formation of new hexaploid triticales.

Quite a few new octoploid triticales have been made, involving crosses between high yielding dwarf Mexican bread wheats possessing good milling, baking and grain quality characteristics and several different ryes. This has been done for two reasons.
First, to re-examine the feasibility of developing a high yielding triticale with acceptable bread baking properties, and second, to serve as a "bridging species" for further improvement of hexaploid triticale through future intercrosses. Since it is much more expedient to make new octaploid triticales than to make new hexaploid triticales, this indirect approach to further improvement of the latter triticale appears feasible.

<table>
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<tr>
<th>Species combination</th>
<th>Total number of spikes pollinated</th>
<th>florets pollinated</th>
<th>seed obtained</th>
<th>% seeds</th>
<th>% Germ.</th>
<th>No. of parent combinations attempted</th>
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<tr>
<td><em>T. durum</em> x <em>T. durum</em></td>
<td>445</td>
<td>11947</td>
<td>5215</td>
<td>43.6</td>
<td>80-90</td>
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<td>Triticales x triticales</td>
<td>815</td>
<td>21799</td>
<td>4319</td>
<td>19.8</td>
<td>40-50</td>
<td>425</td>
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<tr>
<td><em>T. durum</em> x rye</td>
<td>164</td>
<td>4141</td>
<td>926</td>
<td>22.4</td>
<td>&gt;1%</td>
<td>98</td>
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<tr>
<td>Bread wheat x rye</td>
<td>158</td>
<td>3900</td>
<td>415</td>
<td>10.6</td>
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<td>86</td>
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<tr>
<td>Triticales x rye</td>
<td>79</td>
<td>2055</td>
<td>344</td>
<td>16.7</td>
<td>20-30</td>
<td>49</td>
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<tr>
<td>Bread wheat x triticales</td>
<td>200</td>
<td>4884</td>
<td>1196</td>
<td>24.5</td>
<td>&gt;2%</td>
<td>103</td>
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<tr>
<td><em>T. durum</em> x triticales</td>
<td>114</td>
<td>3121</td>
<td>452</td>
<td>14.5</td>
<td>&gt;4%</td>
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<tr>
<td><em>T. durum</em> x bread wheat</td>
<td>27</td>
<td>698</td>
<td>194</td>
<td>27.8</td>
<td>10-15</td>
<td>16</td>
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**CROSSES MADE AT CIANO 1968-69 (WINTER):**

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<th>Species combination</th>
<th>Total number of spikes pollinated</th>
<th>florets pollinated</th>
<th>seed obtained</th>
<th>% seeds</th>
<th>% Germ.</th>
<th>No. of parent combinations attempted</th>
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<tr>
<td><em>T. durum</em> x rye¹</td>
<td>3552</td>
<td>609</td>
<td>17.1</td>
<td>±15</td>
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<td><em>T. vulgare</em> x triticales</td>
<td>1806</td>
<td>567</td>
<td>31.4</td>
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<tr>
<td>Triticales x <em>T. vulgare</em></td>
<td>190</td>
<td>0</td>
<td>0</td>
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<td></td>
<td></td>
</tr>
<tr>
<td><em>T. durum</em> x triticales</td>
<td>238</td>
<td>45</td>
<td>18.9</td>
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<tr>
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<td>0.5</td>
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<tr>
<td>Triticales x rye</td>
<td>188</td>
<td>17</td>
<td>9.0</td>
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¹ Embryos were excised 15 to 35 days after pollination and cultured on nutrient agar media.

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<th>Generation</th>
<th>Identity</th>
<th>Chromosome no.</th>
<th>No. spikes examined</th>
<th>Av. spike length cm</th>
<th>Av. no. spikelets</th>
<th>Av. no. seeds/spike</th>
<th>Av. no. florets/spike</th>
<th>% florets with seed</th>
<th>Av. no. seed/spikelet</th>
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<tr>
<td>Maya-1R A₁</td>
<td>Inia x rye</td>
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<td>10</td>
<td>16.0</td>
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<td>89</td>
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<td>Inia x rye</td>
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<td>10</td>
<td>15.7</td>
<td>13.6</td>
<td>30</td>
<td>93</td>
<td>33.4</td>
<td>1.8</td>
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<td>10</td>
<td>17.0</td>
<td>13.1</td>
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<td>84</td>
<td>69.3</td>
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<tr>
<td>&quot; 2P A₁</td>
<td>Inia x Guarda X 1517-04¹</td>
<td>56</td>
<td>10</td>
<td>16.0</td>
<td>12.8</td>
<td>38</td>
<td>81</td>
<td>71.1</td>
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<tr>
<td>&quot; 3P A₁</td>
<td>Inia x Guarda X 1518-04¹</td>
<td>56</td>
<td>10</td>
<td>16.2</td>
<td>13.2</td>
<td>64</td>
<td>92</td>
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<td>&quot; 4P A₁</td>
<td>Inia x Guarda X 1519-04¹</td>
<td>56</td>
<td>10</td>
<td>14.4</td>
<td>13.3</td>
<td>56</td>
<td>105</td>
<td>53.2</td>
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<td>&quot; 3P A₁</td>
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<td>10</td>
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<td>13.3</td>
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<tr>
<td>&quot; 6P A₁</td>
<td>Inia x Guarda X 1521-04¹</td>
<td>56</td>
<td>10</td>
<td>14.9</td>
<td>12.3</td>
<td>53</td>
<td>87</td>
<td>61.4</td>
<td>2.2</td>
</tr>
<tr>
<td>&quot; 7P A₁</td>
<td>Inia x Guarda X 1522-04¹</td>
<td>56</td>
<td>10</td>
<td>14.6</td>
<td>12.6</td>
<td>48</td>
<td>93</td>
<td>50.8</td>
<td>1.9</td>
</tr>
<tr>
<td>Average all A₁'s</td>
<td></td>
<td>90</td>
<td>15.6</td>
<td>13.0</td>
<td>54</td>
<td>86</td>
<td>60.2</td>
<td>2.1</td>
<td></td>
</tr>
</tbody>
</table>

Amphiploids produced at CIANO in 1968-69:

<table>
<thead>
<tr>
<th>Generation</th>
<th>Identity</th>
<th>Chromosome no.</th>
<th>No. spikes examined</th>
<th>Av. spike length cm</th>
<th>Av. no. spikelets</th>
<th>Av. no. seeds/spike</th>
<th>Av. no. florets/spike</th>
<th>% florets with seed</th>
<th>Av. no. seed/spikelet</th>
</tr>
</thead>
<tbody>
<tr>
<td>DR-28 A₁</td>
<td>Durum x rye</td>
<td>42</td>
<td>2</td>
<td>17.0</td>
<td>16.0</td>
<td>43</td>
<td>121</td>
<td>35.5</td>
<td>2.7</td>
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<tr>
<td>HR-5 A₁</td>
<td>Inia x rye</td>
<td>56</td>
<td>2</td>
<td>19.0</td>
<td>14.0</td>
<td>31</td>
<td>104</td>
<td>29.8</td>
<td>2.3</td>
</tr>
<tr>
<td>HR-6 A₁</td>
<td>Nortefio x rye</td>
<td>56</td>
<td>2</td>
<td>18.0</td>
<td>12.0</td>
<td>18</td>
<td>85</td>
<td>21.1</td>
<td>1.5</td>
</tr>
</tbody>
</table>

¹ A₁ = The second generation of the amphiploid.
X = Represents cross numbers given to the hybrids and subsequent amphiploids.
A₁ = The amphiploid tillers produced by doubling the F₁ hybrid.
CIMMYT is now distributing small experimental samples of triticales to any legitimate research organization interested in initiating or expanding research on this species.

An international triticale yield nursery is being prepared by CIMMYT for distribution to collaborators in different parts of the world. This nursery will include 10 experimental CIMMYT triticales, the recently released commercial Canadian triticale variety Rosner, a dwarf durum wheat variety, two dwarf bread wheat varieties, and a barley variety.

The progress that has been made in triticale improvement at CIMMYT during 1968-69 has been fantastic. It has resulted in the identification and isolation of the genes that were needed to make this man-made species a challenger to the venerable position of wheat, and oats, as a food grain, and to barley as a feed grain. It may also have a future in some areas as a winter forage.

The time has now arrived to launch a major research effort to further improve this species.

Training

The value of the CIMMYT in-service training cannot be over-emphasized. Without it, it is highly improbable that Pakistan could have successfully launched and won the battle of the accelerated wheat program. Many countries, such as Afghanistan, Tunisia and Morocco, are trying to launch national production programs with only a very few qualified scientists. Under a training grant from U.S. AID, CIMMYT is attempting to increase the number of trainees from these and other countries to provide additional leadership as soon as possible. During the past year a new staff member was appointed to handle the CIMMYT in-service training program.

The wheat program worked with 23 in-service trainees from 6 nations this past year. Since this was the most trainees that had participated in the wheat program at any one time, CIMMYT asked two senior scientists to assist in the training program for about 2 months this spring in CIANO. These two worked closely with the trainees in the field and held classes and seminars in plant breeding and genetics. These classes were particularly useful and relevant, because of the great diversity in the previous education of the trainees. In addition, CIMMYT's entire breeding program was available for use as an excellent practical laboratory to relate the classroom discussions to the work in the field. The trainees also studied certain production problems.

Two CIMMYT soil scientists spent approximately 1 month with the trainees working on fertilizer determinations under field conditions, date of planting trials, and varietal trials.

<table>
<thead>
<tr>
<th>Name</th>
<th>Country</th>
<th>Months of training</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mohammad K. Eltiya</td>
<td>Afghanistan</td>
<td>8</td>
</tr>
<tr>
<td>Mohammad H. Malikzai</td>
<td>Afghanistan</td>
<td>8</td>
</tr>
<tr>
<td>Sayed Pacha</td>
<td>Afghanistan</td>
<td>8</td>
</tr>
<tr>
<td>Mohammed Sofi</td>
<td>Afghanistan</td>
<td>12</td>
</tr>
<tr>
<td>Abdul Wakil</td>
<td>Afghanistan</td>
<td>12</td>
</tr>
<tr>
<td>Alfeu E. de Campos</td>
<td>Brazil</td>
<td>4</td>
</tr>
<tr>
<td>Valentín Azañón López</td>
<td>Guatemala</td>
<td>6</td>
</tr>
<tr>
<td>Tayeb El Harrak</td>
<td>Morocco</td>
<td>8</td>
</tr>
<tr>
<td>Houcine El Mniai</td>
<td>Morocco</td>
<td>8</td>
</tr>
<tr>
<td>Miloud Khlifi</td>
<td>Morocco</td>
<td>8</td>
</tr>
<tr>
<td>Mohammad Tourkmani</td>
<td>Morocco</td>
<td>8</td>
</tr>
<tr>
<td>Syed M. Afzal Shah</td>
<td>Pakistan</td>
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<tr>
<td>Sufi M. Ahmed</td>
<td>Pakistan</td>
<td>12</td>
</tr>
<tr>
<td>Umed Ali Arain (Cereal Technology)</td>
<td>Pakistan</td>
<td>12</td>
</tr>
<tr>
<td>Muhammad S. Qari</td>
<td>Pakistan</td>
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</tr>
<tr>
<td>Abdul Samad</td>
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<td>Abdus Sattar</td>
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<td>Ghulam Siddig</td>
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<tr>
<td>Chedlv Ben Diemia</td>
<td>Tunisia</td>
<td>4</td>
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<tr>
<td>Taoufik Ben Salah</td>
<td>Tunisia</td>
<td>8</td>
</tr>
<tr>
<td>Habib Ennajjar</td>
<td>Tunisia</td>
<td>6</td>
</tr>
<tr>
<td>Fredj Mhiri</td>
<td>Tunisia</td>
<td>6</td>
</tr>
</tbody>
</table>
Training includes the use of machinery. The introduction of new wheats is stimulating mechanization in many countries.
At CIANO, Dr. Borlaug teaches agronomic terms in Spanish. Training is given in both English and Spanish. CIMMYT staff, visiting scientists who teach, and trainees come from many different nations. Below: graduation.

CIMMYT wheat research staff

CIMMYT continues to receive requests from many countries for assistance in organizing national wheat production and research programs. The challenge can only be accepted within the limits of the ability of the CIMMYT staff to participate adequately and give proper guidance to such new undertakings. To over-extend the staff will only mean failures. Additions of more of scientists to the CIMMYT staff would provide little immediate assistance for expanding such activities, for new staff members must obtain several years of experience working closely with CIMMYT or one of its affiliated programs before they are likely to be effective in launching a program in a new country. For this reason, Drs. Ignacio Narváez and R. Glenn Anderson will expand their activities into other countries that have asked CIMMYT for help in wheat production and research.

TUNISIA

Two years ago, the Government of Tunisia, with technical assistance from U.S. AID, established the Project for Increase of Cereal Production (ACPP). The major original effort centered around increasing the production of wheat, Tunisia's most important cereal. Several Mexican dwarf varieties were introduced and evaluated successfully in
the 1967-68 crop season. During the summer of 1968, CIMMYT was invited to help develop this program. This challenge was accepted and five scientists were sent to Tunisia in time for the 1968 planting season. The team consisted of:

1. A wheat breeder with experience in the All-India Coordinated Wheat Program; he will also help the Moroccan wheat program.
2. A production research agronomist with rich experience in research and management of dry land wheat production.
3. A production agronomist to develop research on fertilizer requirements.
4. Two production agronomists to help extension apply new technology to wheat production; one was assigned to assist the Moroccan wheat program.

Tunisia cultivates about 1 million hectares of wheat. Virtually all of this is dry land winter rainfall production. The 10 year average production is 550,000 metric tons, and the annual consumption is 800,000 tons. Approximately two-thirds of the production is bread wheat, and the remainder is durum.

The Tunisian national wheat production program was spectacularly successful during the 1968-69 season. The weather favored the growth of Mexican dwarfs in that the winter temperatures were normally mild and the spring was cloudy and cool. Rainfall was 20 to 60% below average but well distributed over most of the season and yields of 2,000 to 3,000 kg/ha were obtained on 250-300 mm of rainfall where good management was used.

About 12,000 ha were sown to Mexican dwarfs during the 1968-69 season. The varieties used were Inia 66 (4,250 ha), Tobari 66 (4,250 ha), Jaral (1,750 ha), and Sonora 63 (1,750 ha). Despite the shortage of moisture, the results were very good. On the basis of the outstanding performance of the Mexican dwarfs during the current season, plans have been revised upward from the original projections of 50,000 ha to be sown during 1969-70, to 150,000 ha.

Production and production research

The production management program in Tunisia in 1968-69 involved over 12,000 ha of production and multiplication. About 5,500 ha were planted for multiplication of seed of Inia 66 and Tobari 66 imported from Mexico and the USA in 1969. The remainder of the production was from locally produced seed. Most of the wheat was harvested by June 25, but not all of the yield data are available. The average yield will be between 1,500 and 2,000 kg/ha for all of the production of wheat, and somewhat less on the multiplication. A higher percentage of the multiplication was planted in the lower rainfall area, where normally weeds and loose smut were not much of a problem, but the management on this was generally much poorer than in the production fields.

In the production fields, Inia 66 was the best commercial variety. It appears to be the most widely adapted in both the dry and the heavy rainfall regions. In the areas with 350 mm or more rainfall, Tobari 66 was about equal to Inia 66, but did not yield as well in the lower rainfall area. Sonora 63, Siete Cerros, and Jaral yielded less but were generally better than local varieties. Siete Cerros and Sonora 63 were too late in maturity for this year's rainfall patterns and the grain in general was shrivelled. Jaral was early but the yield potential is less and it was also more severely damaged by birds. Birds were a serious problem in both Inia 66 and Jaral 66 this year; since these varieties were earlier than local varieties, the birds concentrated on them. Tobari 66 seems to be less attractive to birds. Next year, with an estimated 150,000 ha of Mexican wheat production, there will be less concentration of birds in the early fields, but the total damage from birds will be just as much.

Diseases were not a problem in Tunisia this year. Isolated infections of leaf, stem, and yellow rust developed late and did not reduce yield much. Septoria and mildew occurred but had little adverse effect on yield. Loose smut was present in all Mexican varieties except Siete Cerros in small amounts. Even the new seed from Mexico and the USA was infected. This poses a threat of increased damage if the weather favors infection. About 300 tons of seed will be treated with Vitavax for initial increase of smut-free seed next year. In fields that had two or more consecutive crops of wheat or cereal, take all (Ophiobolus graminis) was present in small amounts and reduced yield seriously in one field. The fact that this disease is present indicates the need for rotation with no more than two consecutive crops of wheat or cereal.

The most serious production problem in Tunisia is lack of weed control. Infestations of wild oats are heavy in much of the high production area, and are spreading rapidly. In one of the experimental areas with wild oat infestations, 120 plots were harvested in a rate and date of seeding trial. The average yields of wheat were 3,400, 2,400, 1,700, 1,500, 1,500, 1,300, and 1,200 kg/ha where wild oats were estimated at 0, 30, 40, 50, 60 and 70% of the plant population, respectively. Other weeds are also serious and some are
not controlled by 2,4-D. The Mexican varieties with their short straw, in general are not as competitive with wild oats as the taller local varieties. More wheat was lost this year from wild oats and weeds than from all other production hazards, other than lack of rainfall. A major effort must be started to manage the infested fields with crop rotation and proper tillage to eliminate the wild oats and other difficult weeds, if the yield potential of Tunisia is ever to be realized. The full yield potential of the Mexican dwarfs will not be realized without better weed control.

The production research program this year included 24 demonstrations with 8 varieties of wheat and 1 variety of barley. Five Mexican varieties (Inia 66, Tobari 66, Jaral 66, Sonora 63 and Siete Cerros) were compared with two Tunisian varieties (Fl. Aurore and Ariana 66), one durum (D 5825), and Martin barley. Top yield from the demonstrations on dry land was 4,300 kg/ha of Tobari at Mateur with 377 mm of rainfall.

Table W15 presents data available on yields of the demonstrations. The area was divided into low, medium and high rainfall areas for variety comparisons. Inia has the best overall performance, and Tobari also performed well, especially in the higher rainfall areas. Sonora 63, Siete Cerros, and Jaral did less well. Ariana 66 and D 5825 were the best of the Tunisian varieties. Ariana performed well in the higher rainfall areas. The late rains and cool spring helped mature the late Tunisian varieties. The late maturing Mexican varieties, Siete Cerros

<table>
<thead>
<tr>
<th>Variety</th>
<th>Rainfall 250 mm</th>
<th>Rainfall 275 mm</th>
<th>Rainfall 305 mm</th>
<th>Rainfall 330 mm</th>
<th>Rainfall 350 mm</th>
<th>Rainfall 375 mm</th>
<th>Irrigated (Location)</th>
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</thead>
<tbody>
<tr>
<td>Inia 66</td>
<td>966</td>
<td>941</td>
<td>3444</td>
<td>3700</td>
<td>4258</td>
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<tr>
<td>Tobari 66</td>
<td>755</td>
<td>1046</td>
<td>2753</td>
<td>3597</td>
<td>4662</td>
<td></td>
<td></td>
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<tr>
<td>Jaral 66</td>
<td>628</td>
<td>616</td>
<td>2236</td>
<td>2920</td>
<td>2236</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sonora 63</td>
<td>844</td>
<td>856</td>
<td>2217</td>
<td>3169</td>
<td>2554</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Siete Cerros</td>
<td>835</td>
<td>829</td>
<td>1964</td>
<td>3108</td>
<td>3324</td>
<td></td>
<td></td>
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<td>Florence-Aurore</td>
<td>847</td>
<td>941</td>
<td>1979</td>
<td>2279</td>
<td>3042</td>
<td></td>
<td></td>
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<tr>
<td>Ariana 66</td>
<td>795</td>
<td>800</td>
<td>2414</td>
<td>3255</td>
<td>2464</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D 5825</td>
<td>785</td>
<td>888</td>
<td>1689</td>
<td>2089</td>
<td>3097</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Average of 9 locations ranging from 165-222 mm
*Average of 3 locations ranging from 276-305 mm
*Average of 4 locations ranging from 290-339 mm
*Average of 5 locations ranging from 365-561 mm

Next year, the demonstration program will be modified. Smaller replicated plots, including the promising new selections from the CIMMYT program, together with a few of the varieties used this year as checks, will be compared. Plot size will be decreased from 1 ha to less than .01 ha. Planting, fertilizing and harvest will be done by the project personnel.

One of the studies this year was on the effect of stored moisture on wheat yields. Application of 125 mm and 250 mm of water by sprinkler irrigation was made before seeding. A total of 185 mm of precipitation occurred during the crop year, and an additional 30 mm was applied by mistake during the growing season.
the year. Yields of 3,500 to 3,900 kg/ha respectively, were obtained with Inia 66 with this management. The average yield without pre-irrigation was less than 1,000 kg.

The results show the value of having stored moisture in the soil and the importance of proper summer fallow management. Soil samples show that root penetration in the heavy clay soils of Tunisia is 1 meter. Therefore, up to 150 mm of water could be stored and effectively used in this region. The 350 mm treatment yielded about 400 kg less than the 125 mm treatment. The reduction in yield may have been caused by deep leaching of nutrients by the heavy application of water all at one time.

Studies with rate and date of seeding at different levels of nitrogen indicate that 80 kg of seed per hectare is the maximum amount of Inia 66 necessary under dry land conditions in the absence of wild oat infestation. Yields were better in wild oat infested fields with seeding rate of 100 or 125 kg/ha. Under irrigation, the highest yield was obtained with 125 kg/ha. This was the result from one trial where an early phosphorous deficiency probably influenced tillering, biasing the results in favor of the higher seeding rates. Additional information is needed concerning seeding rates.

Optimum date of seeding appears to be between November 15 and December 1, in the low rainfall areas. December seedings appear to be better for Inia 66 in the higher rainfall areas, though wet soils may cause some difficulty in seeding. More investigations need to be conducted with varieties to determine optimum management for varieties of different maturity classes for specific areas in Tunisia. December seedings will be recommended for irrigated areas.

Limited research with irrigation was conducted this year. Maximum yield obtained with Inia 66 was 6,300 kg/ha under irrigation. The research included levels of nitrogen and levels of irrigation. Stopping irrigation shortly after seed set reduced yield 900 kg/ha compared to full irrigation up to soft dough stage. Terminating irrigation in late milk stage resulted in a 200-kg loss compared to full irrigation. Yield would probably be reduced more in years when temperatures are more nearly average. May was very cool this year, without any long period of high temperatures. Locking occurred with levels of over 120 units of N. However, the natural level of fertility was high in these trials. The yield of the check was about 5,000 kg. Nitrogen had been built up in the soil at this location by a series of poor crops under dry land management. This was the first year the land at this site was irrigated. Only limited research on irrigated production is planned for next year.

Fertilizer studies

Rainfall for the 1968-69 cropping season was far below the 50-year average for all the wheat producing area of Tunisia. Late or insufficient rains in many areas resulted in very low yields, especially in the Bou Rebia, Pont du Fahs, Zaghouan, El Aroussa and Siliana regions, where dry land yields were 100 to 1,000 kg/ha. Yields were much higher in the other regions of Tunisia where rains were more favorable, especially in the Bizerte, Mateur, Beja, Thibar and Bou Salem-Jendouba areas. These yields were in the range of 1,000 to 4,000 kg/ha. The highest reported yield to date was 5,500 kg/ha on a 7-ha production field of Inia 66 near Mateur. Even though these yields are encouraging, sometimes poor management and failure to follow recommendations made by the wheat project (ACPP) resulted in low yields even where moisture was not the limiting factor.

Two types of fertilizer trials were conducted during 1968-69. One was a nitrogen rate and date of application study. The second was an N-P-K trial. These experiments were made to study the yield response of the short stemmed Mexican bread wheats under various levels of fertilization and varying natural rainfall.

The fertilizer rates used were increased for those regions receiving more rainfall. Rainfall regions were broken down into three sections based on average rainfall (rainfall data for 50 years) as follows: less than 400, 400-500 and greater than 550 mm.

Table W16 shows yields, monthly rainfall, and total precipitation from October 1, 1968 to May 31, 1969 for each experimental area. The deficits as compared to the long term averages for each farm-region where experiments were conducted are also listed. The mean yield from each nitrogen experiment and the amount of rainfall for each experimental area are highly related.

The past cropping season was another dry year for many of the Tunisian farmers. Fertilizer responses in the dry regions (less than 250 mm of rainfall) were in general insignificant. Even though a few farmers obtained yields of 1,000 to 1,400 kg/ha in the dry regions, probably because of moisture reserves from the previous year of summer fallow, seldom was there a significant nitrogen response. This substantiates earlier observations made throughout the growing season that the wheat plants never showed symptoms of nitrogen deficiency and yield differences among nitrogen treatments probably
Another aspect of the cooperative program in Tunisia has been the determination of fertilizer requirements and recommendations. Dr. Naceur Bakhtri, co-director of the cooperative program for wheat improvement, observes fertilizer tests with unirrigated Mexican wheats.


<table>
<thead>
<tr>
<th>Farm and location</th>
<th>Monthly rainfall, October-May, mm</th>
<th>Total mm</th>
<th>Deficit compared to the 50 year average, mm</th>
<th>Yield means kg/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amel, Pont du Fehs</td>
<td>8.5 5.0 16.5 43.0 33.0 41.2 19.0</td>
<td>199.2</td>
<td>-253.5</td>
<td>390</td>
</tr>
<tr>
<td>Aziza, Medjez El Bab</td>
<td>5.0 15.0 38.0 54.0 35.0 44.5 8.0</td>
<td>290.3</td>
<td>-155.7</td>
<td>1260</td>
</tr>
<tr>
<td>Assa, Pont de Jazirte</td>
<td>0 6.1 35.0 55.0 70.0 31.0 40.0 0</td>
<td>310.0</td>
<td>-135.0</td>
<td>3120</td>
</tr>
<tr>
<td>Marja II, Bou Salem</td>
<td>7.0 33.5 73.4 86.6 42.0 41.2 8.9</td>
<td>339.6</td>
<td>-126.4</td>
<td>3760</td>
</tr>
<tr>
<td>Bakhazi, Mateur</td>
<td>27.1 74.2 70.5 68.4 88.5 18.0 22.5 7.8</td>
<td>377.0</td>
<td>-176</td>
<td>3840</td>
</tr>
</tbody>
</table>

Mean: 2470

NOTE: Two other experiments were not harvested because of insufficient moisture and bird damage.

would not be significant. There apparently has been a nitrogen build-up in these areas after four consecutive droughty years. This information will be very useful in making fertilizer recommendations for the next season. The consensus now is that a light nitrogen application (22.5 kg/ha) should be made at or before seeding. Additional nitrogen can be added at tillering or when enough moisture is available. The decision depends on whether the plants are in the proper stage of growth to use additional nitrogen.

Another interesting point was learned from
experimentation in the drier areas this year. Adding nitrogen in amounts up to 67 kg/ha did not depress yield. Many people thought that the plants would "dry up and burn up", producing little or no grain. Granted that probably not all the nitrogen was used by the wheat crop and remains available in the soil, it has not been lost and will be available for succeeding crops, if weeds are controlled.

In the wetter areas of Tunisia (more than 250 mm of rainfall), definitive positive nitrogen responses have been obtained. Some reports from production fields have indicated yield increases of 50-70% from judicious application of nitrogen in the range of 45-90 kg/ha.

One could easily identify those fields of both Mexican and Tunisian wheat that were inadequately fertilized. Deficiencies were observed from the beginning of the growing season right through to harvest. The plants did not tiller well, yellowed, and lacked overall vigor. The inadequately fertilized fields yielded correspondingly less than those properly fertilized, even with favorable rainfall.

The two experimental sites selected for nitrogen studies in the medium and high rainfall areas (Marja II, Bakharia) had unknown but very high base nitrogen levels. Therefore, no significant differences were found among treatment means for nitrogen rates of 0-125 kg/ha. However, these trials did indicate that following a green manure crop such as feve (Vicia faba), one can cut back the commercial nitrogen application to about 45 kg/ha.

The N, P, K trial at Pont de Bizerte final statistics have not been completed yet, but there certainly are real differences among treatment means. The N₀₀₀, P₀₀₀, K₀₀₀ treatments gave the highest yield, 3,500 kg/ha or 68% more than the check yield of 2,130 kg/ha. More than 90 kg of N depressed yields slightly. There was no significant response to potassium.

Much valuable experience and knowledge of wheat production has been gained from our research and production activities over the past cropping season. Many questions remain unanswered and some problems unsolved, but we certainly are in a better position now to move ahead more intelligently in both research and production than a year ago.

The problem of variety acceptance or switch (Tunisian to Mexican) is no longer of much consequence. What remains now is to develop data through experimentation to learn more about the best cultural practices to obtain maximum production.

### Varietal improvement

The varietal improvement (breeding) section of the Wheat Project (ACPP) was established in cooperation with INRAT (National Institute of Agricultural Research of Tunisia) centered in Tunis. Major emphasis during the first year was on growing the breeding material at Tunis. About ½ hectare of material was also sown at Bou Salem in northern Tunisia.

Of the commercial Mexican bread wheat varieties grown as checks in yield trials, Inia 66, Tobari 66, and Siete Cerros were the highest yielding, followed closely by Norteño 67 and Ciano 67. Average yields for these varieties under rainfed conditions ranged from 2,900 to 4,000 kg/ha (Table W17). A number of advanced lines with yields as good or better than the commercial varieties are also listed in this table. These lines showed good resistance to the prevalent races of stem, leaf and yellow rust in Tunisia.

An attack of powdery mildew (Erysiphe graminis) was heavy throughout the Tunis nurseries, permitting selection for resistant plants and lines. Commercial varieties Norteño 67 and Siete Cerros have very good resistance, and Tobari 66 and Florence-Aurore have medium resistance to mildew.

Table W18 lists the lines with outstanding resistance to mildew.

### TABLE W17. Highest yielding varieties and lines of bread wheats in replicated yield trials in Tunis, Tunisia, 1968-69.

<table>
<thead>
<tr>
<th>Variety or selection</th>
<th>kg/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inia 66</td>
<td>3150</td>
</tr>
<tr>
<td>Tobari 66</td>
<td>3450</td>
</tr>
<tr>
<td>Siete Cerros</td>
<td>3100</td>
</tr>
<tr>
<td>Norteño 67</td>
<td>2980</td>
</tr>
<tr>
<td>Ciano 67</td>
<td>2920</td>
</tr>
<tr>
<td>[(Ciano x Kl. Rendidor) x 8156]</td>
<td>3370</td>
</tr>
<tr>
<td>[(Tob 66 (Son 64-Knott x Crespo)]</td>
<td>3300</td>
</tr>
<tr>
<td>25047-15M.4Y-0M</td>
<td></td>
</tr>
<tr>
<td>Ciano &quot;s&quot; x Bj 66</td>
<td>3490</td>
</tr>
<tr>
<td>Tob 66 x Ciano &quot;x&quot; x 29000-4M.1Y-0M</td>
<td>3410</td>
</tr>
<tr>
<td>Ciano &quot;s&quot; x Tobari &quot;s&quot;</td>
<td>4000</td>
</tr>
<tr>
<td>Ciano &quot;x&quot; x Jaral &quot;s&quot;</td>
<td>3490</td>
</tr>
<tr>
<td>[(Wt e &quot;Nar 59) x 64 Tzp-Y34)]</td>
<td>3260</td>
</tr>
<tr>
<td>11-22402-1M.9R-1M</td>
<td></td>
</tr>
<tr>
<td>Tob-Purdue x Ciano 11-22477-20Y-1M.1T</td>
<td>3280</td>
</tr>
<tr>
<td>[(Ciano-Pj 62) x 64 Tzp]</td>
<td>3330</td>
</tr>
<tr>
<td>(Son 64-Y30 e x Gro)] II-25386-1M.2R</td>
<td></td>
</tr>
<tr>
<td>NP 838 [(Tzp-Son 64 x Nar 59)] II-25906-4M.1R</td>
<td>3740</td>
</tr>
<tr>
<td>Nar &quot;s&quot; x Pi &quot;s&quot;</td>
<td>3673</td>
</tr>
<tr>
<td>Son 64 x Kl. Rendidor</td>
<td>3350</td>
</tr>
<tr>
<td>V-278</td>
<td>3460</td>
</tr>
<tr>
<td>L364-P4130 e</td>
<td>3790</td>
</tr>
<tr>
<td>Y30-L52 x LR&quot;</td>
<td>3710</td>
</tr>
</tbody>
</table>
owing to an unusually cool spring with dry winds. Early January. Table W19 gives some of the lines check variety. Line #5 from cross 11-24102 yielded mildew. This line was also high yielding at both seed. The trials were sown in late December and CIANO and Roque, Mexico, in 1968-69. as well as Inia and had very good infection. Not give the desired level of infection hoped for. was not heavy Septaria breeding nursery for selection. for resistance. Triticum dicoccum sown late, prohibiting evaluation under natural con­ditions. Many F1 populations showing very good promise were selected on an individual plant basis. The following are a few of the F3 head selections

### Table W18. Advanced lines of bread and durum wheat showing good resistance to powdery mildew at Tuni, Tunisia, in 1968-69 crop season.

<table>
<thead>
<tr>
<th>Pedigree</th>
<th>Mildew infection/reaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mg41 x Ciano “s” 25679-3M-3Y-0M</td>
<td>0/R</td>
</tr>
<tr>
<td>(Ciano x Siete Cerros) (Ciano x Pi) 25917-20Y-OM</td>
<td>0/R</td>
</tr>
<tr>
<td>Tob-Purdue x Ciano “s” 24277-9Y-1M-2Y-0M</td>
<td>1/R</td>
</tr>
<tr>
<td>TzpP-Son 64 x Ciano “s” 25431-2M-3M-3Y-0M</td>
<td>1/R</td>
</tr>
<tr>
<td>Ciano “s” x Chris 23583-10M-6Y-3M-2Y-0M</td>
<td>1/R</td>
</tr>
<tr>
<td>(TzpP-Son 64 x Napo 63) x Ciano “s” 25463-6M-3Y-0M</td>
<td>1/R</td>
</tr>
<tr>
<td>(LR 64-S64 x Napo) [(Son 64 x TzpP-V54) (Son 64-Y50 x Gto)] 0/R</td>
<td></td>
</tr>
<tr>
<td>(Napo 63 x TzpP-S64) [(TzpP-S64) (LR 64 x TzpP-An e)] II 25310-4M-1R</td>
<td>1/R</td>
</tr>
<tr>
<td>(Ciano x TzpP-S64) II 24626-10R-1M-1R</td>
<td>0/R</td>
</tr>
<tr>
<td>Inia x (Son 64-850-5Gr6) II 23476-13M-10R-2M-1R</td>
<td>1/R</td>
</tr>
<tr>
<td>(Ciano F6) [(Son 64 x TzpP) (Son 64-Y50 x Gto)] II 25386-10R-1M-1R</td>
<td>3/MR</td>
</tr>
<tr>
<td>Triticum dicoccum var. “Verum” (SrW 63) [(Pi-Tm x Tc) (Z-B x Wells)] 3/MR</td>
<td></td>
</tr>
<tr>
<td>23626-5M-3R</td>
<td>3/MR</td>
</tr>
<tr>
<td>[(Pi-Tm) Tc60] (Z-B-Wells) 21584-100M-103Y-105C</td>
<td>1/R</td>
</tr>
<tr>
<td>[(Pi-Tm) Tc60] (Z-B-Wells) x (Ciano x 8156 R) x Calidad 2200</td>
<td></td>
</tr>
<tr>
<td>[(Pi-Tm) Tc60] (Z-B-Wells) x Calidad 21564-3M-1R-1M</td>
<td>7/MR</td>
</tr>
<tr>
<td>Charpela (Tm x Tc) (Z-B x Wells) 3/MR</td>
<td></td>
</tr>
<tr>
<td>22334-47M-5Y-1M-0Y</td>
<td>0/R</td>
</tr>
<tr>
<td>[(Bell-Tc) (Z-B x Wells)] [(Tm x Tc) (Z-B x Wells)] 3/MR</td>
<td></td>
</tr>
<tr>
<td>21402-3Y-1M-0Y</td>
<td>1/R</td>
</tr>
</tbody>
</table>

* R = resistant; MR = moderate resistance; 0-7 = amount of infection.

All of the durum yield nurseries were sown late, owing to delay in shipment and receipt of seed. The trials were sown in late December and early January. Table W19 gives some of the lines showing respectable yields compared to Inia, the check variety. Line #5 from cross II-24102 yielded as well as Inia and had very good resistance to mildew. This line was also high yielding at both CIANO and Roque, Mexico, in 1968-69.

Artificial inoculation with the three rusts did not give the desired level of infection hoped for, owing to an unusually cool spring with dry winds. Fortunately, natural infection of the three rusts was good, although the attack was late. It was possible to select for good rust resistance in the later maturing durums and late sown bread wheats. Septoria was not heavy in Tunisia because of lack of moisture, but was adequate in the irrigated breeding nursery for selection for resistance.

The F1 material from Mexico was received and sown late, prohibiting evaluation under natural conditions. Many F1 populations showing very good promise were selected on an individual plant basis. The following are a few of the F3 head selections

### Table W19. Advanced Triticum durum lines with high yield in 1968-69 yield trials, Tunis, Tunisia.

<table>
<thead>
<tr>
<th>Variety or selection</th>
<th>kg/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>[(Y54 x N10-B) By] 76</td>
<td>2530</td>
</tr>
<tr>
<td>Tac 125 Tc6</td>
<td>2809</td>
</tr>
<tr>
<td>[(Y54 x N10-B) By] 76</td>
<td>2690</td>
</tr>
<tr>
<td>[(Y54 x N10-B) By] 76</td>
<td>2450</td>
</tr>
<tr>
<td>[(Y54 x N10-B) Ld357] 76</td>
<td>2000</td>
</tr>
<tr>
<td>[(Y54 x N10-B) Ld357] 76</td>
<td>2400</td>
</tr>
<tr>
<td>[(Y54 x N10-B) Ld357] 76</td>
<td>2710</td>
</tr>
<tr>
<td>[(Y54 x N10-B) Ld357] 76</td>
<td>2420</td>
</tr>
<tr>
<td>[(Y54 x N10-B) Ld357] 76</td>
<td>2350</td>
</tr>
<tr>
<td>[(Y54 x N10-B) Ld357] 76</td>
<td>3260</td>
</tr>
<tr>
<td>[(Y54 x N10-B) Ld357] 76</td>
<td>2700</td>
</tr>
<tr>
<td>[(Y54 x N10-B) Ld357] 76</td>
<td>2820</td>
</tr>
<tr>
<td>[(Y54 x N10-B) Ld357] 76</td>
<td>2900</td>
</tr>
<tr>
<td>[(Y54 x N10-B) Ld357] 76</td>
<td>2960</td>
</tr>
<tr>
<td>[(Y54 x N10-B) Ld357] 76</td>
<td>2420</td>
</tr>
<tr>
<td>[(Y54 x N10-B) Ld357] 76</td>
<td>2420</td>
</tr>
<tr>
<td>[(Y54 x N10-B) Ld357] 76</td>
<td>2350</td>
</tr>
</tbody>
</table>

* This line also produced a high yield at CIANO, Mexico 1968-69 (7,927 kg/ha); Roque, Mexico 1968-69 (7,927 kg/ha), and at Toluca during the summer of 1968.

families from Toluca that show excellent promise:

<table>
<thead>
<tr>
<th>Selection family</th>
<th>Mexican cross no.</th>
</tr>
</thead>
<tbody>
<tr>
<td>HD 832-5-30Y x (Ciano “s” x Son 64-64-Kl. Rend) &quot;Calidad&quot; x Norteño 67*</td>
<td>27005</td>
</tr>
<tr>
<td>(Ciano x 8156 R) x HD 832-5-30Y &quot;Calidad&quot; x Norteño 67*</td>
<td>27100</td>
</tr>
<tr>
<td>(Ciano x 8156 R) x HD 832-5-30Y &quot;Calidad&quot; x Norteño 67*</td>
<td>27144</td>
</tr>
<tr>
<td>(Ciano x 8156 R) x HD 832-5-30Y &quot;Calidad&quot; x Norteño 67*</td>
<td>27281</td>
</tr>
<tr>
<td>(Ciano x 8156 R) x HD 832-5-30Y &quot;Calidad&quot; x Norteño 67*</td>
<td>27283</td>
</tr>
<tr>
<td>(Ciano x Son 64-64-Kl. Rend) 8156</td>
<td>23584-303M</td>
</tr>
</tbody>
</table>

The major problems confronted by the breeding program this year were lack of adequate moisture; too many weeds, especially wild oats; and damage from birds, both at seeding time and just before harvest. Alternate irrigation and tillage during the summer should help alleviate the weed problem.

**Insect problems**

Although the European leaf beetle, sawfly, and Hessian fly are all known to be in Tunisia, there was virtually no damage from any of these insects this season. However, Hessian fly did considerable damage in Morocco. It will be necessary to begin to incorporate resistance to each of these species into the dwarf varieties as soon as other improvements with higher priorities are met.

**“Calidad” refers to the Mexican cross II 22429, ["Tezanos Pintos Precoz x Sonora 64 (Lerma Rojo 64 x Tezanos Pintos Precoz-Andes)]**
The cooperative program with Morocco, begun in 1968, includes yield trials of introduced varieties. Dr. Ralph Edwards of U.S. AID, Dr. M. Tergwey, plant breeder of the Moroccan Ministry of Agriculture, and Dr. S. Litzenberger of U.S. AID examine a planting of Mexican varieties near Rabat.

Plans for the fall of 1969 include the separation of all bread wheats and durum wheats into individual sections so that the efforts of all personnel will be directed and used to their utmost advantage. Tunisia needs an early, high-yielding, resistant durum variety and such can only be found through a coordinated, aggressive effort. Unless a vigorous program is launched immediately, the dwarf Mexican bread wheats, because of higher yield, will take over the area now devoted to durum.

The cooperative varietal breeding program between the Government of Tunisia, CIMMYT and U.S. AID, despite many obstacles, got off to a good start during the 1968-69 season. This excellent start and the enthusiasm already generated by the success of the production program, may well evolve into a base for general wheat improvement throughout North Africa.

MOROCCO

Morocco's first experience with Mexican dwarf wheats began during the 1967-68 crop season when 200 ha of Siete Cerros, Inia 66, Penjamo 62, and Tobari 66 were grown with excellent results. Siete Cerros outyielded all other varieties substantially. On the basis of this performance, additional seed of Siete Cerros was imported for the fall, 1968 planting.

A total of 5,000 ha of Mexican dwarfs were grown during the 1968-69 season with mixed results.
About 2500 ha were sown to Siete Cerros. The other half was divided about equally between Inia 66, Tobari 66, and Penjamo 62.

The 1968-69 crop season had nearly double the normal rainfall. There was virtually continuous cloudy and rainy weather from mid-November until mid-May, especially in the northern part of the country. As a result, a very serious epidemic of septoria leaf and glume blotch developed on both Mexican and local varieties. The attack was particularly devastating on the variety Siete Cerros, which appears to be hypersusceptible to this disease. Tobari 66, Penjamo 66, Inia 66 and Norteño 67 were much less severely attacked than was Siete Cerros. The Septoria infection on the four former varieties was as severe as on the local bread and durum varieties that headed at the same time. Late in the season, a severe attack of both leaf and stem rust also developed on the local bread wheats, and to a lesser degree on the durums. The Mexican dwarfs were resistant to the rusts.

In general, Tobari 66, Penjamo 62, and Inia 66 produced satisfactory to good yields of grain at most locations, especially when adequately fertilized. Considerable observational evidence indicates that fields or strips across fields that were top-dressed with nitrogen before heading withstood Septoria much better than those that were deficient in nitrogen, or where nitrogen uptake was reduced by waterlogged soil.

The local wheats were also badly detiolated by Septoria and leaf rust, in much of the northern region.

The yield results of the Mexican varieties and local wheats from the demonstration site at Sidi Kacem are in Table W20. This location was in the area of the severe Septoria epidemic. The local variety BT 908 and the Italian variety Mara (3597) are known to have some resistance to Septoria; preliminary reports indicate they are yielding in the same range as Inia and Tobari.

In southern parts of the rain-fed region where there was less rain, Tobari, Inia, Penjamo, and Norteño produced good to excellent yields, and outperformed the local varieties by a good margin. In the extreme south under dry conditions and irrigation, Siete Cerros yields were excellent.

On the basis of the incomplete results now available, it appears that Tobari 66, Inia 66, and Penjamo 62 can be grown successfully in all of the major wheat production areas if planted at the right time. Siete Cerros should be grown only under irrigation in the south.

### TABLE W20. Yields of grain from varietal demonstration plots at Sidi Kacem, Morocco, 1968-69.1

<table>
<thead>
<tr>
<th>Rank in yield</th>
<th>Variety</th>
<th>Grain yield, kg/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Penjamo 62</td>
<td>3316</td>
</tr>
<tr>
<td>2</td>
<td>Tobari 66</td>
<td>3272</td>
</tr>
<tr>
<td>3</td>
<td>BT 3597 (Mara)</td>
<td>2951</td>
</tr>
<tr>
<td>4</td>
<td>BT 908</td>
<td>2932</td>
</tr>
<tr>
<td>5</td>
<td>Inia 66</td>
<td>2895</td>
</tr>
<tr>
<td>6</td>
<td>Norteño 67</td>
<td>2696</td>
</tr>
<tr>
<td>7</td>
<td>BT 2511</td>
<td>2673</td>
</tr>
<tr>
<td>8</td>
<td>BT 2306</td>
<td>2502</td>
</tr>
<tr>
<td>9</td>
<td>Siete Cerros</td>
<td>1950</td>
</tr>
</tbody>
</table>

1 Sown December 25, 1968, harvested June 4, 1969. Fertilized with 40 kg N and 27 kg P₂O₅ at planting and 46 kg N at tillering.

2 20% shattering.

### Experimental wheat lines

During the 1968-69 season, more than 2,000 lines and varieties of experimental wheats, mostly of Mexican origin, were grown at Rabat and Merchouche under heavy epidemics of septoria leaf and glume blotch, and leaf rust.

Many lines and varieties in these nurseries had usable field resistance to Septoria under severe epidemic conditions. Many of these, however, are poorly adapted and will yield poorly.

The following varieties have considerable resistance: Mara and Victor (Italy); Carazinho (Brazil); Gaboto and Buck Manansial (Argentina); Crim and Red River (USA); Manitou (late?) (Canada); Tobari 66, Penjamo 62, Inia 66 and Lerma Rojo 64 (Mexico).

Heads of Siete Cerros completely destroyed by Septoria in a heavy rainfall area in Morocco. Yields of this same variety were excellent in drier parts of the country.
Among the most promising experimental lines were:

1. (Tzpp*Sonora 64) (Lerma Rojo 64 x Tzpp*ANDES e) Mexican Cross II 22429** (8 different lines).
2. Ciano x Chris Mexican Cross II 23582 (2 lines).
3. (Klein Petiso-Rafaela) x Inia Mexican Cross II 22437 (2 lines).
4. "Pato" = (Tzpp-Sonora x Nariño 59) Mexican Cross II 21974 (3 lines).
5. Sonora 64-Yaqui 50e x Gaboto Mexican Cross II 19792 (4 lines).
6. Other Mexican derivatives of crosses with Tzpp — 19 different lines representing 7 different crosses.

Observations made during the past season in Morocco under severe epidemics of Septoria, show that many CIMMYT lines carry functional resistance to this disease. The vast majority of the lines showing resistance have the Argentine variety Tezanos Pintos Precoz in their pedigree. Other varieties that appear to be transmitting resistance to their progeny are Gaboto (Argentina) and Andes (Colombia). Many lines of wheat from the CIMMYT program that carry resistance to both Septoria and mildew have been unidentified because of inadequate sites for testing.

It has become apparent that screening nurseries for selecting lines resistant to Septoria, and powdery mildew should be established at two places in Morocco. If this is done, and combined with the breeding program in Tunisia, and an anticipated spring wheat nursery site on the Mediterranean coast in Turkey, it should be possible to add a new dimension—a greater spectrum of disease resistance — to the spring wheat breeding programs of the world. The screening nurseries also should be linked through CIMMYT with the programs in Argentina and Brazil, where successful selection pressures can be exerted to identify lines with good combinations of resistance to Fusarium (scab), septoria leaf and glume blotch, and to the rusts.

Attempts must be made to assure a flow back to CIMMYT of the outstanding lines from each Mediterranean nursery and from Argentina and Brazil so that they again can be crossed into the CIMMYT gene pool, and recycled to collaborators in all parts of the world.

Sixty-eight lines showing the best combinations of resistance to Septoria, mildew, and rusts from the Moroccan and Tunisian programs are being increased in a summer nursery at Seirou, Morocco. Moreover, about 40 kg of seed of two of the promising lines from the Mexican Cross II 22429 are available in Mexico and will be sent to Morocco for fall, 1969 sowing.

With a continuation of the research already underway and progressing well in Tunisia, and with a strengthening of the breeding program in Morocco, a sound basis for the expansion of wheat production across North Africa is well launched.

**ARGENTINA**

Ninety advanced generation lines were included in the official pre-inscription replicated yield tests during 1968, wherein they were compared with the principal commercial varieties. These experiments were sown from two different dates of planting at Balcarce, Pergamino, Marcos Juarez, and Parana. The many lines that outyielded the best check varieties included:

(Sonora 64A x Tzpp Nai 60)  
- 1. (Tzpp* Sonora 64 x Lerma Rojo 64 x ANDES) Mexican Cross II 22429  
- 2. Ciano x Chris Mexican Cross II 23582  
- 3. (Klein Petiso-Rafaela) x Inia Mexican Cross II 22437  
- 4. "Pato" = (Tzpp-Sonora x Nariño 59) Mexican Cross II 21974  
- 5. Sonora 64-Yaqui 50e x Gaboto Mexican Cross II 19792  
- 6. Other Mexican derivatives of crosses with Tzpp — 19 different lines representing 7 different crosses.

...
This is the second consecutive year that a number of lines from the crosses II 18889, II 19975 and II 18893 have exhibited high yield.

Thirty-three dwarf durum lines were compared for yield to the tall strawed Argentine commercial varieties at Balcarce. Although 19 of the dwarfs outyielded the best commercial check variety, the yields were 1 ton/ha less than the best experimental bread wheat lines listed above.

There is an need to increase both the speed and scope of the INTA wheat breeding program in Argentina. The program has been greatly handicapped by the shortage of trained personnel. Moreover, shortage of staff at the CIMMYT base has made it impossible for any of their members to devote enough time to properly assist the Argentine program.

A new member of the CIMMYT staff has been assigned to Argentina, where he will collaborate with INTA scientists on agronomic studies of both wheat and maize.

DENMARK

The dwarf varieties Tobari 66 and Inta 66 are being grown successfully in a considerable, but undetermined acreage in Denmark. At these high latitudes, it is necessary to use high rates of seeding (1250 kg/ha) and heavy fertilization to obtain high yields. When properly sown and fertilized, the two Mexican varieties are reported to yield with the best European spring wheat varieties, and have the advantage of being 2 to 2 1/2 weeks earlier in maturity.

Wheat is grown in Iran in several different ecological areas. In the north, rainfed wheat is grown in the province of Azerbaijan and in the coastal plain along the Caspian Sea, particularly in the eastern section, and extends toward the north-east on the border of Turkmen, USSR to Afghanistan. Wheat is grown under irrigation in the southwest bordering Iraq and the upper part of the Persian Gulf. Smaller areas include the regions of Isfahan and Tehran. Scattered acreages are raised throughout the mountains where rain is adequate.

In all, approximately 4 million ha are grown, and about 350,000 ha of paddy. The long time national average yields are about 800 kg/ha; with 600 on rainfed and 1,200 kg/ha on irrigated land. In the last 3 years, conditions have been particularly favorable and average yields have been 1,000 kg/ha. Akova, a variety introduced from Turkey, that is tall, awnless, strong-strawed and resistant to stripe rust, occupies the major acreage in the north. In central Iran, a local variety, Roshan is widely grown. It is susceptible to all three rusts, is tall, and has a large amber grain. The variety is sown early and grazed during the fall. Income from grazing is considered to be worth the equivalent of 2 tons of grain.

Varieal improvement is conducted at 12 stations throughout the wheat areas. Dwarf wheats are now widely used in the breeding program when land is irrigated or rainfall is high. Yield trials beyond the station level are divided into three types. The

*Fertilizing wheat on the land of Mr. Flemming Junker, who introduced Mexican wheats to Denmark. The machine requires wide tires on the spongy land near Overgaard.*
earliest trial is grown at the 12 breeding centers. Trials in the next stage of advancement are grown at the same centers and 10 additional, for a total of 22 locations. A third series is conducted at about 50 locations in farmers' fields.

The rusts are the major disease problem. All three are normally present in the north, and stem rust periodically causes heavy damage. Yellow rust can also be very heavy. In 1968-69, rust development was relatively light and caused little damage. At Karaj Station near Teheran, all three rusts were present but the strongest attack was by yellow. At Isfahan, leaf rust had never been a problem, but this year all three species of rust were very heavy. This heavy infection produced a good condition under which to select the segregating material, much of which was susceptible because of previous years' light infection.

Penjamo 62 was grown on about 9,000 ha during 1968-69. There was considerable stripe rust infection on it in some areas. Although there was undoubtedly some damage at some locations, the variety was filling the grain well at all locations. Penjamo 62 tillers heavily under Iranian conditions and appears to be well adapted. Inia 66 had much less stripe rust infection, and in yield tests appeared very promising. Iran proposes to import 500 tons of this variety for sowing in the fall of 1969.

Iran is also showing interest in the variety Bezostaya from Russia. It has fair resistance to yellow rust but is highly susceptible to leaf and stem rust. It is tall and awnless and is being considered for growing in the rainfed areas of Azerbaijan. Small commercial seed fields of San Pastore and Campodoro, two Italian varieties, were grown near the Caspian Sea. The straw strength of these varieties was evident and the varieties appeared promising. However, rust is normally quite severe in the area and it is unlikely that these highly susceptible varieties will find a place.

The dwarf varieties are beginning to be used. However, virtually no agronomic research has been conducted to determine what modifications in cultural practices are necessary to adapt the dwarfs to Iranian conditions. If this research gap is filled, the stage will be set for a rapid breakthrough in production built around dwarf varieties and more intensive cultural practices.

The northern plains of Iran are considered to have good potential for ground-water development which could be used as a supplement to rainfall during critical periods. The heavy soil and flat terrain of this region would certainly lend themselves to this type of development.

The need to organize collection of the indigenous wheat variations present in such profusion in Iran has become critical. Local varieties have already been replaced in much of the area. There is still a good deal in the mountainous regions and the less progressive areas. These will not last long against the onslaught of new technology. The time is late for effective collecting!

**TURKEY**

Turkey began sowing Mexican dwarfs wheats on the Mediterranean and Aegean coastal plains on a semi-commercial basis during the 1966-67 crop season. The culture of these types expanded very rapidly following the large-scale importation of seed from Mexico in 1967. An area of 170,000 ha was sown during the 1967-68 season from which 700,000 tons were harvested, a yield of slightly more than 4 tons/ha (60 bu/acre). It is estimated that about 800,000 ha, most of the area sown to wheat on the coastal plains, were sown to the Mexican dwarfs during the 1968-69 season. Harvest is now being completed but no production data are yet available.

There have been some reports of yellow rust infection on Siete Cerros in some areas. This undoubtedly has resulted from extending the area sown to Siete Cerros to areas ecologically favorable for stripe rust. The variety is known to be susceptible to both stripe rust and Septoria in the Mediterranean region. Large areas are planted to Tobari 66, Inia 66, Lerma Rojo 64, and Penjamo 62, all of which have better resistance to these diseases. It will therefore be possible to shift to the cultivation of these latter varieties, wherever indicated, for the 1969 planting season. Nevertheless, the rust infection on Siete Cerros in Turkey indicates the need for developing strong research programs in the near East to cope with this and many other problems that are certain to appear.

**Cooperative research and training center**

An agreement was signed on April 28, 1969 between the Ministry of Agriculture of the Government of Turkey and the Rockefeller Foundation to develop a Cooperative Center of Research and Training in Wheat Improvement for Turkey and the neighboring countries. This agreement visualizes undertaking a dynamic, large wheat improvement program to develop varieties with spring habit for the coastal areas and varieties with winter or semiwinter habit for the Anatolian plateau. The development of a durum wheat breeding program is also visualized, along with such other aspects of wheat improvement as agronomy, plant pathology, and entomology.

CIMMYT will be indirectly linked to all three aspects of the Turkey program. The Mexican spring
harvest Penjamo 62 in the field of Mustafa Azak at Ari­fiye, Sakarya, Turkey. The field yielded 4,800 kg/ha. Other Mexican varieties planted in Turkey were Penjamo 62, Super X, and Nadadores; all unirrigated.

Habit bread wheat and durum wheat materials will be of particular value on the coastal plain. Some of the Mexican durum breeding material may also have adequate frost resistance for some areas of the Anatolian plateau. The CIMMYT materials being developed by Dr. J. A. Rupert at Davis, California are mainly derivatives from crosses between winter and spring habit varieties. These materials will serve as a valuable base for initiating the building of a breeding program for the Anatolian plateau.

The establishment of an aggressive spring wheat breeding program on the coastal plain of Turkey, together with the programs now being developed in Tunisia and Morocco, will provide excellent sites for screening for resistance to Septoria and powdery mildew, which do not occur in Mexico.

LEBANON

The Arid Lands Agricultural Program of the Ford Foundation is centered at Beirut, Lebanon. Last year, a modest wheat varietal testing program, largely involving CIMMYT materials, was initiated as one of the projects of this program. Both the scope and sphere of influence of the wheat research program are being expanded. Dr. Ignacio Narvaez, who has been based in Pakistan for the past four years, has joined the Ford Foundation staff in Beirut. He will develop a cooperative wheat improvement program for a number of Near and Mid­dle East countries, including Lebanon, Jordan, Iran, and Iraq. Dr. Narvaez also will continue to act as a consultant to the Pakistan wheat program.

The Lebanon-based Ford Foundation wheat improvement program will be intimately linked with CIMMYT. A large breeding nursery will be established in Lebanon to screen materials for many of the collaborating Near East countries. It is also anticipated that the Lebanese based program will cooperate closely with the spring-wheat breeding program that is to be developed for the coastal areas of Turkey.

AFGHANISTAN

Afghanistan's experience with Mexican dwarf wheats dates back to the 1966-67 season, when 1200 ha were sown with seed from Pakistan. Currently an estimated 150,000 ha are sown to Mexican varieties. However, wheats with more frost resistance are needed in many areas. In the future, arrangements will be made to evaluate materials being developed by the CIMMYT California program.

A U.S. AID team has helped the government of Afghanistan to develop a highly successful wheat production program. Eight young Afghani­scientists have received training in the CIMMYT in-service training program in recent years. They are now developing various aspects of the program.
Research to overcome limitations on wheat yields requires careful measurement of many factors involved in soil-plant-water relationships. This photo shows a study of the effects of "excess" moisture on wheat development. Ingeniero Oscar Moreno is reading manometers connected to tensiometers in the soil to determine the moisture content. Contrary to expectations, flooding wheat fields for as long as 4 days at 3 different stages of plant growth did not reduce yields of any of the 4 varieties tested.
SOILS AND PLANT NUTRITION

SEVERAL ACTIVITIES IN PROGRESS hope­fully will improve productive practices for maize and wheat in different parts of the world. The influence of several production factors—soil moisture, applied nitrogen, row spacing, herbicides—on the yield and nutrient uptake by different wheat varieties is being studied. Work was begun on Andosols in Western Mexico to determine economical fertilization prac­tices for corn. Crops respond very little to normal rates of fertilization of these soils. Apparently, high levels of active aluminum interfere with the uptake of phosphorus and possibly other essential nutrients. Studies to determine more efficient procedures for agronomic field trials and for interpreting experimental results are continuing. The Puebla Project is being helped to plan, execute, and interpret agronomic studies.

The agronomic and nutritional studies with wheat are being carried out cooperatively with the Graduate College at Chapingo, the Mexican National Agricultural Research Institute, Dr. S. K. Ries, Michigan State University, and Drs. Lewis M. Stolzy and S. D. Van Gundy of the University of California at Riverside. The corn fertilization study on Andosols has the collaboration of Dr. Nathaniel T. Coleman, University of California at Riverside, Dr. Foster B. Cady, University of Kentucky, is participating in the studies on fertilizer use methodology.

Results of agronomic studies with wheat and research on fertilizer use methodology are summarized below. The results of a cooperative study of agronomic practices for corn in the pampas region of Argentina are also presented.

AGRONOMIC STUDIES WITH WHEAT
Effect of flooding on yield

Reductions in plant growth and yield of wheat have often been attributed to flooding or saturating the soil for extended periods. Excess soil moisture before and at tillering reportedly reduces yield, even though conditions are optimum during the rest of the season. Excess moisture at some critical stage before flowering is believed to reduce fertility, and consequently yield. Flooding during grain forma­tion reportedly causes poorly filled grains with low volume weights, light kernels, and reduced yield.

In 1969, the wheat variety Inia was used to measure the effect of excess moisture at different periods of development on growth, yield and other characteristics of the plant and grain. The study was made at CIANO (Northwest Agricultural Research Center at Ciudad Obregón, Sonora, Mexico). Three levels of excess moisture were attained by flooding the soil for 2 hours (normal irrigation practice), 1 day, and 4 days. All three flooding treatments were applied when the wheat was 38, 79, and 104 days old. Oxygen diffusion rates (O.D.R.) were measured as soon as possible after flooding and continued until the rates were adequate for normal growth. (Table S1).

If we consider 20 x 10^{-6} g/cm^{2}/min as the critical O.D.R. value below which wheat root growth stops, as is true for many plants, flooding this soil greatly extended the period of unfavorable aeration associated with irrigating.

Flooding the soil for 1 or 4 days when the wheat was 38 days old reduced the height of the plants 5 weeks later from 101 cm to 97 cm or by 4%. This difference in plant height tended to disappear a few weeks after heading.

Flooding 38-day-old wheat significantly reduced straw yields. One day of flooding at that time reduced straw production from 9.38 to 8.79 ton/ha, or by 6%. Four days of flooding lowered yields to 8.05 ton/ha, a reduction of 14%.

Flooding at 79 and 104 days increased straw yields. The average effect of flooding for 1 and 4 days at the two periods was an increase in straw yields.

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**TABLE S1. Average number of days required for the oxygen diffusion rate to reach 20 x 10^{-6} g/cm^{2}/min.**

<table>
<thead>
<tr>
<th>Time of flooding</th>
<th>Days to O.D.R. of 20 x 10^{-6} g/cm^{2}/min</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In the top 2 cm</td>
</tr>
<tr>
<td>2 hours</td>
<td>1</td>
</tr>
<tr>
<td>24 hours</td>
<td>5</td>
</tr>
<tr>
<td>96 hours</td>
<td>8</td>
</tr>
</tbody>
</table>

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If we consider 20 x 10^{-6} g/cm^{2}/min as the critical O.D.R. value below which wheat root growth stops, as is true for many plants, flooding this soil greatly extended the period of unfavorable aeration associated with irrigating.
Flooding wheat for 4 days at certain growth periods did not reduce yields. More work is needed to determine whether low oxygen diffusion rates at other periods will damage the plants. This experimental field includes canals, drains, and borders between plots. Plot dimensions must permit a given amount of water to be applied uniformly. The water level in the canals is controlled by gates, and applied to the plots through the 38-mm siphons.

Flooding did not significantly influence grain yields, density of heads, number of spikelets per head, volume weight of the grain, or weight of individual grains. Evidently, grain yield of Inia wheat is not significantly affected by several days of flooding, with low oxygen diffusion rates at certain periods. The same conclusion was reached in a similar study with four other wheat varieties: Inia, Ciano, Tobari, and Azteca. This experience suggests that these double dwarf wheat varieties can supply some oxygen to their roots by transporting it through the aerial portion of the plant.

Further work is needed to investigate the effect of low oxygen diffusion rates in the soil at other periods of development when the plant may be especially sensitive to an oxygen deficiency.

Response to nitrogen fertilization

In most wheat regions of the world, the soils are deficient in essential nutrients, especially nitrogen and phosphorus. Applications of these elements are made to obtain high yields of grain. The
optimal amounts to apply under diverse conditions vary greatly because of differences in soils, climate, management, and the varieties used. Consequently, fertilizer recommendations have to be determined through research for specific producing conditions. Nonetheless, information on the relative response of different varieties of wheat to fertilization under specific conditions is helpful in evaluating the potential of the varieties for use in other parts of the world. Results obtained under irrigation on a heavy clay at the CIANO Experiment Station, Sonora, in 1969 are shown in the figure. The double dwarf varieties Inia and Ciano yielded about the same without applied nitrogen. At high levels of nitrogen fertilization, however, Inia yielded almost 1 ton/ha more than Ciano. At the 50 kg/ha rate of fertilization, each kilogram of nitrogen increased the grain yield of Inia by 35 kg and that of Ciano by only 27 kg. The application of 200 kg/ha of nitrogen increased grain yields of Ciano and Inia by 3.07 and 4.22 ton/ha, respectively. At this level of fertilization, the efficiency of the nitrogen in increasing grain yields was 37% greater using Inia than with Ciano.

It is interesting to note other differences in the performance of the two varieties. The straw:grain ratio of Ciano was 1.43 without nitrogen fertilization. The ratio increased to 2.05 as nitrogen fertilization was increased to 150 kg/ha, and remained at this level with higher rates of fertilization. The straw:grain ratio of Inia varied only from 1.64 to 1.87 as the rate of fertilization increased from 0 to 400 kg/ha. At high levels of fertilization, Ciano produced 449 heads per square meter, and Inia

The amounts and kinds of fertilizer needed for high production of wheat vary greatly among regions and between soils within regions. Nitrogen is the element usually needed in the largest amounts. The wheat shown here followed sorghum at the CIANO experiment station. The crop on the left shows the response to 180 kg of nitrogen per hectare; that on the right is unfertilized.
produced 396. Grain size and the number of spikelets per spike were similar for the two varieties. Apparently, Inia had many more grains per spike than Ciano.

Timing of the first supplementary irrigation

In recent studies in India, maximum yields were obtained when the first irrigation following planting was made at the time crown root development began, 20 to 25 days after planting. An experiment at CIANO in 1969 obtained more information on this point. The first supplementary irrigation was applied 15, 22, 29, 36, or 43 days after planting. The available moisture percentages in the top foot of the soil were 50, 37, 26, 16, and 5 at the time these irrigations were made. The average yields of the two varieties used, Sonora 64 and Tobari, were 5.00 and 4.78 ton/ha respectively. Grain yields were not significantly affected by the time of applying the first supplementary irrigation.

Effect of Simazin

In recent years, Dr. S. K. Ries and his colleagues at Michigan State University have shown that small applications of Simazin and other herbicides can increase the protein content of many species, including wheat. Studies at CIANO in 1969 observed the effect of several doses of Simazin on wheat at four levels of nitrogen fertilization. The protein content of wheat treated with Simazin was significantly higher than that of untreated wheat. Simazin increased percentage protein the most at low levels of nitrogen fertilization.

Effect of manure on wheat yields

Several studies in recent years have reported that maximum yields have been obtained in soils fertilized with animal manure, especially chicken manure. The possible superiority of chicken manure over chemical fertilizers in the heavy clay soils at CIANO was investigated in 1969. Wheat yields were compared in plots fertilized with 200-60-0, 20 ton/ha of chicken manure + 0-60-0 and 20 ton/ha of chicken manure + 100-60-0. The average grain yield was 5.87 ton/ha, and differences among treatments were not statistically significant.

METHODOLOGICAL RESEARCH

Evaluation of the predictive ability of regression models

Fertilizer use research to determine optimum fertilization practices normally involves many well conducted field trials. These are distributed through time and space to sample a wide range of values of the important factors affecting yields. These factors are described carefully for each experiment at the plot or site level. The results obtained at the different sites are combined into a general yield function using multiple linear regression procedures.
In a recent study of corn fertilization in central Mexico, the results obtained with 4 rates of nitrogen fertilization in 76 experiments conducted over a 4-year period were combined into a general yield function comprising applied nitrogen variables, site variables, and interaction variables. In fact, four distinct regression models were generated from the data obtained in the 76 trials. Four solutions were obtained rather than a single one because there are no well defined procedures for introducing independent variables into a regression model nor for eliminating unimportant ones. One of the regressions, the full model, contained all of the 36 independent variables that were expected to have agronomic significance. The "stepwise" and "backward elimination" models were derived from the full model, using statistical procedures for eliminating insignificant variables. The "agronomic" model was developed following a procedure whereby agronomic bases were used to decide the order of introducing variables, and statistical tests were used to decide which variable or group of variables should be included in the model.

The four models were evaluated using the regression sum of squares, expressed as a fraction of the total sum of squares ($R^2$), as the criterion for comparison. Intuitively, this procedure is not totally satisfactory because $R^2$ represents the efficiency of a regression model in predicting the same set of yield values used earlier in its estimation. Consequently, it was decided to investigate a procedure whereby a regression model would be evaluated

Crops on the Andosols of western Mexico respond very little to normal amounts of fertilizer. The corn on the left did respond vigorously to 200 kg/ha of $P_2O_5$, applied in the form of diammonium phosphate. Other plots showed that the added growth was not due to the sulfur. The smaller corn plants on the right received only nitrogen. Sierra Tarasca, Michoacan.
in terms of its ability to predict a different set of yield values.

The set of data mentioned earlier, corresponding to the 76 experiments, was divided into two groups of 38 each. This division of the data was made at random with the restriction that each of the four years have equal representation in the two groups. The regression coefficients corresponding to the four models — full, stepwise, backward elimination, and agronomic — were calculated in this manner from one set of 38 experiments were next used to predict yields for the other set of experiments. The predictive mean squares were calculated for the four models and are in Table S2, together with the $R^2$ for the same regressions. The predictive mean square is the average squared deviation of a predicted yield from the observed yield for data not used in the estimation of the regression equation.

In terms of the predictive mean squares, the full backward elimination models do relatively poorly in predicting yield for values of the independent variables not included in the estimation of the regression coefficients. The agronomic and stepwise models appear to predict much better for new producing conditions. The relative efficiency of the four models, when compared using the predictive mean square criterion, is almost the opposite of that observed when the $R^2$ criterion was employed. The reason for this is being studied. Logically, the predictive mean square criterion is a better basis for comparing the efficiency of regression models, especially if they are to be used for estimating fertilizer recommendations.

**Selection of the factor space for fertilizer experiments**

The results obtained in a fertilizer trial involving only one element can be represented with a simple curve. The optimal rate of fertilization can be determined by comparing the ratio of fertilizer cost to yield value with the slope of the curve. Results from experiments comprising two or more elements, however, are represented most usefully in the form of a yield equation. Optimum rates of the elements are determined by taking the partial derivatives of the yield equation with respect to each of the elements, setting them equal to their corresponding fertilizer cost:yield value ratios, and solving the equations simultaneously.

The quadratic polynomial is commonly used to represent the yield data from fertilizer experiments. However, optimal levels of fertilization often cannot be calculated directly from quadratic equations generated from data obtained in fertilizer trials.

For example, 27 fertilizer experiments were conducted in the state of Puebla, Mexico, in 1967 to determine the response of corn to nitrogen and phosphorus. Corn yields were increased significantly by applications of both nitrogen and phosphorus in 13 of the locations. The yield equations corresponding to the 13 sites were estimated, the partial derivatives with respect to nitrogen and phosphorus were calculated, and the optimal levels of fertilization were determined. For 10 of the 13 equations, the optimal levels of nitrogen and phosphorus calculated in this manner were incorrect.

One of the yield equations that produced erroneous estimates of the optimal levels of nitrogen and phosphorus is:

$$ Y = 240 + 44.78N - 0.0985N^2 - 10.05P + 0.0675P^2 + 0.0235NP $$

$Y$ represents yield in kilograms per hectare, $N$ and $N^2$ are the linear and quadratic effects of nitrogen expressed in kilograms per hectare, $P$ and $P^2$ are the linear and quadratic effects of phosphorus expressed in kilograms of $P_2O_5$ per hectare, and $NP$ is the interaction between nitrogen and phosphorus. Based on current corn prices and fertilizer costs, the optimal levels of nitrogen and $P_2O_5$, estimated from this equation, are 184 and 108 kg/ha, respectively.

These values were substituted in the above equation, and the net gain from the use of this fertilizer treatment was found to be 2,078 kg of corn. If our estimates of the optimal levels are correct, this net gain of 2,078 kg should be the maximum obtainable from the use of fertilizers. However, this was not the case.

For example, the calculated net gain from using only nitrogen (184 kg/ha) was 2,865 kg, 787 kg more than that obtained when both elements were applied. This equation failed to correctly predict optimal levels of nitrogen and phosphorus because it has a negative linear effect of phosphorus and a positive quadratic effect.

Seven of the 13 yield equations had negative linear effects of phosphorus and positive quadratic effects. The phosphorus effects assumed these forms in the equations because of a very low level of nitrogen in these soils. The average yield of corn without fertilizer in these seven experiments was 0.36 ton/ha. Under these circumstances, the application of phosphorus alone decreased yield and consequently had a negative linear effect in the equations.

This deficiency of the yield equations can be overcome by selecting carefully the factor space that is studied in fertilizer experiments. For Puebla, the lowest rate of nitrogen fertilization in the experiments underway has been increased from 0 to 80
kg/ha. This level of nitrogen fertilization is expected to be high enough so that a "diminishing returns" type response will be obtained with the application of phosphorus, and the linear and quadratic phosphorus effects in the yield equations will be positive and negative, respectively.

One further observation was made as to the limits of the factor space for fertilizer experiments. The figure represents the response of two wheat varieties to nitrogen fertilization; it has three observations at rates of fertilization higher than 250 kg/ha, the rate at which the maximum yield was obtained. If quadratic functions are to be fitted to these data, it will be better to discard the highest couple of rates. This is due to the fact that when only one independent variable is present, the quadratic curve rises in a diminishing returns manner to a maximum and then curves back to the X-axis, describing a perfectly symmetrical figure. Obviously, the quadratic function can only adjust closely to the data points up to the maximum. If it is forced to adjust to several points at the maximum yield level, as in the example given in the figure, the average fit will be poor. This is illustrated in Table S2.

<table>
<thead>
<tr>
<th>Variety</th>
<th>7 points</th>
<th>9 points</th>
<th>Deviation as % of 7 pts ÷ 9 pts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ciano</td>
<td>0.01279</td>
<td>0.01492</td>
<td>85.7</td>
</tr>
<tr>
<td>Inia</td>
<td>0.00469</td>
<td>0.03070</td>
<td>15.2</td>
</tr>
</tbody>
</table>

It is seen that the improvement in fit is especially great in the case of Inia. In general, the highest rate of a fertilizer studied should be slightly more than that corresponding to the maximum yield.

ARGENTINE CORN STUDY

The National Institute of Agricultural Technology of Argentina (INTA), the Ford Foundation, and CIMMYT initiated a cooperative corn and wheat improvement program in 1968 to accelerate the production of these crops in Argentina. An agronomic study of crop production in the pampean region of the country was carried out during the latter part of 1968 and early 1969. This involved 24 field experiments, 16 to study the effect of 4
levels of nitrogen fertilization and 2 of phosphorus on corn production, and 8 to compare the behavior of eight hybrids with and without fertilization at three plant densities.

These field experiments were carried out in 15 widely separated areas of the corn belt of Argentina. They were conducted on farmers' fields under natural rainfall conditions, except for one experiment that received one irrigation. Insecticides were used to combat soil insects and weeds were controlled by a broadcast application of an herbicide at planting. The plant population was about 50,000 per hectare in the 16 experiments to study response to different rates of nitrogen and phosphorus. Information was obtained at each location on soil moisture conditions, rainfall, soil characteristics, previous cropping history, management practices, soil temperature at planting, and the effects of insects, diseases, birds, rodents, etc.

In the 1968 season, severe drought during early December affected the corn just before and at the beginning of tasseling. Rainfall was especially limited in the northern and western parts of the corn belt. Three experiments were lost to extreme drought. A fourth was destroyed by a hailstorm in November. Yield data were obtained at the other 20 locations.

The average grain yield of fertilized corn in these 20 experiments was approximately 4.7 ton/ha. Yields were significantly increased by the applications of nitrogen at about 60% of the locations and by phosphorus at 25%. Under natural rainfall conditions, the average increases in yield at sites where responses were noted were 0.39 ton/ha from 50 kg of nitrogen and 0.35 ton/ha from 50 kg of P₂O₅. In the irrigated experiment, average yields were increased from 3.91 to 6.24 ton/ha by the application of nitrogen and phosphorus. Significant responses to applied nitrogen were obtained on soils containing less than 3.5% organic matter but not on soils with higher percentages.

Especially interesting in this study was the "starter effect" from banding 110 kg/ha of the fertilizer, 18-46-0, at planting time. A visual response in seedling growth to this treatment was observed at all locations. Plant heights 40 to 50 days after planting reflected significant increases in growth in 11 of the 16 experiments. When only phosphorus was banded near the seed at planting, the increases in seedling growth varied from 30 to
80% of those observed when both elements were applied. Although available levels of soil phosphorus as determined by chemical analysis were high at all locations, an inverse relationship was observed between seedling response and soil phosphorus level. The average yields obtained with 8 hybrids at the 8 locations differed by as much as 40%. The best hybrid with fertilization and good management yielded 7.2 ton/ha at one location without irrigation and 9.1 ton/ha at another location with irrigation. The optimum plant population was around 60,000 per hectare at high levels of production and about 50,000 for average producing conditions. Apparently, the optimum population at a given level of production was about the same for all varieties.

The average crude protein content of the grain at 12 locations was increased by fertilization from 11.3 to 12.9%. In the irrigated experiment, where yields were greatly increased by fertilization, the average protein content was increased from 8.1 to 10.8% by the application of nitrogen and phosphorus. The protein content of the grain was highest in the flint hybrids, intermediate in the semi-dents, and lowest in the dents.
Communications teamwork with other CIMMYT projects helps get research results applied rapidly. A folder that included basic recommendations was one of several media used in meetings throughout the Puebla area.
COMMUNICATIONS

THE WORK IN COMMUNICATIONS has four main aspects: dissemination of technical information through printed matter, the production of audio-visual material, research on gaining adoption of more productive practices, and training of specialists to bring about changes in production practices on farms. For the time being, the department is also handling the development of a small CIMMYT library.

Every effort is made to assure that the results and research experience of CIMMYT staff are made available to others as quickly as possible. The research staff faces a difficult task in attempting to combine dynamic field research with adequate attention to writing and publishing results. This is especially true in the tropics, where scientists plant and harvest throughout the year. The communications staff helps assure that the results are recorded and rapidly distributed. Liaison is maintained with journals, farm magazines, and other media in order to disseminate this information promptly. The several CIMMYT series provide additional publication channels.

At the same time, the department is concerned with developing additional know-how on successful communications strategies. This means doing research on effective communications and training young men who can produce informational materials and plan strategy for gaining adoption of more productive practices in the developing countries where CIMMYT works.

TECHNICAL PUBLICATIONS

CIMMYT publications are now distributed to individuals and libraries in more than 100 countries (Table C1).

The mailing list includes 231 libraries around the world. To widen the distribution, a selected list of 568 other libraries, principally from nations of the developing world, were recently sent sample publications and a list of available CIMMYT material. Requests to be included permanently in the mailing list are beginning to come in.

Continuous contact was kept with the above readers through six issues of CIMMYT News published bi-monthly in both English and Spanish. Annual reports, also published in English and Spanish, give more complete progress accounts. The other publications that appeared during the past year were:


CIMMYT, purpose, organization, and programs. Special brochure. 1969.

¿Quiere usted aumentar su cosecha de maíz? A farm bulletin prepared for use in the Puebla Project.

Research Bulletin No. 9, Field technique for fertilizer experiments, which was mentioned in last year's report, continued to elicit heavy demand. In addition to the basic mailing list, 600 copies were mailed in reply to 234 requests from agronomists in 48 countries.

The Spanish edition of Borlaug's recent Wheat Breeding and its Impact on World Food Supply is beginning to draw a similar response. In addition to personal requests from many technicians, several organizations have requested quantities to distribute to all of their personnel. Four of them
—in Mexico, Venezuela, Colombia, and Argentina—have obtained 230 copies. In the opinion of one Venezuelan scientist, “this publication reflects a practical and efficient approach for resolving production problems in a backward agriculture and proposes, based on experience, useful lines of attack...”

This underlines once again the fact that not only the results of research, but also the methodology and institutional experience of CIMMYT staff are of value to other scientists.

**Cooperation with other information media**

CIMMYT is a rich source of information for the many newspapers and magazines that frequently reproduce the material it publishes. During the past year, for example, the magazines *Agricultura de las Américas* and *World Farming* published condensed versions of the 1967-68 annual report and of the bulletin, *Field Technique for Fertilizer Experiments*, as well as independent articles based on the work of the center. Also, the international magazine *Life in Español* pointed out the role of CIMMYT in the “green revolution”. The Sunday agricultural pages of the Mexican national newspapers often print news of the activities of the Center, articles from *CIMMYT News* and sections of the annual report. CIMMYT often helps the news media get additional information and photographs in order to attain maximum dissemination of technical information to all who can use it.

The efforts of the department are focused on technical information rather than publicity for CIMMYT itself. For example, the wheat production recommendations that come out of joint programs with national institutions, such as the INIA in Mexico, are published in national or regional publications series.

<table>
<thead>
<tr>
<th>TABLE C1. Distribution of CIMMYT reports.</th>
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<th>No. of addresses</th>
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CIMMYT is rapidly becoming a clearing house for technical information on maize and wheat. In addition to the libraries and scientists in

**AUDIO-VISUAL MATERIALS**

The objective of the audio-visual work is to assure the maximum possible diffusion of both research results and the experience of CIMMYT scientists. In some cases this means cooperating with other audio-visual specialists who wish to cover CIMMYT activities. One such was the British Broadcasting Corporation, which produced a television film entitled *The Man of the Year* on Dr. N. E. Borlaug’s outstanding work in wheat improvement. It also means cooperation with CIMMYT scientists to produce training materials such as the slide series with written narration on *Wheat — Emasculation and Crossing*. These slides show the traditional and the new method of emasculation and of fertilizing the ovaries. The differences between the two methods, both in the techniques used and results obtained, are shown in detail macrophotography. Whenever possible, advice and help have been given on photographic coverage of experimental work. Photos have also been taken to illustrate bulletins, annual reports, and articles for farm magazines. Others have been provided for

104 countries who regularly receive bulletins of the center, many scientists from developing countries request specific publications.

Articles in the popular press describing CIMMYT activities.

As a result of the strong response from nearly 50 countries of the developing world to the manual on *Field Technique for Fertilizer Experiments*, a complete audio-visual package on this subject has been completed. This includes a 16 mm color film in English and Spanish, copies of which are on loan in Bolivia and India, as well as a slide set and a film trip with accompanying narrations. These materials show how to select the experimental sites for field experiments on corn fertilization. They teach how to prepare the fertilizer mixture and how to distribute the treatments in the experimental area. They show how to make scientific observations during the growing cycle on response to fertilizer treatments, levels of insect and disease damage, environmental effects, and description of the soil and sub-soil. They conclude with instructions on how to do an economic interpretation of the data in order to determine the optimum fertilizer application for a specific area.

This material is intended to be used in colleges
of agriculture and by technicians who work in development programs. In this case we are not recommending a particular fertilizer application. Rather, we are teaching a method for determining valid optimum recommendations in any area, no matter how remote, where an agronomist or extension agent must develop local information.

CIMMYT projects of all kinds are assisted whenever audio-visual methods can be useful in attaining objectives. This was the case in the Puebla Project in the spring of 1968, when it was decided that a movie would be extremely helpful in organizing groups of cooperators for the following year. With this in mind, 16 mm color scenes were taken throughout the 1968 growing season. This material was put together quickly into a 28-minute movie to be used specifically in the Puebla area. The title is, Would You Like to Increase Your Corn Harvest? The goal was two-fold. The first objective was to show procedures in sufficient detail so that farmers could follow them. The other goal was to motivate farmers to want to participate in this program for rapidly increasing corn yields.

To achieve these objectives, local farmers and places play prominent roles in the movie and are identified by name as they appear. The film shows how certain farmers greatly increase their corn yields through correct fertilization — applying the necessary elements at the right time and in sufficient quantity — optimum plant populations and control of weeds and insects.

The film was highly successful. It not only was an attraction for bringing together groups of farmers, but also convinced them of the possibility of increasing their yields, and showed the details of the practices that should be followed.

The production of this film also provided an opportunity to experiment with new methods of film use closely integrated with personal contact methods. One innovation was to include a frame about half way through the projection reading “Questions and Answers”. At this point the film was stopped and the information presented up to that time was discussed with farmers. A flyer distributed at this point explained the different fertilization rates to be used in different parts of the area and a simple way to calculate needed quantities of fertilizer.

This approach proved to be highly successful, as farmers who had grown high yield plots or visited demonstrations during the previous year also used this pause to explain their experiences and to encourage their colleagues to participate in the program. The intermission often lasted a full half hour. The projection was then resumed and other questions were answered at the close.

Too often, educational films are used as a mass medium without comment. Integrating our film showing with personal contact and group methods and clearly defining the goal of the meetings made the presentations highly effective. Later in the season, farmers were asked why they decided to plant all of their land according to recommendations of the project. Many gave two reasons: confidence in the farm advisor and “you could see it all in the film”. In this case, the film was attributed a high level of credibility. In the coming year, it is hoped to add a mobile unit for projections in villages without electricity.

Starting in February, 1969, a total of 71 exhibitions were made in 62 localities throughout the area and more than 4,500 farmers saw the film.

Most exhibitions were in rural schools, in farmers’ homes, or in the open air. Largely as a result of these meetings, more than 50 groups of cooperating farmers were formed.
CIMMYT training in communications is given in collaboration with the Graduate College at Chapingo. CIMMYT staff member, Dr. Gregorio Martínez, left, instructs a course in basic theory of communications.

RESEARCH ON GAINING ADOPTION OF MORE PRODUCTIVE PRACTICES

Millions of dollars are being spent each year in programs to increase the production of food crops, to improve the level of living of farm families, or both. In many cases, the programs are based on an inadequate understanding of the factors that have held back progress in the past, and consequently fail to achieve their objectives. The reason for including evaluation in the Puebla Project, and the role of the Communications Department in this evaluation, is to assure that the maximum of knowledge is gleaned from the project. One of the first steps was a study of the existing situation before final planning and action began.

In the past, most evaluations of development projects have been made after the fact, and with inadequate data, in such a way that each person who viewed the project arrived at different and often contradictory interpretations. The evaluation procedures of the Puebla Project and results to date are described in a separate publication now in press.

Estimating the use of increased production on small farms

The goal of a second study was the development of a model for predicting what would happen to the additional harvest if it were possible to rapidly increase yields of a basic food crop, in this case corn, in an area currently producing near subsistence levels. What proportion of the additional production would go into expanded human consumption? How much for animal feed? How much into market channels?

The study was conducted in the village of San Luis Coyotzingo, a Mexican highland community where most of the maize produced is used at home by the family and farm animals. Twelve families
Field training includes farm visits and studies of successful development programs. The first graduate class includes eight men from four Latin American countries.

were chosen to obtain adequate variability on two characteristics: the quantity and source of income, and the amount of corn produced. Income sources ranged from families obtaining nearly all of their income from the farm to those obtaining most of their income from off-farm work. The level of maize production ranged from below subsistence in the case of those who normally bought part of the corn needed for home consumption to semicommercial production by those who frequently had a saleable surplus of up to 3 tons.

The importance of this study rests in one of the important policy questions related to development. In a country where resources for public investment are scarce and it is necessary to increase the production of a basic food crop in order to supply adequate food for urban centers, should preference be given to investing public funds in a small number of large commercial holdings or to the large number of small holders now producing near subsistence levels? If it is known that substantial yield increases can be obtained quickly on subsistence holdings, then a key consideration in answering this question becomes: how much of this increase can be expected to enter market channels? Or as the question is phrased in this study, if production is doubled in an area where present yields are at the family subsistence level, what will be the distribution of the additional production?

There is a belief underlying some of the development literature that the main result of increasing production of a basic food crop among small holders is to increase the amount consumed at home, thereby bringing these farmers further away from starvation, but providing very little marketable surplus. This would undoubtedly be true in areas where there is an absolute shortage of basic foodstuffs in an entire region. It is not true in the Central American areas studied earlier by the INCAP, nor was it true in the present study which was carried out farmers with net sales of -575 kg. Although these people are poor, apparently they can nearly always buy or borrow enough to maintain a constant level of consumption of the basic food grain. Probably, if corn production stays up for several years, there will be a gradual change in eating habits made possible by the increased income from corn sales. However, there appears to be very little short-run effect.
In reality, the amount of off-farm income appears to have more influence on consumption patterns than does total corn production or the amount of total income. Those who obtain their income off the farm tend to eat less corn and have a more varied diet, probably influenced by cultural contacts away from the village.

In order to construct a model that might later be refined for use in predicting the distribution of any particular harvest, it was necessary first to identify the most important variables and then determine their order of importance. In this case a constant price was assumed, which is a fair assumption in Mexico, where the guarantee price is relatively effective.

Prediction was attempted from two kinds of data: first, data based on recall of the distribution of the best harvest ever, the poorest harvest ever, and the previous year's harvest, in this case 1967; and second, differences in distribution of the previous harvest by farmers producing varying quantities of corn. In each case, figures were obtained for the distribution of the total harvest plus the use of purchased grain. To check these figures and obtain a more accurate measurement, a third set of figures were obtained by working closely with 18 housewives using home scales to measure exactly the amount of corn, masa, nixtamal, and tortillas consumed during one week. Previous experience in Mexican rural communities had indicated the importance of consumption by animals, so a careful record was obtained for each type of poultry and animal. The data are not conclusive because of the small number of cases, but do suggest the basic components of any model for predicting distribution of increased harvest.

Although these farms were small (average size, 2 hectares), the farmers poor, and the diets in many cases with up to 80% of the calories from

The course in audio-visual methods includes the production of farm radio programs aimed at increasing crop yields.
corn, the size of the harvest had practically no effect on the amount of corn the family consumed. As corn is the basic food, in bad years the farmers left their villages if necessary to find other work and with the money, bought corn. In years with exceptionally good harvest, some of the corn was sold to improve the house and to buy consumer goods. Above all, in years of good harvest, farmers quickly increased the number of poultry and hogs, and to a lesser extent, cattle and mules. These animals were in turn sold in time of need or when the harvest was poor. Part of such by-products as eggs and milk were often consumed, thereby improving the diet.

Data from the preliminary test yielded the following estimates of distribution if the total harvest of the 12 farmers should be doubled — from 31,000 to 62,000 kg. Household use would stay constant except that tortillas eaten by watch dogs would increase slightly. Sales would increase sharply — from a net purchase of 575 kg to net sales of 11.5 tons. Another large portion of the increase would go into animal feed — principally poultry and hogs, but some to cattle and mules. Corn fed to animals would increase from about 17 tons to 30 tons.

The model requires testing on a broader scale but has already called attention to the need for
studieng the efficiency of the animal aspects of small scale agriculture if accelerated corn yields are to have the implied impact on rural levels of living.

TRAINING

The objectives of the training in communications are twofold: 1) to train men with a broad understanding of strategies for bringing about agricultural development, especially increasing yields among small holders, who have been the slowest to take advantage of advances in technology in the past, and 2) to train people in specific communications and methods.

This training program is closely coordinated with the new Communications Department in the Graduate College at Chapingo, in order to provide the most complete training possible. Staff members of the Department also teach at the Graduate College, giving courses in Production and Use of Audio-Visual Materials, Farm Decision Making, Processes and Effects of Communications, and Technical Editing.

These courses are directed to applied needs of the future development agents. For example, in the audio-visual course, the section on production of radio programs takes the students to the field to record interviews with farmers who explain how they were able to increase yields. The students learn how to take, develop, and enlarge photos and then how to use them in meaningful ways to convey agricultural messages. During the course, each student also produces a slide series on a topic of importance to him in the development program to which he will return on the completion of the course.

The graduate program began in February, 1969, with eight students: three from Mexico, one from Peru, one from Honduras, and three from the International Center for Tropical Agriculture at Cali, Colombia. Three of these men have CIMMYT scholarships. The program has awakened considerable interest in Mexico, and throughout Latin America. It is the first program with the specific goal of preparing a balanced agricultural specialist who can take the lead in development projects. This program is closely integrated with the Puebla Project in order to provide field training along with basic academic course work.

In addition, in-service training in audio-visual methods is provided at CIMMYT for two men from the Mexican National Institute of Agricultural Research (INIA). These men, an agronomist and a cameraman, are participating in all stages of film production, including the completion of three films for the INIA.

LIBRARY DEVELOPMENT

The development of library resources is taking on growing importance as the number of staff and international trainees at CIMMYT headquarters continues to grow. Maximum use is being made of the library resources at the National Center for Agricultural Education, Research and Extension at Chapingo. However, there has been a growing demand to have certain basic references and journals more immediately at hand. As a result, one man has been assigned full-time to this task during the past year. He has begun to determine the pressing needs of the several research and training programs and to acquire certain basic references. An inter-library exchange has been established with the neighboring libraries in order to quickly obtain other references as needed. A list of new acquisitions is published monthly to acquaint the research staff with new material as it arrives. Several staff members have loaned their reprints to the library and these are being rapidly classified to make them more easily available to staff and trainees.
**SOURCES OF SUPPORT FOR 1969**

**GENERAL SUPPORT**

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<td>US AID</td>
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**RESTRICTED GRANTS AND/OR CONTRACTS**

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<td>68-848 Maize and Wheat Program, United Arab Republic, and North Africa, 2 years beginning September 10, 1968</td>
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<td>Special Projects in Mexico, November 21, 1968 through December 31, 1969</td>
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<td>Puebla Pilot Program, 1969 calendar year</td>
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