CIMMYT REPORT

on progress toward increasing yields of maize and wheat

1967-68

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CENTRO INTERNACIONAL DE MEJORAMIENTO DE MAIZ Y TRIGO
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contents

	Page
BOARD OF DIRECTORS	5
OFFICERS AND STAFF	6
INTRODUCTION	9
NEW FIELDS OF WHEAT RESEARCH	9
NEW FIELDS OF MAIZE RESEARCH	11
RESEARCH ON PRODUCTION PRACTICES	12
THE PUEBLA PROJECT	13
BREEDING FOR MORE NUTRITIVE GRAIN	14
COORDINATED APPROACH IN PRODUCTION CAMPAIGNS	14
North Africa, Argentina, United Arab Republic	15
DEVELOPMENT OF DYNAMIC BREEDING PROGRAMS	16
TRAINING	16
CENTRAL OFFICES AND LABORATORY FACILITIES	17
MAIZE	19
TRAINING SCIENTISTS — Mexico, Thailand	19
GERM PLASM BANK	20
GENETICS AND CYTOGENETICS	21
Genetic Marker Bank	21
Chromosome Morphology	22
Maiz Ancho: a New Maize Type	23
The Transmission of B Type Chromosomes in Maize	24
PROTEIN QUALITY	24
PATHOLOGY — Diplodia Ear Rot, Corn Stunt, Downy Mildew	28
ENTOMOLOGY	31
Pest Control Through Host Plant Resistance — Stem Borer, Fall Armyworm, Thrips	31
Insect Control with Insecticides	34
Stored Grain Insects	36
BREEDING — Broader Area of Adaptation; High, Low and Intermediate Elevations; Indirect Selection for Resistance to Lodging	37
CENTRAL AMERICAN PROGRAM	43
ANDEAN REGION — Yield, Agronomic Characteristics, Production Methods, Storage and Marketing	45
INTER-ASIAN PROGRAM — Thailand, Pakistan, Philippines, Afghanistan, Nepal, India	49
EASTERN AFRICA PROGRAM	55
INTERNATIONAL MAIZE MEETINGS	56

	Page
WHEAT	59
PAKISTAN — Storage, Transport, Availability of Fertilizer and Pesticides, Need for Better Machinery, Support of Floor Price for Wheat, Varietal Improvement, Agronomic and Soils Research, Extension Program, Effect of Breakthrough in Wheat Production on Other Crops	63
INDIA — Storage and Transport, Price Supports, Fertilizers, Varietal Performance and Varietal Development, Agronomic Research, Pathology Research	68
TURKEY	72
AFGHANISTAN	72
TUNISIA	72
MOROCCO	73
ARGENTINA	73
OTHER COUNTRIES	74
MEXICO: JOINT INIA-CIMMYT RESEARCH	74
Agronomic Research	74
Performance of Commercial Varieties	75
Promising Advanced Generation Lines	76
Most Promising Early Generation Lines	76
More Dwarfness in Commercial Varieties	76
Improvement in Milling and Baking Quality	78
Improvement in Protein Quality and Protein Level	79
Spring-Winter Varietal Breeding Program	80
Hybrid Wheat Research	80
Promising New Durum Wheat Varieties	83
Research on Triticales	85
Experimental Seed	86
Training	86
NEAR AND MIDDLE EAST SEMINAR	87
SOIL AND PLANT NUTRITION	89
BIAS ERROR IN YIELD FUNCTION	89
COMBINED ANALYSIS OF DATA FROM FERTILIZER EXPERIMENTS	90
COMMUNICATIONS	95
INFORMATION EXCHANGE	95
Publications	95
Providing Information for Other Media	96
Visual Aids	96
TRAINING	97
SOURCES OF SUPPORT FOR 1968	99

During the 1967 annual meeting, members of the CIMMYT International Board visited the experimental wheat plantings in the Toluca Valley. From left to right: C. Subramaniam, Sterling Wortman, Lowell Hardin, Emilio Gutiérrez Roldán, Virgilio Barco, Manuel Elgueta, Nicolás Sánchez Durón, M. C. Chakrabandhu, Carlos Krug, Edwin J. Wellhausen and Galo Plaza. At the extreme right, Norman E. Borlaug explains the research under way in the summer plantings.

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introduction

DURING THE PAST YEAR CIMMYT strengthened its research and training in Mexico and enlarged the network of cooperative research and production programs in the tropical and subtropical areas of the world. In addition to directing central research projects, many CIMMYT staff are involved in developing new cooperative programs and in assisting scientists of various countries in the solution of local and regional problems which have obstructed increases in maize and wheat production.

New staff members have been added and the central training programs enlarged to more effectively meet demands for technical assistance, materials and information.

The hard-core group of CIMMYT scientists, together with an increasing number of outstanding scientists and policy makers in cooperating countries, are catalyzing a series of events leading to an upward spiral in wheat and maize production throughout the tropics and semi-tropics. The major effort of this group is concentrated on the development and utilization of better varieties and production practices. The new high yielding varieties of wheat, developed in Mexico in cooperation with INIA and other local agencies, have sparked a yield revolution in India and Pakistan which is helping to alleviate hunger. The desire for this kind of a revolution has spread to other wheat-deficit countries of the Middle East and North Africa. As a result the Mexican dwarf varieties are improving the well-being of millions of people in widely separated areas of the world. About 13 million acres, 7½ times more than the total area sown to wheat in Mexico, are now planted to these varieties.

In maize, new germ plasm complexes made up of prevailing Latin American races have gone out to the various maize growing areas of the tropics to serve as basic breeding materials for the development of new hybrids and open pollinated varieties. These germ plasm complexes are changing the breeding and production techniques in Latin America and are revealing higher yield possibilities for corn production in Southeast Asia and parts of Africa. New cooperatively developed varieties and hybrids are now going into production in Mexico, Central America, Venezuela, Colombia, Ecuador, Peru, Brazil and Argentina. Open pollinated varieties such as J1, developed from introduced materials in India, are moving into West Pakistan and Nepal. The varieties coming out of the cooperative program in Thailand are opening up new horizons for corn production in Southeast Asia.

NEW FIELDS OF WHEAT RESEARCH

Broader adaptation and disease resistance

To reduce major losses from diseases and extend the usefulness of superior varieties, CIMMYT is developing raw materials with a more diversified and permanent type of resistance to the rusts and other devastating pathogens. This effort has been greatly enhanced through the

NOTE: The terms "maize" and "corn" are used interchangeably in this report to refer to *Zea mays*.

dynamic cooperative breeding programs now in operation with Mexico's National Institute for Agricultural Research (INIA), with the experiment station of the State of Mexico in the Toluca Valley, and with the principal agricultural research institutions in India, West Pakistan and Argentina. This cooperative work not only permits evaluation for disease resistance of a large number of segregating plants, but it also helps to identify superior genotypes under a wide range of climatic conditions, thus speeding the development of still higher yielding varieties.

Spring-winter wheat breeding program

Up to now wheat improvement throughout the world has been separated into two general types of programs: one dealing with the spring wheats, on which CIMMYT has concentrated, and the other with the cold-hardy winter types. There has been very little interchange of germ plasm between the two.

CIMMYT, in a recently organized cooperative program with the University of California at Davis, has undertaken a project designed to blend the two germ plasm complexes. In the initial stages, selected winter wheats will be crossed with the dwarf, fertilizer-responsive Mexican wheats in the attempt to create a new germ plasm pool from which new varieties can be developed for areas like Argentina, southern Chile, and the highlands of Turkey, Iran and Afghanistan, where the winters are often too cold for the present spring wheat types and not cold enough for the better winter varieties. This inter-mixture of genes from the winter and spring germ plasm complexes will also provide new genetic variation from which wheat breeders may be able to develop new winter and spring types with higher yield potential.

Hybrid wheat research

Most varieties of wheat are highly homozygous in their genetic constitution. As in crosses of inbred homozygous lines of corn, the progeny of crosses between wheat varieties often exhibit marked increases in yield over the highest yielding parent. In wheat this yield increase has varied, according to the parentage involved, from 0 to 20%. Although it is easy to commercially exploit this heterotic effect in corn, it is more complicated in wheat because of its self-pollinated nature. Special lines must be developed before commercial seed production can become feasible. To produce hybrid seed, the line used as a "female parent" must be "male sterile" and the line used as a male parent to supply the pollen must be able to restore complete fertility in the hybrid progeny. Unless the male parent has the faculty of restoring male fertility, the hybrid progeny will be male sterile. So hybrid wheat becomes a question of developing "restorer" lines with the proper genetic mechanisms to completely restore fertility. Otherwise the female parent will pass on the "cytoplasmic" sterility to the first generation progeny. Another complicating factor is that male sterile lines vary as to type of sterility and specific restorers needed.

CIMMYT now has developed restorer lines which will specifically restore the male fertility to certain cytoplasmic male sterile types of wheat. The genetic restorer mechanism fixed in these lines will no doubt be widely useful in the production of hybrid wheat seed.

Triticales

Triticale is a promising man-made species of grain combining the characteristics of wheat and rye. The CIMMYT work with this new species has been greatly expanded with the addition of two new staff members. The short vigorous plant types resulting from the incorporation of genes from the Mexican dwarf wheats into the Triticales, may be capable of outyielding the best wheats. The grain also appears promising from a nutritional standpoint; the variation in content of protein and essential amino acids is much greater than in wheat, and it is likely that more nutritive varieties can be developed within the Triticales than within the wheats. In addition, the Triticales may be useful as a forage crop, cultivated pasture, concentrated feed grain for animals, and in the distillation of grain alcohol.

NEW FIELDS OF MAIZE RESEARCH

Conservation and evaluation of germ plasm

In maize improvement there is nothing that has paid greater dividends than the central Maize Bank. Out of the 5,000 varieties in this bank have come the materials for most of the good tropical varieties available today. Many have come out of the inter-mixture of four tropical races —Cuban Flint, Coastal Tropical Flint, Eto and Tuxpeño— identified through extensive testing in Latin America. From this it has become apparent that the improvement of maize yields through inter-racial hybridization offers enormous opportunities. With the material at hand, varieties can be made to order for almost any ecological situation. The possibilities are so exciting that CIMMYT is spearheading a special effort to identify superior germ plasm complexes and show how they may be used in different combinations to develop high-yielding varieties for the various maize producing areas of the tropics and semi-tropics.

In the development of these new varieties, special attention is also being given to built-in protection mechanisms against the vicissitudes of weather and the myriads of insects and disease-producing organisms prevalent in the tropics. Genes controlling such specific characters need to be identified and fixed in such a way that they can be manipulated at will. Excellent progress has been made in identifying materials resistant to stunt virus, diplodia ear rots, head smut and downy mildew— diseases which markedly retard production in certain areas. Progress has also been made in isolating varieties resistant to heat, drought, frost and devastating insects. Perhaps most exciting of all is the variation in genetic factors governing the physiological processes in the plant. There are excellent possibilities for the identification of genes affecting height of plant, reaction to day length, nitrogen reductase activity and the amount and quality of protein.

In order to incorporate these kinds of genes into high yielding varieties, joint efforts are underway with various scientists and institutions in the tropics to form widely-adapted, pest-resistant populations with more nutritive grain. This work will involve combined selection in highly variable composites under diverse conditions and for multiple characters such as productivity, desirable agronomic traits, high lysine content, and resistance to diseases, insects, cold, heat and drought. In this way it is hoped to form broad-based populations with the genetic potential for development of highly productive varieties.

RESEARCH ON PRODUCTION PRACTICES

In order to more fully exploit the new varietal potential, more basic information is needed concerning the interaction of all factors influencing yield. For this reason CIMMYT is placing new emphasis on agronomic and physiological studies to determine the package of practices needed for maximum yield.

If the potential yield of the new wheats is to be fully exploited, a great deal of additional information is needed in each country on proper fertilization, irrigation, seeding rates, and dates and depths of planting. Cultural practices adequate for one type of varieties or set of conditions are frequently not right for another. Field experiments were initiated in 1967 at CIANO in Sonora, Mexico, to study the effect of various production factors on the yield and nutrient uptake of wheat. The variables included in the study are: (1) soil moisture level, (2) rates of nitrogen fertilization, (3) time of nitrogen application, (4) method of applying nitrogen, (5) tall, double-dwarf and triple-dwarf varieties, (6) dates of planting, and (7) aeration levels at two or more stages of development.

The experiment will be conducted for several years and plans are being worked out to obtain the collaboration of scientists at the University of California at Riverside. Dr. Lewis Stolzy visited Sonora in January and March of this year for preliminary observations and discussions. Dr. S.D. Van Gundy also visited the Yaqui Valley and the Hermosillo area in March to collect soil samples and make nematode counts. His survey showed that three genera of parasitic nematodes are found widely in these regions. The lesion nematode (*Pratylenchus* sp.) was the most prevalent plant parasitic nematode in the wheat fields of the Obregon (73%) and Hermosillo (75%) regions. He also felt there was a good correlation between his observations of depressed plant growth in the field and very high populations of the lesion nematode (5-10 thousand per 500 c.c. of soil).

In maize, such factors as soil fertility and cultural practices must be improved in most areas before rapid production increases can be obtained. There is need for research on plant efficiency in the use of light, fertility and moisture. In spite of adequate moisture and fertility, and with insects and plant diseases under reasonable control, yields of grain in the lowland tropics are disappointingly low. Efforts are now underway with the help of physiologists to determine the principal contributing factors. The maize breeders urgently need more information on various physiological processes in the maize plant and must take these into consideration in their selection programs if much better varieties are to become a reality. CIMMYT is adding a number of young plant physiologists to its hard-core staff to help obtain this badly needed information.

THE PUEBLA PROJECT

Most of the corn in Latin America is grown as a subsistence crop under natural rainfall, usually by farmers with few resources. Problems of increasing yields of corn under such conditions are being studied in a CIMMYT pilot project in Mexico's State of Puebla.

The project was initiated in the spring of 1967 with a special grant from the Rockefeller Foundation. The CIMMYT Maize, Soils and Communications Departments have the technical responsibility for the Project, and the coordination is carried out jointly with the Graduate College at Chapingo. Other cooperating agencies include the Government of the State of Puebla, the Ministry of Agriculture and official banks.

The objectives of the program are to: 1) double corn yields in an area of 100,000 hectares within a period of three to five years; 2) develop an efficient methodology which may be applied to other areas of Mexico and in other countries; 3) train technicians in all aspects necessary to increase corn yields.

The chosen area has many characteristics similar to other agricultural regions of Mexico and other developing countries. It is an area of high demographic pressure where the land has been cultivated for centuries. The holdings are small —slightly over one hectare per family— and the basic food crop is grown on more than 70% of the arable land.

Average corn yields have never surpassed one ton per hectare yet the region has good ecological potential.

In terms of existing technical knowledge the area is similar to a vast number of valleys and small ecological areas of Mexico and Latin America in that it has not had the benefit of a local experiment station. In the Puebla Project the experimentation is done with cooperating farmers in order to sample the full range of climates and soils existing in the region.

The project is based on tight coordination of four lines of work: 1) agronomic research and breeding, 2) dissemination of results, 3) evaluation of the project, and 4) changing the infrastructure.

On the breeding side, six experiments were planted under different soil and moisture conditions in 1967; this work is going forward in 1968 in order to obtain a variety with greater production potential than the native varieties currently in use. A total of 27 fertilizer trials were planted with farmers in 1967. Striking yield increase were obtained at 22 of the locations through the application of nitrogen. The application of phosphorus increased yields at 15 locations; additions of potassium and zinc had no effect.

With the analysis of this information, a demonstration program was immediately launched in 1968. In addition to continued experimentation, a total of 140 high yield demonstration were planted with cooperating farmers.

A unique aspect of the project, in addition to the dynamic and integrated approach, it that the project is being systematically evaluated from the very beginning in order to gain a maximum of knowledge. The evaluation includes two kinds of research: 1) preliminary data collection about farmers' production methods and levels of knowledge in order to orient the action program, and 2) "before and after" measurement to determine the extent to which the objectives of the project are realized.

A detailed report of this important project will be published separately and consequently is not included here.

BREEDING FOR MORE NUTRITIVE GRAIN

The major part of the protein consumed by people in the developing areas of the world comes from the grains they eat. There are differences among varieties of maize, wheat, rye and Triticales in their protein content and amino acid composition. In wheat the high lysine types identified in the USDA-University of Nebraska project are being crossed with the high yielding Mexican dwarf varieties in a special CIMMYT project aimed at improving the amount and quality of protein. This project is being facilitiated by a new, simpler chemical test specifically for lysine, developed in CIMMYT's protein quality laboratory. This test shows promise for screening segregating populations of both maize and wheat for lysine content on an individual seed basis. If this can be perfected for handling large numbers of samples, it will greatly accelerate the breeding program for more nutritive varieties.

In maize, the opaque-2 and floury-2 genes are being incorporated into the important low, intermediate and high altitude races of Mexico, Central America and the Caribbean. In addition, a search for mutants with high protein quantity and quality has been started by analyzing the collections available in the central Maize Bank. This work is benefiting from the new laboratory technique for the analysis of individual kernels in such a way that they can still be propagated. In certain races an extreme range has been found among varieties, in total protein and in content of lysine and trytophan.

Variation in total protein due to environmental effects has also been noted in various collections. Varieties grown in lowland tropical environments at apparent high fertility levels contained from 44 to 92% less protein than the same varieties grown at similar fertility levels under cooler conditions at intermediate altitudes. Further information is needed on the interactions of variety, fertility level and temperature in determining total protein content.

COORDINATED APPROACH IN PRODUCTION CAMPAIGNS

The value of a coordinated approach in production campaigns has been clearly demonstrated in West Pakistan and India. The main catalytic agent that sparked the rapid acceleration in wheat production on irrigated land in these two countries was the yield impact of the Mexican dwarf wheat varieties grown under heavy fertilization and special management practices. This, together with an awareness of the dire food deficit, opened the way for aggressive national production campaigns taking into account all important factors affecting production-economic and psychological as well as biological. With a well coordinated effort to remove production bottlenecks, impressive increases have been obtained in both countries. As a result of these successes, CIMMYT has received other requests for technical assistance in accelerating food production. The work initiated in response to these invitations is described below.

North Africa

In a joint effort with USAID and the Ford Foundation, CIMMYT has agreed to assist Tunisia and Morocco in the development of a coordinated program designed to erase present deficits in wheat production. The production campaign will be initiated with the Mexican dwarf wheat varieties which in extensive tests conducted last year by USAID in collaboration with local institutions yielded about 50% more than varieties now commonly grown. North Africa is different from Pakistan and India in that almost all the wheat produced is grown under natural rainfall conditions. In view of this, CIMMYT will devote its major effort to field research in collaboration with the appropriate local institutions to determine the package of agronomic practices needed to raise yields. Although the Mexican dwarf varieties are fairly well adapted, a vast amount of other genetic material will be evaluated in the area to develop varieties even better adapted and with greater resistance to locally prevalent diseases.

Argentina

The pampean area of Argentina is one of the important food production regions of the world with about 10 million hectares planted each year to maize and wheat. For the past 20 years, yields of both crops have been nearly static, yet soil and water resources are sufficient to double present production. At the request of INTA and with the help of the Ford Foundation, CIMMYT will increase its collaboration with INTA in the development and execution of a coordinated program designed to accelerate both corn and wheat production in the pampas. The basic work needed in the development of high yielding varieties of maize and wheat will be intensified and a field research program has been initiated to determine the factors that are limiting present production.

United Arab Republic

About 800,000 hectares of maize are planted each year in the UAR. Significant yield increases have been obtained by moving up the planting date from early August to June. Average yields are around three tons per hectare, but considering the available soil and water resources, should be six tons or more. There are many problems, biological and social, which limit present production. Before a marked change can be brought about in farming practices, a high-yielding, fertilizer-responsive and disease resistant variety will be needed. At the request of the Ministry of Agriculture and with the help of the Ford Foundation, CIMMYT will continue to assist the maize team in the UAR in the development of better varieties and in getting such varieties into wide scale use with the production practices indicated for bringing about a rapid production increase.

DEVELOPMENT OF DYNAMIC BREEDING PROGRAMS

Since varieties with high yield potential are essential to the success of every production campaign, CIMMYT is making an extensive effort to promote the development of broad and dynamic breeding programs in various parts of the world. Such programs are badly needed to maintain disease resistance and to augment present yield potentials and nutritive quality. The task ahead can best be accomplished through closely knit team work among breeders, plant pathologists, entomologists, chemists, physiologists and agronomists, at a network of breeding centers strategically located throughout the important maize and wheat regions.

CIMMYT's wheat team has developed a broad range of materials and effective breeding methods to achieve the combination of yield, industrial quality and disease resistance which is being fed out to the vigorous new breeding programs of India, Pakistan, Argentina and other areas. The formation and distribution of this genetic material is a vital function in the further improvement of wheat throughout the world. Hundreds of crosses are made each year between highly selected gene pools of bread and durum wheats as well as Triticales. F_2 bulk seed from such crosses is then widely distributed. Last year seed was shipped to 60 different countries.

CIMMYT's maize breeders are also concentrating on the production and distribution of superior genetic materials. They are closely allied with their counterparts in Southeast Asia, India, Pakistan, Egypt, East and West Africa, and with all the maize breeders in Latin America, in a cooperative effort to develop better varieties for the different ecological areas. Seed of superior varieties and composites was sent to 39 countries during the past 12 months.

TRAINING

In CIMMYT's training programs, high priority is given to the preparation of young scientists for countries that have a genuine desire to improve yields in wheat and maize. The in-service training is being shared insofar as possible with the regional research and extension programs. For example, some of the in-service trainees from Southeast Asia are being sent to Thailand for work in maize. Some in Eastern Africa are being sent to Kitale in Kenya, and many in the Andean region are being sent to Colombia. However, apart from India, most of the in-service trainees in wheat are coming to Mexico.

At the graduate level, CIMMYT has an arrangement with the Graduate College at Chapingo through which certain trainees can work toward a Master of Science degree. Some of CIMMYT's staff members are adjunct professor in the Graduate College and supervise resarch on thesis problems. Several young scientists are working on PhD theses under the joint supervision of CIMMYT staff members and professors at leading graduate schools abroad.

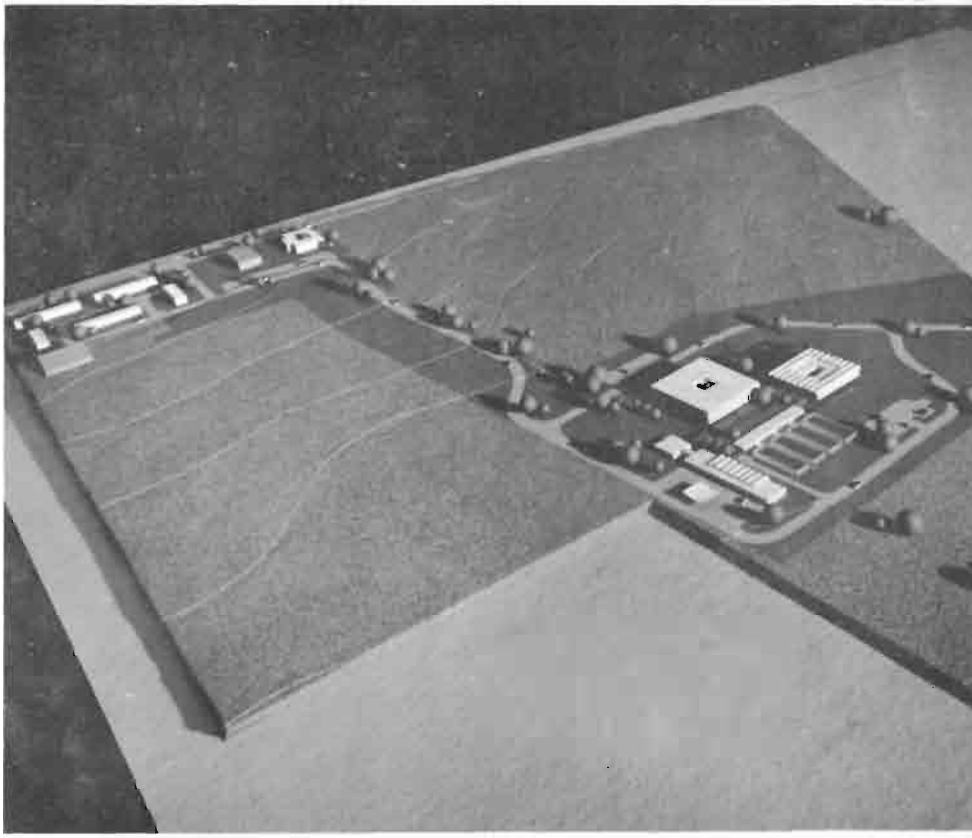
CIMMYT has recently established a number of Special Research Assistantships open to young scientists who have completed a Master's or a PhD degree and wish to spend a period of two years with CIMMYT working on special problems.

CENTRAL OFFICES AND LABORATORY FACILITIES

Early this year the Mexican Ministry of Agriculture purchased a fraction (43 hectares) of the ex-hacienda El Batán and transferred it to CIMMYT for the establishment of its central headquarters. The former project for building on land of the National School of Agriculture at Chapingo has been abandoned and the architectural plans for this area have been discarded. A new set of plans for offices and laboratories are being drawn up, and it is hoped that construction will get under way during the final quarter of 1968.

El Batán is located four kilometers from Texcoco on the highway to Veracruz. It is about a 10 minute drive from Chapingo and close enough for cooperative research and training projects and the joint use of certain facilities with INIA and the Graduate School.

Plans provide for the construction of: 1) an office building to house all of CIMMYT central staff; 2) a laboratory building including space for all essential laboratories; 3) greenhouses and corresponding head houses; 4) seed storage and processing area; 5) dormitory for 56 people; 6) ten two-bedroom apartments for visiting scientists and married students; and 7) repair shops and farm machinery area.



Mock-up of the CIMMYT facilities to be built at El Batan, near Chapingo, Mexico. In the foreground are the offices, laboratories and greenhouses. Toward the back are located the seed storage and farm machinery areas as well as the dormitories and apartments for graduate students and visiting researchers. Construction work should start late this year.

Adequate use of new inputs resulting from research is an important way to increase production in over-populated countries with limited arable land. Such is the case of El Salvador, where Jesus Merino Argueta has obtained 18 ton/ha of maize in less than one year by growing three consecutive crops. He used the Salvadorean hybrid H-1 to obtain the highest yearly production from a half-hectare plot in the contest organized last year by the PCCMCA.

maize

maize

■ THE AVERAGE YIELDS OF MAIZE are extremely low in most countries, with little evidence of improvement over the past two decades (see 1966-67 CIMMYT Report). However, there are clear possibilities for improvement. A multiple approach is needed involving cooperative and persistent effort on the part of technicians in many disciplines. Better varieties may provide higher yield potential and greater resistance to various crop hazards such as insects, disease and drought. Improved husbandry is required, including correct fertilizer use, weed control and well-time planting and harvesting. Improved storage and marketing facilities need attention so that the harvested grain can be protected from deterioration and made available to the ultimate user. If any link in this production chain is not functioning effectively, food production falls short of its potential. With this in mind, wherever possible the CIMMYT Maize Program is cooperating with national public and private agencies. Only by working together will it be possible to attain the increased production of the high quality food and feed urgently needed in the world today.

The main limiting factors in maize production provide the focal point for research. These include problems of soil fertility, husbandry, insects and diseases. In the tropics there is also a need for research on plant efficiency. In many areas, in spite of adequate moisture, fertility, and with insects and diseases under reasonable control, the yields of grain are disappointingly low. Plant size is excessive. Efforts are now underway with the help of physiologists to determine what contributes to efficient plant production. For too long the system used has been trial and error; it is time to learn exactly what type of a plant is needed in order to select more intelligently. In general it is thought that the ideal maize plant should be short-stalked, prolific, have a high grain to stover ratio, and be resistant to major crop hazards and lodging. A more precise description based on physiological studies could lead to a breakthrough in maize breeding.

The maize plant is quite sensitive to day length. Is it possible to reduce this sensitivity thereby greatly increasing the area of adaptation of much of the germ plasm now available in the germ plasm banks in the tropics? Selection schemes of varying scope are being initiated in an effort to increase the area of adaptation of some of the tropical germ plasm. It is possible that day length sensitivity genes are acting as a serious deterrent to wide adaptation and hence limiting the usefulness of otherwise superior material.

The following pages provide a progress report on these and other research efforts aimed at greater production and higher nutritional quality or maize.

TRAINING SCIENTISTS

The maize program is providing in-service training as well as under-graduate guidance.

The in-service training program has been broadened to impart the best possible training in accordance with the capabilities and needs of the participants, as well as to make the best possible use of CIMMYT facilities in this field. Training centers for maize technicians are well underway in Mexico and Thailand, and similar work is planned in Colombia and Kenya where CIMMYT collaborators are located.

Mexico

Starting in 1969, all trainees must be in Mexico by January 15, regardless of their length of stay. During the first 4-6 weeks they will participate in a series of formal orientation lectures as background for a better understanding of the research program, and the factors limiting corn yields. In this way all trainees will have the opportunity to follow a complete cycle, from seed preparation through note taking and harvest operations, to analysis and interpretation of experimental results. Those currently receiving in-service training are:

Alfonso Alvarado Dumont	Panama
Emilio Salvador Bonilla	El Salvador
Leonidas Ureña Vega	Panama
Carlos N. Pérez Rodas	Guatemala
Jose Maria Troncoso	Argentina
Bosso N'Guetta	Ivory Coast

Graduate and undergraduate training is conducted by CIMMYT staff in collaboration with degree granting institutions. The thesis research of students is done using materials and facilities of the CIMMYT maize research program and under the supervision of various staff members depending upon the student's area of interest. The staff member who participates in a graduate program is usually given adjunct professorship status; in other cases a special agreement is made with the University or College.

The following persons are being advised in the elaboration of their theses for the "Ingeniero Agronomo" degree:

Salvador Domínguez S.	Mexico
Ricardo Suárez	Paraguay
Angel Ripol Castillo	Dominican Rep.

The following individuals are being advised for the completion of the requirements for an M.S. degree at the Graduate College in Chapingo:

Hernán Cortés	Mexico
Federico Poey	Mexico
José Díaz	Peru
José Oscar Gomes de Lima	Brazil

Students being advised on research problems for PhD training in the United States are:

Ing. Odon Miranda	Mexico
Ing. Fidel Berlanga	Mexico

Thailand

A vigorous training program has been undertaken during the past year at Farm Suwan. National and international trainees in corn research and extension as well as selected university students participate in all phases of research and developmental activities on the experiment station. They also participate in formal lectures, seminars and discussion groups.

Training at Farm Suwan includes conferences, seminars and actual participation of the trainees in all phases of maize production. This program serves many countries of Southeast Asia. In the picture, Dr. D.G. Smeltzer discusses production of lines with trainees from Pakistan and Afghanistan.

Regional farm testing has been introduced and provides and important aspect of the training. Extension personnel from the locality, along with researchers and trainees from the maize center put out tests with cooperating farmers using the best materials and latest technology coming from the experiment stations.

The number of trainees, categories and countries are listed below:

International	No. of persons	Months/ persons	
Ceylon	1	9	
Philippines	2	6	
W. Pakistan	12	6	
Afghanistan	1	12	
India	1	12	(Post doctoral fellow, breeding)
India	1	12	(Post Doctoral fellow, pathology)
Thailand			
breeding	2	12	
agronomy	2	12	
pathology	1	6	
extension	20	3	
Kasetsart University students	64	2½	
Substation researchers	7	2	

GERM PLASM BANK

The function of the corn germ plasm bank is to preserve the genetic variability that exists in the species *Zea mays* L. and to make it available to interested breeders. During the period May 1, 1967 to April 30, 1968, a total of 103 seed shipments involving 2,387 items were sent from Mexico to 39 countries. The largest number of shipments (65) and of items (1,733) were sent to countries in the Western Hemisphere. This seed movement is summarized in Tables M1 and M2.

The stations in Thailand and India are collecting, maintaining and distributing germ plasm of interest in Asia. During the past year seed was supplied to 12 countries —Malaysia, South Vietnam, Afghanistan, Turkey, Philippines, Laos, Hawaii, Taiwan, Ceylon, Pakistan, Australia and Nepal.

Starting in mid-October, a complete reorganization of the germ plasm bank in Mexico was undertaken. A new inventory was initiated and all information about race, group, composite, amount of seed available, agronomic adaptation, characteristics, disease and insect reaction and chemical composition of the corn populations stored in the bank, is being punched in IBM cards. This will facilitate the preparation of listings required for easy seed and information retrieval and to maintain a running inventory of all seed stocks in the bank. The IBM work will be completed during the current year. Immediately afterwards, racial composites and other populations will be initiated to reduce the number of items stored in the bank without losing any of the variability. A series of genetic studies will also be undertaken, utilizing the materials in the bank.

TABLE M1. Number of corn seed shipments and of items sent by CIMMYT-MEXICO to 39 countries during 1967-1968.

Country	Number of Shipments	Items
Afghanistan	1	13
Antigua	1	4
Argentina	4	27
Australia	2	71
Barbados	1	2
Bolivia	4	31
Brazil	3	23
Cameroon	1	9
Ceylon	1	23
Ecuador	2	3
England	2	18
France	1	81
Ghana	1	60
Grenada	1	4
Honduras	1	2
India	6	81
Indonesia	1	2
Japan	2	5
Kenya	4	101
Malaysia	2	23
Mexico	9	129
Nepal	1	22
New Zealand	1	19
Nicaragua	3	415
Niger	1	35
Nigeria	2	8
Panama	1	6
Paraguay	1	9
Philippines	1	8
Rhodesia	1	31
South Africa	1	9
Thailand	1	4
Trinidad	4	15
Tunisia	2	6
Turkey	1	9
U.S.A.	28	1034
Venezuela	2	29
Yugoslavia	1	6
Zambia	1	10
SUM	103	2387

The germ plasm distributed by CIMMYT has had broad usage in the development of better varieties. In Nigeria the Mexican race Tuxpeño is used in crosses with local floury materials.

TABLE M2. Area summary of corn seed shipments made by CIMMYT-MEXICO during 1967-1968.

Destination	Shipments No.	Shipments %	Items No.	Items %
Africa	14	13.59	269	11.27
North and South America	65	63.12	1733	72.60
Asia	16	15.53	181	7.58
Australia and New Zealand	3	2.91	90	3.77
Europe	5	4.85	114	4.78
SUM	103	100.00	2387	100.00

GENETICS AND CYTOGENETICS

Activities during the year were cooperative with the breeders, the Graduate School at Chapingo, Mexico and with other cytogeneticists including Dr. Almiro Blumenschein, Brazil and Dr. Barbara McClintock, Cold Spring Harbor, New York. The goal is to obtain a better understanding of chromosome morphology as related to origin and behavior of maize in crosses. The relationship of chromosome morphology and genetic mutants to growth and physiology is also being studied.

Genetic Marker Bank

A group of genetic marker stocks (plant, aleurone and pericarp colors) obtained from the Graduate School at Chapingo were increased and crossed to Chalqueño and Tuxpeño so as to develop stocks with different adaptation backgrounds.

New mutant characters as they appear in the various breeding programs will be maintained for possible future ontogenetic studies of the maize

The study of the chromosome morphology of maize races yields information about combining ability between races. It also reveals relationships between chromosome organization and racial stability so as to determine when the process of selection can be applied. Dr. Almiro Blumenschein of the Genetics Institute, Piracicaba, Brazil, is shown here studying the knobs on the ten pairs of chromosomes of each sporocyte with a special microscope

plant. Several new mutants are being studied. A brachytic, "Tallo Cuadrado" from Argentina, appears to have a double growing point. At each node there are two opposite leaves and at the ear bearing node there are two opposite ears. The mutant may be useful for increasing stalk strength. Likewise, a mutant giving bifurcate stalk is divided at the second or third node giving two stalks which develop normally. With both of the above mentioned mutants it appears possible to develop materials with the effect of having "two blades of grass where one grew before". Population density studies with normal and mutant types are contemplated after the necessary stocks have been developed.

Chromosome Morphology

The cytological study of Mexican races of maize is being continued. Several collections of the races Bolita, Zapalote Chico, and Zapalote Grande were analyzed cytologically and compared with previous data from the Tuxpeño race (Table M3. The average knob number of each race together with the range in values for different collections is given. Since the race Tuxpeño is widely distributed in Mexico, the collections studied were grouped representing different regions. The groups are fairly consistent by regions (about 10 knobs per plant) suggesting the existence of some mechanism for maintaining a relatively uniform amount of knob material wherever the race is adapted and cultivated.

The race Zapalote Chico exhibited the largest average number of knob position followed by Bolita, Zapalote Grande and Tuxpeño.

TABLE M3. Means of the number of knobbed positions by race and by collection within each race.

Race Name	No. of Collections	Race mean of knobbed positions
BOLITA	7	12.5
ZAPALOTE CHICO	12	14.5
ZAPALOTE GRANDE	7	10.9
TUXPEÑO:		
Veracruz	16	9.7
Chiapas-Oaxaca	9	10.3
Guerrero-Michoacán	15	10.7
Campeche-Yucatán-Quintana Roo	9	10.5
Coahuila	7	9.9
Tamaulipas	7	9.5

The frequencies of different knob sizes (small, medium and large) in the four races are shown in Table M4. In the Tuxpeño collections by regions a consistently larger percentage of medium size knobs is evident. Since some of the Tuxpeños are grown near populations of Zapalote Chico, Zapalote Grande, and Bolita which have relatively higher frequencies or large knobs one wonders why the Tuxpeños have such a consistent knob pattern. Surely populations growing in near proximity are subject to gene flow in either direction but there is a suggestion of an isolating mechanism in operation. The transfer of knobs and knob patterns between populations which grow in pollinating proximity needs study.

The distribution of knobs in maize races as related to the distribution of Teosintes and their

TABLE M4. Frequencies of the different knob sizes found in the races Bolita, Zapalote Chico, Zapalote Grande and Tuxpeño.*

	Number of chromosomes analyzed					Percent Frequency			
	O**	S	M	L	Total	O	S	M	L
BOLITA	565	105	119	345	1134	49.8	9.3	10.5	30.4
ZAPALOTE CHICO	1118	331	419	840	2708	41.3	12.2	15.5	31.0
ZAPALOTE GRANDE	716	135	165	290	1306	54.8	10.3	12.6	22.2
TUXPEÑO:									
Veracruz	2284	395	645	332	3656	62.5	10.8	17.6	9.1
Chiapas-Oaxaca	1159	238	358	218	1973	58.7	12.1	18.1	11.0
Guerrero-Michoacán	1934	372	622	310	3238	59.7	11.5	19.2	9.6
Campeche-Yucatán-Quintana Roo	1092	241	539	255	2127	51.3	11.3	25.3	12.0
Coahuila	868	164	267	151	1450	59.9	11.3	18.4	10.4
Tamaulipas	916	133	423	121	1593	57.5	8.4	26.6	7.6

* Homozygosity and heterozygosity of the knobs are considered, and all the knob forming positions of the ten chromosomes are pooled. Some plants were not analyzed entirely, although in general the ten chromosomes were considered.
** Knobless; S = Small knob size; M = Medium knob size; and L = Large knob size.

At Piracicaba, studies of plant and ear morphology are also underway. The races of maize are classified and their distribution mapped.

knob patterns is under study. Certain infrequent knob patterns in maize (1L, 2S, 3S, 4S, 5S, and 6L) are found in collections obtained in the western and southern regions of Mexico, following the western Sierra Madre mountains. These are the general areas of distribution of the Teosintes. A total of 25 collections of Teosinte were made in the States of Guerrero, Michoacán and Mexico. The collections were made with the assistance of Dr. Lauro Bucio A. and Ing. Jorge Curtis P. of the Department of Genetics, Graduate School, Chapingo. The collections will be planted and sampled for analysis of their chromosome morphology.

Maíz Ancho, a New Maize Type

During the year collections of maize in the States of Morelos, Guerrero and Mexico revealed the presence of a new type of maize known as "Maíz Ancho". Preliminary study of the morphological characteristics of the collections indicate a lack of correspondence to the races of maize previously classified in Mexico by Wellhausen et. al. (1952). Efforts are being made to determine whether Maíz Ancho is a newly developing type from crosses of previously described races. Crosses between defined races in the area —Pepitilla, Bolita, Tabloncillo and Chalqueño— as well as the parents, were grown together with 14 selected collections of Maíz Ancho. In addition a sample of S_1 lines from each collection were grown.

Within each 2 row x 10 m. plot, measurements were made on 10 plants for plant and tassel characters. Sporocyte samples were collected for cytological measurements. At harvest measurements for ear and kernel characteristics will be obtained.

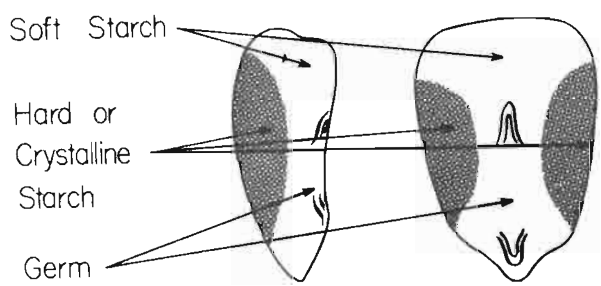
The Transmission of B Type Chromosomes in Maize

An accessory type of chromosome body known as B type chromosomes are found in some races of maize. Little is known relative to their importance in these races and their mode of transmission through the female and male sides of the parentage. Occasionally a portion of the standard A chromosomes may be translocated to a B type chromosome. These translocations have been used in genetic studies. Because of interest in determining the effect of B chromosomes on growth and development, stocks containing a relatively large number of these chromosomes are being developed. The comparison of plants having 0B with others having many B chromosomes in the same genetic background will permit the determination of such effects.

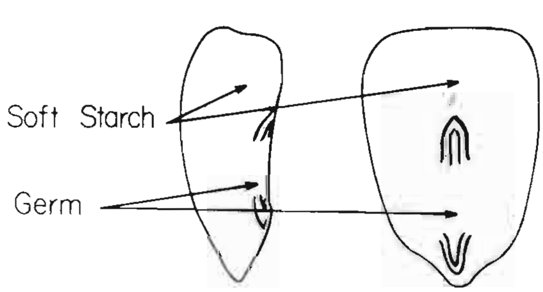
In order to develop stocks useful in studying the effects of B chromosomes, studies were initiated to determine their mode of transmission in crosses. Plants having 0B x 1B resulted in about ⅔ of the progeny with 0B and ⅓ with 2B, although de latter class varied from 25 to 44% in different crosses. The reciprocal crosses (1B x 0B) resulted in a 1:1 ratio of 0B and 1B. It thus appears that in the female parent plant the B chromosomes behave normally, that is, in all meiotic divisions of the megasporocytes and further mitotic divisions of the megaspores during the formation of the embryo sacs, B chromosomes invariably carry on normal chromatid disjunction.

On the other hand the microspores in male parents having a single B chromosome underwent non-disjunction so that either 0B or 2B pollen grains were produced. The variation in percentage of 2B types in the several crosses suggest the possibility that fertilization with 2B pollen grains may be under genetic control. Several working hypotheses have been developed which will be studied experimentally.

TYPES OF CORN KERNELS



Normal Corn Kernel



High Lysine Corn Kernel

Kernels rich in lysine generally are softer than normal grain. This softness makes them more susceptible to insect attack and less acceptable as human food. One goal of research is to obtain grain rich in lysine which also has hard endosperm.

PROTEIN QUALITY

The introduction of the protein quality controlling genes opaque-2 and floury-2 into races of maize adapted to low, intermediate and high altitudes, was continued. The materials which have been backcrossed three generations include the Chalqueño, Tuxpeño, Vandeño, Tabloncillo, Pepitilla and Bolita races. Following three generations of backcrossing, racial composites of homozygous mutant seeds are being formed. These composites will be subjected to mass selection for further improvement of yield and other agronomic traits. The converted and selected racial composites will be used to introduce the protein quality genes into populations being selected for improved yields so that a more adequate balance of essential amino acids may be incorporated into the varieties released for farmer use.

A program involving selection for higher total protein in the presence of opaque-2 has been initiated. This involves crosses between Illinois High Protein and some high altitude Mexican races converted to opaque-2. Self-pollinated plants (S_1 lines) are analyzed for total protein. Opaque-2 seeds from the higher protein families are to be used in making up the new population for the next cycle of selection. The objective is to develop a population having more than 15% total protein with the opaque-2 gene present. Such a population would provide an adequate diet for children (carbohydrates and proteins) when supplemented with the necessary vitamins and minerals.

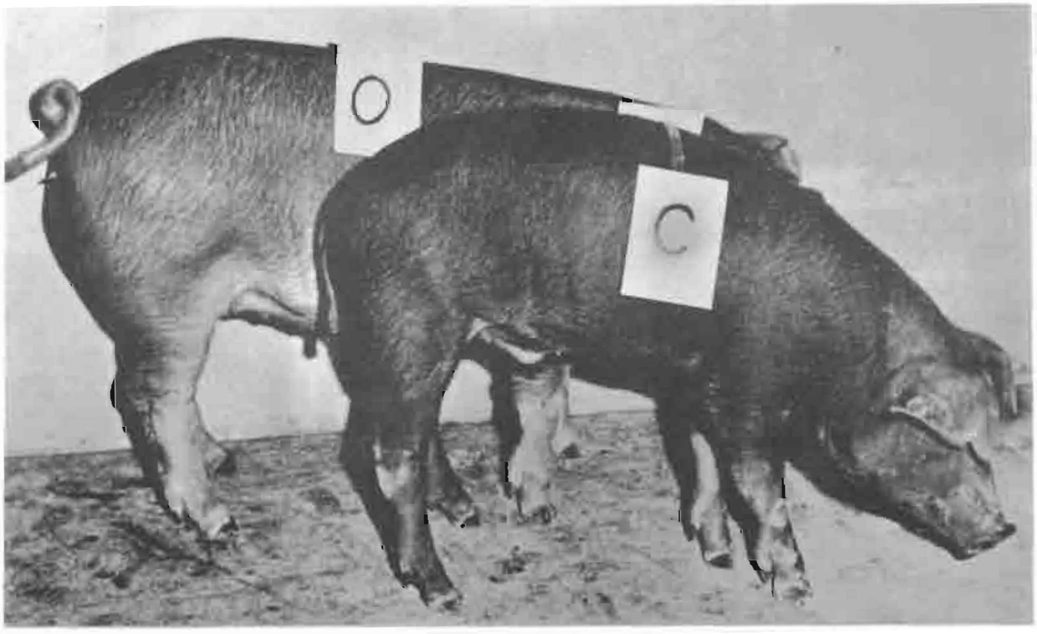
The protein laboratory has developed a rapid tryptophan screening procedure of value in the systematic evaluation of the world maize germ plasm. Since tryptophan and lysine are highly correlated ($r = .81^{**}$ with 57 d.f. in our lab-

Ear of a Colombian experimental variety rich in lysine. The dark kernels are the result of fertilization with pollen from normal varieties.

In studies of human nutrition at the Hospital of the Universidad del Valle in Cali, Colombia, Dr. Alberto Pradilla found that children in an advanced state of malnutrition reestablished the normal nutritional balance in their system when the ordinary maize in their diet was replaced with opaque-2. The children in the photo gained weight, reestablished their bone growth, and the nitrogen retention of their bodies returned to normal.

oratory) the use of the method provides an important assist in the evaluation screening program.

The search for new advantageous protein quality mutants was done by analyzing the large number of maize collections available in the germ plasm bank. A consistent pattern of minor differences led to the belief that new mutants probably not be found in this way unless the new mutant had a selective advantage causing it to increase in frequency in a population. Since this was not likely, the system of screening for new high quality protein mutants was changed. In each collection (variety) 30-50 plants are self-pollinated. A total of 10 individual seeds from each S_1 ear is analyzed for tryptophan using the new single kernels analysis developed in the laboratory. New protein quality mutants are apt to be rare. Any plant in a population to be sampled which is heterozygous for a protein quality mutant will, on selfing, produce one homozygous mutant seed out of four. The analysis of 10 seed from each of these plants will provide a high probability of locating one such seed if, in fact, it exists. Any



These two hogs show the effects of opaque-2 obtained by Dr. Jorge Gallo in an experiment at Palmira, Colombia. The pig marked "O" received a diet based on opaque-2 corn while the other pig "C" received an identical diet but based on normal corn.

family (S_1 ear) showing a favorable response on analysis will be studied further. A sample of mutant seed from such an ear can then be obtained for propagation and increase. An example of the variation found to date in 10 kernels from S_1 ears in Puebla Gpo. 1-A is shown in Table M5. Out of 30 S_1 families sampled, 6 gave tryptophan values for the high extreme kernels to merit further sampling and study. The number of families with high values is surprisingly large. It will be of interest to follow the pattern in other varieties and collections.

Considerable variation in total protein has been noted in various collections due to environmental effects. Thus comparisons of total protein in materials grown at different locations which may differ in altitude, temperature, rainfall, soil fertility, etc., are not reliable. The same varieties grown at tropical and semitropical locations showed 44 to 92% more total protein in the grain at the latter location. Further information is being sought on the variety, fertility level and interaction on total protein at several locations in 1968.

Sufficient high lysine maize (opaque-2) was produced in Colombia to permit experimental trials in feeding and industrial processing. Dr. Jorge Gallo of the swine section at the Palmira station (ICA) has fed high lysine maize to 140 animals in controlled tests. In one experiment growing pigs were fed over a 28 day period. Three protein levels were established by the addition of soybean meal. Within each level normal maize and opaque-2 maize were compared. A partial summary of the results is shown in Table M6. The diets containing opaque-2 maize were significantly superior to those with normal maize except at the 16% protein level diet.

TABLE M5. Frequency distribution for protein and triptophan of individual seeds in 30 S_1 ears (10 kernels/ear) of Puebla Gpo. 1-A. 1968.

Ear No.	% Protein (class centers)									% Tryptophan (class centers)															
	6	7	8	9	10	11	12	13	x	.25	.30	.35	.40	.45	.50	.55	.60	.65	.70	.75	.80	.85	.90	.95	x
71*	3	6	1						6.64										4	2	1	1	1	1	.78
78*		9	1						7.16							1		3	3	3					.68
307		2	7	1					7.86			1	2	3	1	2	1								.48
118		1	9						8.05	1	2	2	2	3											.37
16		2	6	2					8.10						5	4	1								.53
43*			7	3					8.29						1	1	4	2	1		1				.63
98			7	3					8.33					2	5	1	2								.51
280			7	3					8.33					1	2	4	2	1							.56
25			3	7					8.88					2	2	4	2								.53
135				10					9.25			2	4	3		1									.42
120				8	2				9.25			2		3	4	1									.46
17			1	6	3				8.35					1	6	3									.51
118				6	3	1			9.44					3	2	4	1								.52
26				4	5	1			9.62			2	3	4	1										.43
15			1	4	4	1			9.73				1	3	4	1	1								.49
65				2	6	2			9.89					1	7	2									.50
127			1		8	1			9.94					2	4	3	1								.52
424				1	8	1			9.98				1	1	5	3									.50
137				1	7	2			10.26					1	8	1									.49
490*					5	5			10.48				1	3	1	2	1	1	1						.53
500*					4	5	1		10.75		2		1			1	1	2	3						.56
116					3	5	2		10.79				1	3	3	3									.49
6					1	8	1		10.80				3	5	2										.45
14*					4	6			10.85	1				1		1		4	2			1			.61
331					3	6	1		10.93			1	5	3	1										.42
125					1	6	3		11.01	2	4	3													.31
322					1	4	4	1	11.60				2	7	1										.44
92						1	6	3	11.94	1	6	1	2												.32
290						3	5	2	11.98		1		1	4	3		1								.45
444							5	5	12.53			1		1	5	2	1								.50
				Means					9.73																.50

* Selected for further study.

In a second experiment, fattening pigs entered a 42-day feeding trial at an average live weight of 56 kg. Results of this trial are presented in Table M7. Opaque-2 maize alone was equal to normal maize supplemented with soybean meal or with pure sources of lysine and tryptophan.

Human nutrition studies were also carried out using high lysine produced on the I.C.A. farm at Palmira. Dr. Alberto Pradilla, M. D., supervised the treatment of four children who entered the Universidad del Valle hospital in Cali in an advanced state of malnutrition. The children reestablished a normal nutritional balance in their systems when the normal maize in their diets was replaced with opaque-2 maize. The recovery shown by the children was reflected in the gain in weight as well as the reestablishment of bone growth and a normal nitrogen retention balance in the body. The high lysine maize was used to prepare the traditional dishes to which the children were accustomed and did not therefore require changes in eating habits.

Two commercial companies in Colombia — Maizena and Quaker Oats— are now conducting processing trials with opaque-2 maize. The results reported to date, indicate no substantial changes required in the processing machinery or the techniques used. Taste tests on foods prepared from opaque-2 maize are being conducted by the Quaker Oats company. The flavor of foods from opaque-2 maize was slightly different (and sweeter) but in no way objectionable.

TABLE M6. Results of a 28 day feeding trial with growing pigs using normal and opaque-2 maize in diets containing three protein levels. (After Gallo et. al.).

	Diet					
	Normal Maize	Opaque-2 Maize	Normal Maize % Soybean	Opaque-2 Maize % Soybean	Normal Maize & Soybean	Opaque-2 Maize & Soybean
Protein level (%)	10	10	12	12	16	16
Gain (Kg/day)	.36 e *	.64 d	.69 c,d	.80 a,b	.88 a	.79 a,b,c
Kg feed/Kg gain	4.1 z	2.9 xy	3.0 y	2.7 wx	2.4 w	2.4 w

* Groups with same letter are not significantly different (Duncan multiple range test)

TABLE M7. Response of fattening pigs fed on diets based upon normal and opaque-2 maize. (After Gallo et. al.).

	Diet			
	Normal maize	Normal maize & soybean meal	Normal maize, lysine maize & tryptophan	Opaque-2
Protein level (%)	10	16	10	10
Kg feed/Kg gain	.62 b *	.79 a	.81 a	.81 a
Gain (Kg/day)	4.6 z	3.4 y	3.6 y	3.7 y

* Groups with same letter are not significantly different (Duncan multiple range test).

PATHOLOGY

Disease problems in the tropics can be serious because of the favorable environment for rapid development of the pathogens and the greater intensity of insects which may act as vectors or may provide entrance for other pathogens into otherwise healthy plants.

The increasing severity of stunt virus in Mexico, Central America and parts of South America has caused a great deal of concern to maize growers. Where the disease is severe yields of susceptible materials are frequently zero.

Ear rots also cause loss of yield and continued rapid deterioration after harvest where storage conditions are poor and the moisture in the grain remains at a high level.

Populations which have been grown in a particular area over many years generally exhibit less damage from the pathogens associated with the area. The possibilities for improvement of yield and resistance to disease in these populations are good. The movement of otherwise improved materials from other regions to a new area frequently results in extremely severe epiphytotics and a consequent reduction in yield below that obtained from naturally evolved but unselected populations in the area.

The need for a broader approach to selection against likely pathogens in tropical areas is obvious. One of the more promising approaches is the establishment of pilot pest gardens. It is well

In winter plantings in the tropics, corn is commonly attacked by Helminthosporium turcicum. Most of the materials developed by the CIMMYT are resistant to this disease. In this photo Professor H. Oland of Makerere University, Uganda, Africa, observes the attack of this disease on maize from the Caribbean island of St. Kitts, planted at San Rafael, Veracruz.

In selecting for resistance to stunt virus, plantings are deliberately made when the insect vector population is high so as to subject the plants to heavy attacks. Here technicians are counting the number of leafhopper vectors per plant at Santa Cruz Porrillo, El Salvador.

Selections for resistance to stunt virus are being made in Mexico, El Salvador and Nicaragua. These severely damaged plants are at La Calera, Nicaragua.

known that the important insects and diseases of maize wherever it is grown may be found in Mexico. As the major insects and diseases occur naturally, it will be necessary only to find locations where optimum development of the pests occur during each growing cicle. The plan is to establish several such pest gardens: one in the lowland tropics, one at an intermediate elevation, and one in the high plateau. Mass selection for healthy, productive plants will be done in each area using as populations a broad based composite of materials adapted to each. The pilot pest gardens will also provide an opportunity for continued screening of other materials using care to preclude the contamination of the mass selected maize population. The project will be cooperative between pathologists, entomologists and breeders. In the initial stages some partial protection may be required against insects and diseases to avoid complete elimination of the plant population.

Diplodia ear rot

This disease is frequently quite troublesome in the wet lowland tropics. A total of more than 100 varieties from the CIMMYT breeding program and others collected locally in Veracruz and Chiapas were planted in 1967 in five locations where the disease is known to be severe. At harvest the ears were scored for damage due to diplodia. All entries were scored from 0.0 (resistant) to 5.0 (susceptible). A total of 34 with scores from 0.0 to 1.0 were selected for further study with the goal of developing a high yielding population resistant to the pathogen.

The pathology studies include disease observations in the field and controlled infections in the greenhouse and in experimental plots. Here Carlos De León takes spore samples of a fungus disease to prepare for controlled infections.

Corn Stunt

The increasing severity of the corn stunt virus in Mexico, Central and South America led to a search for resistance to this disease. A Cuban composite, a Dominican Republic composite and their cross showed some resistance to this pathogen. A program of modified ear-to-row selection was begun in these populations in 1967. The materials were planted at Cotaxtla, Veracruz and Sta. Cruz Porrillo, El Salvador. Although leafhopper populations were relatively high (5 per plant at Cotaxtla and 15 per plant at Sta. Cruz Porrillo) a very low incidence of the disease was present. Thus selection of the families was based strictly on yield per hectare.

In each population were self-pollinated. The S_1 progenies have been planted at Cotaxtla, Veracruz and in Nicaragua for evaluation of stunt virus reaction. Selected resistant lines will be used to develop populations with a higher degree of resistance. Also a few of the more resistant plants will be self-pollinated to develop materials for studying the inheritance of resistance.

Collections of leafhoppers made at Sta. Cruz Porrillo 10 days after planting were sent to the U.S. Department of Agriculture for identification. Fifteen species were represented in these collections including the two known vectors of stunt virus, *Dalbulus maidis* and *D. elimatus*, and the vector of maize dwarf mosaic, *Peregrinus maydis*.

Downy Mildew

Downy Mildew (*Sclerospora* spp. and *Sclerophthora* spp.) has become a serious disease for maize in Southeast Asia. It has been reported recently in Southern Texas and Northern Mexico in the Río Grande Valley. In 1967 a total of 92 composites of maize germ plasm were sent to Taiwan for evaluation of their resistance to *S. sacchari*, widely prevalent in the area. These materials were planted at the District Agricultural Improvement Station at Putzu where the seedlings were innoculated and provision made to insure a heavy concentration of the natural inoculum. The entries were replicated three times with approximately 30 plants per plot. When the plants were four to five weeks old, selections were made for plants showing no symptoms or only very mild leaf streaking. Some 533 plants were selected and later self-pollinated.

The same materials were sent to the Philippines for planting at Los Baños and on the island of Mindanao. Evaluation at Los Baños was unsatisfactory due to lack of disease development. Several apparent new sources of resistance to the disease were found which will be useful in broadening the germ plasm base of resistance. The S_1 progenies of these plants are being grown in Taiwan and in the Philippines for further evaluation. Based upon the results, a composite will be made of the remnant seeds of the resistant lines for further improvement.

The same 92 collections evaluated in Taiwan and the Philippines are being sent to the Texas Agricultural Experiment Station, College Station, Texas and to the INIA Experiment Station at Río Bravo, Tamps., Mexico for evaluation against *S. sorghi*, the mildew pathogen in this general area. Included in the plantings will be 6 relatively resistant hybrids, two resistant and two susceptible inbred lines, from Taiwan. An attempt is being made to locate resistance to this particular species of the organism and determine if any relationship exists in plant reaction to the two types of mildew

ENTOMOLOGY

Pest Control Through Host Plant Resistance [1]

Until now insect control in the tropical and subtropical regions of the world has seldom formed a part of the improved practices for maize production.

An important approach in attempting to reduce losses due to the insect complex —which in a given region and in a given season is usually formed by few species— is the utilization of insect-resistant varieties. The genetic variability present in the maize germ plasm has been used very little in the tropical areas of the world, for the design of improved varieties with built-in genetic resistance. Granted it may not be possible to develop a high degree of resistance to all major insect pests. Therefore, different methods of control must be blended to form an integral part of the production system.

The present report summarizes previous work along results obtained this year.

Stem borer resistance

Screening for resistance to stem borers (*Zeadiatraea* spp.) has been conducted under natural conditions of infestation at the station in Tepalcingo, Morelos, Mexico, since 1964. During this period, a total of 395 entries have been tested. The materials evaluated are as follows:

Set	Origin	No. of entries	Dates of planting	No. of plantings
1	Mexico, USA, Central America, Caribbean Islands, South America.	82	March-August, 1964	6
2	Mexico, USA, Central America, Caribbean, South America.	92	March-August, 1965	5
3	Colombia, Antigua.	58	March & June, 1967	2
4	Diverse composites and crosses.	55	June, 1967	1
5	Caribbean and Mexican composites.	116	November, 1967	1

In each planting, each entry has been planted in 5 meter rows (two plants per hill, half a meter apart), replicated three (1967) or four times (1964-65) in a randomized complete block design. Records on damage have been taken at harvest time. The reaction of each entry was measured originally by recording the number of exit holes per stem. This measurement was discontinued after the fourth planting of the first set of collections and the number of damaged internodes per stem recorded instead. Damage has been expressed as percentage of infested stems, number of exist holes per stem, number of damaged internodes per stem, and beginning with the third set of collections (1967), as percentage of damaged internodes per plant.

Interpretation of the results on degree of infestation in the first set was complicated by the fact that both diameter of the stalk and earliness of the plant had a significant effect on the degree of infestation among collections. Even though these two factors accounted for no more than ⅓ to ⅖ of the total variability in the level of damage of the collections as a whole, the fact that all of the least infested collections were early strains with short and slender stalks cast doubt on the actual level of resistance recorded.

In the second set of collections tested those found to be significantly less damaged were the following: Costa Rica Gpo. 6A, Salvador 65J, Guatemala 594, Panamá 31B and Honduras 125 from Central America; Cuba V56, Barbados Gpo. 1, Antigua Gpo. 2, Martinique Gpo. 1, Westigua, Republica Dominicana Gpo. 2, and Republica Dominicana Gpo. 7, from the Caribbean area; Flint Guayana Inglesa, Bahía III, and Piracai from South America, and Sonora Gpo. 11 from Mexico. Days

In the tropics the corn plant is attacked by many insects. Ear damage, such as this, permits the entrance of insects and diseases which later destroy the stored grain.

[1] Work at Tepalcingo, Morelos was conducted at the station of the Productora Nacional de Semillas. Work at Roque, Guanajuato was conducted at the Centro de Investigaciones Agrícolas del Bajío of the Instituto Nacional de Investigaciones Agrícolas. Acknowledgment is made for the land and office space provided by both institutions.

to anthesis and diameter of the stalk were found to be less variable in this set.

In the third set of collections tested, Capio and Imbricado were found to be severely damaged by the stem borers. The reaction of the remaining collections in this set was quite uniform in both plantings. These collections will be exposed to a higher infestation level, in order to determine which are more resistant.

A parallel study of the influence of certain characteristics of the plant on the level of damage was carried out in the different collections of the fourth set. The results indicated that the combined effect of diameter of the stalk, number of internodes, and days to anthesis had a significant influence of the amount of damage expressed as number of damaged internodes per plant (R = 0.57). Statistical adjustment for the influence of diameter and number of internodes per plant indicated the following materials to be significantly less damaged than the others included in the test: Westigua; Antigua 2D x (B 10 x B 14); Jalisco 188 x Pepitilla; (B 10 x B 14) x Harinoso de ocho; (Oh 43 x M 14) x Antigua 2D; (Nuevo Leon Gpo. 2 x Honduras Gpo. 14A) x Eto B; Usatigua, Reventador x (Cuba 11J x Eto Amarillo); Reventador x (Cuba 11J, T-62, Eto Amarillo); Chapalote x (Cuba 11J x Eto Amarillo); Tuxpeño x N. Eng. Flint; Chapalote x (Cuba 11J, T-62, Eto Amarillo); and Sintético Cristalino de varias Amarillas.

Two lines of attack are being followed to control the damage of the fall armyworm: development of varieties tolerant to its attack and control with insecticides. The insecticide studies include the most adequate formulas, dosages and periods of application.

Even though significant differences in the number of damaged internodes per plant were found among collections, in the 5th set of collections tested, the high variability in the levels of infestation within collections decreased the precision of the experiment. The least damaged of the Mexican composites were found in materials from the states along the Gulf of Mexico and the southwestern states. Among the least damaged Caribbean collections, Martinique Gpo. 1 was the only one that had registered low damage levels in a previous test.

Fall armyworm resistance

A total of 493 collections, composites, lines and varieties of corn have been screened for resistance to the fall armyworm, *Spodoptera frugiperda* (J. E. Smith), under natural conditions of infestation. These materials have been divided for study into several groups and evaluated in one or several plantings as follows:

Set	Origin	No. of entries	Dates of planting	No. of plantings
1	Mexico, USA, Central America, Caribbean Islands, South America.	82	March, July, September & December, 1964 January & February, 1965.	6
2	Mexico, USA, Central America, Caribbean, South America.	92	March, April, November & December, 1965.	5
3	Colombia, Antigua, other Caribbean, Mexico.	57	March, June, August, 1967 January, 1968*	4
4	Mexico, Caribbean.	6	August, 1967	1
5	Mexican & Caribbean composites.	116	January, 1968	1
6	Brazil.	46	January, 1968	1
7	Colombia (second group)	44	January, 1968	1
8	Early interacial mexican crosses.	19	January, 1968	1
9	Puebla Gpo. 1 x Antigua Gpo. 2	30	January, 1968	1

*Antigua and Mexican collections were not included in this planting.

Field procedures for these materials were the same as those indicated for the stem borer work. The reaction to attack by fall armyworm was estimated by: (a) percentage of injured plants, and (b) estimation of the amount of damage using and arbitrary visual scale from 1 (no damage) to 9 (heavy damage). The scoring was done on a row basis. All records were taken after the injury by the first generation of the insect had reached a peak.

The most resistant collections of the first set tested were Antigua 2-D, Antigua 8-D, and two composites of the race Zapalote Chico: Oaxaca Gpo. 35 and Chiapas Gpo. 18.

Most promising among materials of the second set were Antigua Gpo. 2, Antigua Gpo. 1, Puerto Rico Gpo. 4 and Usatigua.

Five collections of Antigua, together with Oaxaca 134 and Jamaica "Reed Composite" were the best among the materials included in the third set. Dulce Medellin was the only Colombian collection included in the set and was comparable in reaction to the Antigua collections.

A group of Mexican and Caribbean materials including a sorghum variety (Honey) constituted the fourth set studied. The sorghum variety was least damaged by the fall armyworm followed closely by Antigua group 2 and Puebla Gpo. 1 x Antigua Gpo. 2. The commercial hybrid H-412; T_2 x T_8, a single cross used in the making of several tropical hybrids; Guanajuato 20, and Pepeños sustained significantly greater damage.

From the group of Caribbean and Mexican composites which comprised the fifth set, Antigua Gpo. 2, Comp. Coahuila Gpo. 3, and Sonora Gpo. 5, appeared to be the least damaged composites.

There were no outstanding materials among the Brazilian and second group of Colombian collections tested. The same was true of the group of crosses among Mexican races studied. Additional plantings will be required to establish the more resistant materials in these groups of collections.

During the summer of 1967, 50 full-sib crosses were made between plants on Antigua Gpo. 2 and Puebla Gpo. 1. The crosses were made using plants with light damage by the fall armyworm. Antigua Gpo. 2 has shown consistenly less damage by this insect than other materials tested. Puebla Gpo. 1 on the other hand, is less damaged by thrips. Also, the cross of Antigua Gpo. 2 x Puebla Gpo. 1 has shown significantly less injury from thrips. The reaction of 15 lines (S_1), and 15 full-sib crosses, made among plants with light injury by the fall armyworm indicated that only two of the crosses sustained significantly less injury than the population cross included as a check.

Research results indicate that applying a granulated insecticide directly to the bud of the plant, may do less damage to natural predators of the harmful insects and thereby give more adequate control.

Thrip resistance

In some areas is frequently damaged by thrips. There is disagreement among entomologists as to the importance of thrip damage on yield. Losses reported from the Bajio area in Mexico range from 360-1200 kg of grain per hectare. Damage of economic importance has also been reported from other Latin American countries.

Screening of collections for resistance to thrips has revealed differences in tolerance between varieties. Efforts to develop populations resistant to thrip damage were begun in 1967. A broad base composite of materials adapted to the Bajio is being used. The composite is planted in isolation blocks (¼ ha) and the most severely damaged seedlings removed. Two cycles of selection per year are being used (winter in Tepalcingo and spring in El Roque) so that rather rapid progress should be possible.

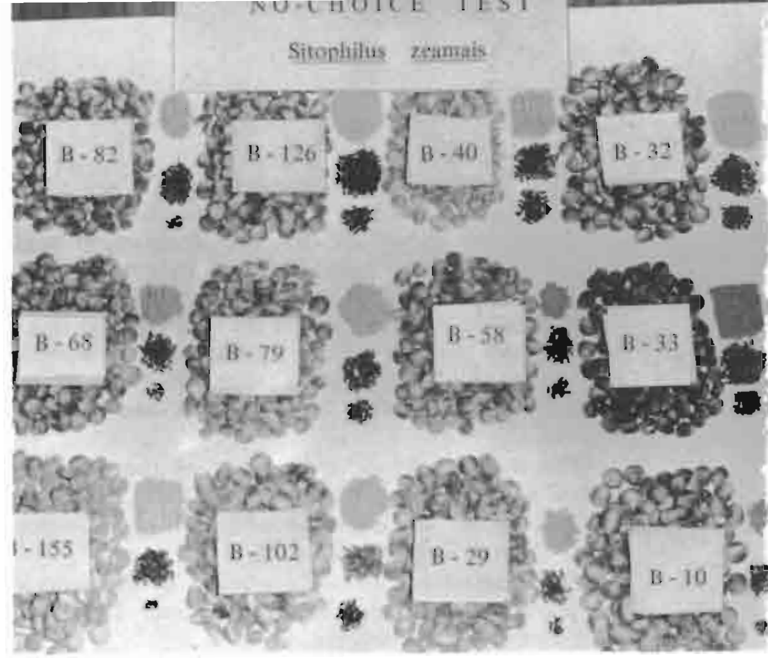
Insect Control with Insecticides *

Research is being conducted in cooperation witn tne pesticide industry to develop efficient granular insecticides. New experimental compounds and their formulations are tested to determine their effect on corn insects as well as on the natural enemies of these insect pests. Except for armyworms, cutworms, grasshoppers, earworms and root feeding insects, the other major insect pests of maize at one time or another inhabit the whorl of the plant. Therefore, this is where insecticides should be deposited to be most effective and to provide selective control. There is evidence that the use of dusts or sprays over the whole plant favors the increase of stem borers, among other pests because of the destruction of egg parasites and predators. At Tepalcingo, the site where the insecticide tests reported here were conducted, the usual practice for controlling the fall armyworm during the dry season, before granular insecticide formulations became available, was to spray four to six times with DDT or methyl parathion.** The elimination of the predators caused a considerable build-up of the red spidermite, **Paratethanychus stickneyi** Mc G. It is quite probable that switch to granular formulations has eliminated the need to spray for mite control during the past three years.

In addition to some degree of ecological selectivity, the persistence of granular formulations is considered to be superior to that of sprays or dusts. Furthermore, they can be applied without specialized equipment. This is particularly important for farmers who plant small areas and have limited economic means.

Several granular insecticide field trials for the control of the fall armyworm, *Spodoptera frugiperda* (E. J. Smith), and the stem borers *Zeadiatraea* spp. have been conducted to: 1) estimate the relative effectiveness of different insecticides formulated in granules; 2) determine adequate dosage of some of the most effective compounds; 3) estimate the appropriate number of applications; 4) determine timing of applications; and 5) observe the influence of the insecticide on the insect fauna associated with the maize crop.

In most cases these insecticide evaluations have been conducted under high natural infestations by planting during the dry season or late in the rainy season. The insecticides have been distributed directly from small bags containing an adequate amount for each plot to be treated. The experimental designs have been: randomized blocks, latin squares or split plots. In any given test four replications have been used. The plot or subplot size has consisted of five rows five meters long, with a plant population, equivalent to about 43,000 plants per hectare. Seed of the tropical hybrid H-507 has been used in all except one trial. Due to soil heterogeneity in the testing site it has not been possible to obtain satisfactory estimates; however, in some tests the yields of the plots protected with effective compounds have been three to four times greater than the production recorded from the untreated checks. The relative effectiveness of the different insecticides has been measured by the percentage of plants undamaged by the fall armyworm and by the number of internodes injured by the stem borers in 10 plants per replication.



In studying the resistance of different corn varieties to attack by the rice weevil, it has been found that when there are several alternatives, the insects express a definite attraction to certain corn collections. However, when the insects are restricted to one collection, damage tends to be equally intense in all varieties.

Four field trials were conducted to screen the most effective materials, out of 20 different granular formulations available. In these tests, Telodrin 1.5% (8-10 kg/ha per application); Sevin 2.5% (= carbaryl, 10-14 kg/ha); endrin 2% (8-10 kg/ha); Dipterex 2% + methyl parathion 2% (12-15 kg/ha); and heptachlor 3% (10-12 kg/ha) were consistently the most effective materials against the fall armyworm. BHC 3% alone or in combination with DDT and or toxaphene was as effective as the products mentioned previously; however it showed phytotoxicity, possibly due to formulating process.

One application two weeks after plant emergence, of any of the indicated materials prevented, for a period of 3 to 4 weeks, the increased of injured plants beyond 15% to 20%. In general, it appears that plants six to eight weeks old re-

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* Appreciation is expressed to the following companies who provided the granulated insecticides for these tests: Distribuidora Shell de México, S. A.; Química Hércules, S. A. de C. V.; Químicas Unidas, S. A.; VIMSA, S. A. de C. V.; and Unicarb Comercial, S. A. de C. V. Mention of trade names does not constitute an endorsement by CIMMYT.

** For chemical names, other designations, structural, and empirical formulas see Bullentin Entomological Society of America 12(2):161-217.

TABLE M 8. Relative effectiveness of several dosages of granular Telodrin and Sevin on the fall army worm *Spodoptera frugiperda*. Tepalcingo, Morelos, Mexico. 1967-1968.

Dosage in commercial Kg/ha of material	Active ingredient gm	Undamaged plants 30 days after 2 applications %
16 Kg Sevin 2.5%	400	73
14 Kg Sevin 2.5%	350	73
12 Kg Sevin 2.5%	300	76
10 Kg Sevin 2.5%	250	77
Check	——	31
	L.S.D. (5%)	10
12 Kg Telodrin 1.5%	180	84
10 Kg Telodrin 1.5%	150	84
8 Kg Telodrin 1.5%	120	80
6 Kg Telodrin 1.5%	90	75
Check	——	30
	L.S.D. (5%)	9

cuperate from fall armyworm injury, although under severe infestations an additional application becomes necessary to prevent further damage.

One application of the same materials made about two weeks after plant emergence did not reduce the number of injured internodes by the stem borer at harvest time, as compared with the untreated check. Only two applications of Telodrin 1.5% or endrin 2% (twice the rate indicated previously) decreased significantly the number of injured internodes to one per stem as compared with an average of four in the other treatments.

Further testing was conducted with Telodrin and Sevin to determine the minimum effective rate per hectare. The differences in results from applications of 10 to 16 kg/ha of Sevin 2.5% and 6 to 12 kg/ha of Telodrin 1.5% were not statistically significant at the 5% level (Table M8).

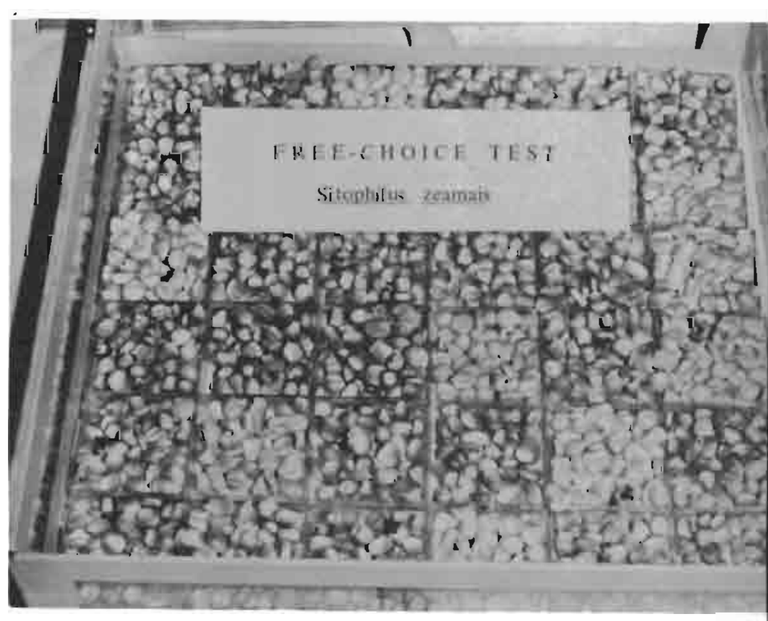
Simultaneously, a series of experiments was conducted to determine the appropriate time to make the first granulated insecticide application. The results to date are shown in Table M9. These indicate that the critical time for making the first application to protect maize from attack by the fall armyworm is two to three weeks after plant emergence. In regions where this pest is endemic a delay in protecting the plants usually results in a considerable stand reduction. Furthermore, the application made at this time, also provided protection against thrips (*Frankliniella occidentalis* Perg.), leafhoppers (*Dalbulus* spp. and *Empoasca* sp.) fleabeetles (*Chaetocnema* sp.) and adult root worms (*Diabrotica balteata* LeC.) feeding in the whorl.

In this test, attempts were made to estimate the influence of the insecticide on the predators and other insects commonly present in maize fields. Although the numbers of both were higher in the untreated plot (Table M9), significant differences were not found among the treatments.

TABLE M9. Relative effectiveness of granular Telodrin for the control of the fall army worm, *Spodoptera frugiperda*, and its effect on the insect fauna associated with maize, when applied two, three, four, and five weeks after plant emergence. Tepalcinco, Morelos, Mexico. 1967-1968.

Dosage, kg/ha of commercial material	No. of weeks after emergence	Undamaged plants 55 days after 1 application %	No. of predators in 40 sweeps	Total No. of insects in 40 sweeps
12 Kg Telodrin 1.5%	2	87	16	242
12 Kg Telodrin 1.5%	3	79	13	217
12 Kg Telodrin 1.5%	4	69	7*	176*
12 Kg Telodrin 1.5%	5	69	13	287
Check		56	24	298
L.S.D. (5%)		9	N.S.	N.S.

* A second application to control borer was made two days previous to recording the information in this treatment. Predators present were in the genera: **Hippodamia, Coleomegilla, Zelus, Sinea, Chrysopa** and **Orius.** Thirty other families of insects were also represented in the samples collected. The most abundant in numbers were the **Cicadellidae**: **Empoasca** and **Dalbulus.**



The tests included "free-choice" with various corn collections in plastic boxes to which the insects could move, and "no-choice" where the insects were restricted to a single sample.

In attempting to develop an integrated control program the value of the naturally occurring biological control must be taken in consideration. A test was conducted to gather preliminary information on this aspect. Table M10 shows that the degree of control by insect predators, on those plots where an equivalent to about half of the plants was left untreated was not enhanced to a level comparable to that provided by treating all plants with insecticide. From these results it may be deduced that it is more satisfactory to treat all plants. However, as it has been pointed out by specialists on the integrated control approach, the utilization of rates lower than those which approach 100% control, are more desirable from the stand point of favoring the beneficial action of natural enemies. Thus, rates of 10 kg/ha of Sevin 2.5% or 6 to 8 kg/ha of Telodrin 1.5% (Table M7), would be the lowest permissible rates to attain an adequate control and still allow part of the fall armyworm population to contribute to the sustaining and propagation of the natural enemies. The predators observed in this test, but not quantified, are indicated in the footnote of Table M9.

TABLE M10. Relative effectiveness of granular Sevin and Telodrin of the fall armyworm, *Spodoptera frugiperda*, when applied to different numbers of plants. Tepalcingo, Morelos, Mexico, 1967-1968.

Dosage in kg/ha of commercial material	Active ingredient gm	Plants treated	Undamaged plants 30 days after 1 application %
16 Kg Sevin 2.5%	400	all	82
8 Kg Sevin 2.5%	200	alternate	67
8 Kg Sevin 2.5%	200	every two	67
8 Kg Sevin 2.5%	200	every three	64
Check	——		42
		L.S.D. (5%)	12
12 Kg Telodrin 1.5%	180	all	88
6 Kg Telodrin 1.5%	90	alternate	69
6 Kg Telodrin 1.5%	90	every two	69
6 Kg Telodrin 1.5%	90	every three	73
Check	——		41
		L.S.D. (5%)	12

Frequently, in tropical and subtropical areas the maize plantings made at the beginning of the rainy season are subject to severe attack of different species of armyworms. These cause a considerable stand reduction and in many occasions force the farmers to make extensive replantings. In order for these outbreaks to have economic significance there must be a syncronization of the life cycle of the insect with the weather conditions, land preparation, planting date, an exhuberant growth of host plants (weeds) within the cultivated fields and surrounding areas, and a detrimental effect of continuous rains on the insecticide treatments.

Extensive areas planted to corn in the state of Morelos were destroyed last year at the beginning of the rainy season by a previously unidentified species of armyworm. A test was conducted in a heavily infested field, to observe the effectiveness of different practices (Table M11). Before the treatments were applied, soil was seeded and larval counts recorded. These revealed that the armyworm population was not significantly different among the various sections in the testing site. Treatments were applied five days after planting. Ten days later (July 13), the percentage of undamaged plants was recorded. Only the herbicide broadcast application had significantly less undamaged plants (38%). Differences among the other treatments were not significant. This may be attributed to the action of the insecticide in those plots where it was applied. In the other treatments the ridges between rows with a dense weed population as a source of food, restrain the larvae from migrating to the maize plants in greater numbers. The diesel oil showed both a herbicide and larvicide action, being the most effective treatment.

Stored grain insects

Additional facilities for research on stored insects at were made available at CIMMYT headquarters in August, 1967. A rearing room with controlled temperature and relative humidity was built. Also a laboratory room was built and equipped.

Collections of maize germ plasm are being screened for resistance to damage by the corn weevil ***Sitophilus zeamais*** Mots. and Angumois grain moth ***Sitotroga cerealella*** Oliv. Grain samples of 40 kernels are used in "free-choice" and "no-choice" tests. Resistance is measured by first generation emergence; attractiveness of the kernels to the females for egg deposition; damage from parent generation; and weight (mgm) of the first generation progeny (per 10 insects).

Collections found to be more attractive to adults appear to be more suitable for the development of the insects. Differences in attraction to collections are evident but when insects are restricted to a particular collection damage occurs with approximately the same intensity.

Studies are now underway to determine whether selection for resistance to stored grain insects can be done. The program is designed to combine selection for agronomic traits and productivity with that for resistance to damage in stored grain.

BREEDING

Selecting within maize populations to develop superior varieties has taken many forms. A number of new procedures have been proposed for further improvement of selection efficiency but there is little information based upon actual field experiments about their relative efficiency.

In recent years the development of quantitative genetic theory has led to the collection of data permitting the estimation of certain genetic, environmental and genetic x environmental parameters in maize populations. These parameters have made possible the prediction of gains from various selection procedures. Nevertheless, the more promising selection method require experimental testing to provide critical data from which to decide procedures that can be recommended for the most efficient and effective utilization of the available germ plasm pools. Since present mathematical models in quantitative genetic research involve simplifying assumptions that may or may not be valid, the experimental evaluation of selection method is needed to provide verification of the predictions based on the mathematical approach. Perhaps the greatest problem inherent in the statistical approach has been a tendency to base prediction largely upon grain yield. Yield may be directly or indirectly associated with other important traits. In many cases a selection scheme is needed which provides for rapid evaluation of these other important traits while keeping a clear focus on the ultimate goal of yield improvement. In this way the breeding program in CIMMYT is aimed at "net worth" improvement of maize populations. At the some time valuable is obtained for comparative studies of selection methods.

TABLE M11. Effect of different treatments on the percentage of undamaged plants by a species of armyworm. Tepalcingo, Morelos, Mexico, 1967-1968.

Treatment	Undamaged plants %	Larvae per square meter* No.
Broadcast application of diesel oil (150 lt/ha)	60	36
Band application of Gesaprim** 50% (3kg/ha) + toxaphene 60% (11 lt/ha)	58	43
Broadcast application of Gesaprim 50% (6 kg/ha) + toxaphene 60% (2 lt/ha)	54	34
Hand weeding at base of row	53	49
Gesaprim 50% band application (3 kg/ha)	52	29
Gesaprim 50% broadcast application (6 kg/ha)	38	32
L.S.D. 5%	8	N.S.

* Armyworm population before applying treatments.
** Gesaprim (= Atrazine)

In seeking higher yielding maize populations prolificacy is sought. One expression of this character is shown here by Dr. E.J. Wellhausen in plants of the race Tuxpeño. Other varieties expressed this character in ear-producing tillers.

In 1964, CIMMYT initiated selection experiments with maize to compare several methods of selection in a limited number of populations. Beginning in 1968 the selection studies were expanded in number but with more populations involved so as to provide critical comparisons between methods and at the same time effect improvement in a wider array of materials (low, intermediate and high elevations) for use in programs in other regions. The objectives of the breeding program are:

a) To obtain empirical comparisons of different methods of selection in materials at low, intermediate and high elevations.

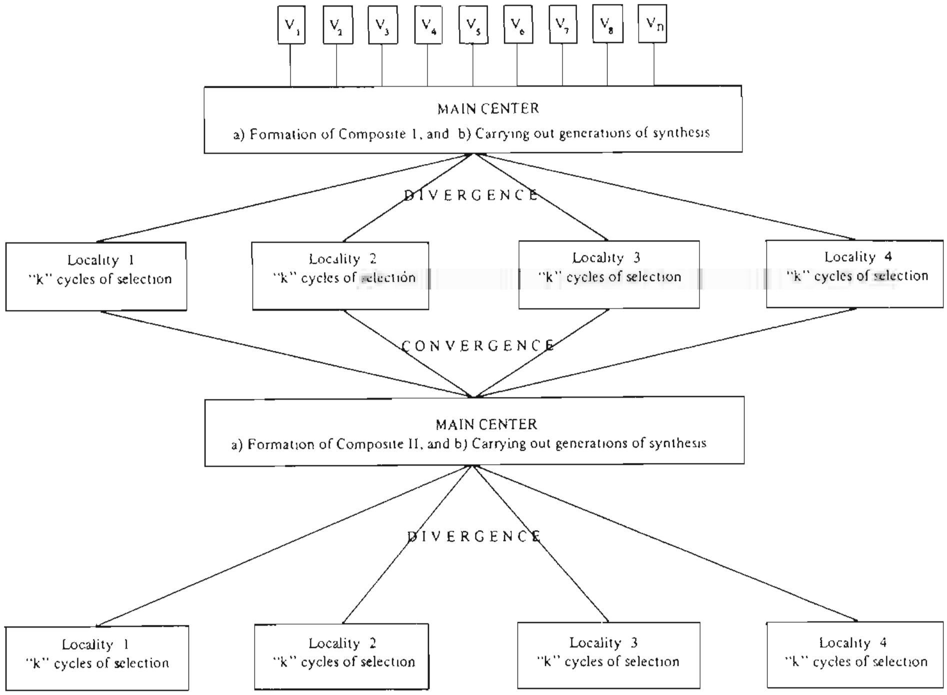
b) To produce improved germ plasm of value in other improvement programs.

c) To obtain information with which to compare theoretical predictions.

d) To provide problems and materials necessary for training technicians.

Broader Area of Adaptation for Maize Populations

Interest in the development of maize populations with a broad area of adaptation and the



desire to establish a program providing possibilities for cooperative effort among a number of corn breeders in a general region led to the suggestion of the area improvement scheme. It is a method of improvement in a composite representing germ plasm materials individually adapted to the subregions of a wider general area. The procedure should provide a means of effecting improvement and a high level of adaptation to the broader area. Patterned somewhat after a suggestion of Wright (1922 & 1931) it is referred to as "convergent-divergent" selection. The objectives of the procedure are as follows:

1. Development of improved population as such, as well as for improved sources of breeding material for the development of future high yielding hybrids with wide adaptation.

2. Development of a germ plasm pool with a high level of resistance to crop hazards that occur in the region.

3. Development of a population having a wide area of adaptation and high average productive potential in the area and thereby of greater utility in other areas of the world where endosperm type and climatic conditions are appropriate.

4. Improvement of food quality through the incorporation of genetic factors, identified and available, contributing to high lysine in maize.

5. Strengthen cooperative research activities among interested maize workers in the region.

The material to be used might be one of the racial composites or a mixture of several composites appropriate for the region and available in the germ plasm bank at CIMMYT. Or it might be suitable composite of materials contributed by each of the interested cooperators in the region.

Selection for prolific plants is proving to be one of the easier recurrent selection techniques by which Latin American breeders are increasing yields in open pollinated populations. These experimental plots are at the College of Agriculture "Luíz de Queiroz", Piracicaba, Brazil.

This genetically controlled leaf character, called "hoja arrugada", was found in S_1 plants of the Chalqueño race. Plant breeders say that it is probably controlled by a single recessive gene, and this could be a good genetic marker for research purposes. It could also be useful for learning more about the genetics of the maize leaf.

If the latter basic material is to be used, the varieties or composites will be sent to a central location for intercrossing and synthesis (convergence). After a generation or two of random mating with precaution taken to assure complete intercrossing the composite thus formed is divided and a portion sent to each of the collaborators (divergence). Simple methodology is followed. Mass selection for healthy, prolific plants of moderate height is carried out in an isolated plot with the usual precautions required in a mass selection procedure. Selection intensities of a standard 10% are to be used with sufficient plants available to provide a selected sample of 250 plants.

After 2 or 3 generations of selection a sample of seed from each collaborators is again sent to the central location for intercrossing (converqence) for one generation prior to subsequent divergence for continued selection. In the meantime each collaborator can also continue selection in the original sample if he so desires.

The plan can be continued as long as progress is evident. Genetic variability should be maintained at a high level. To the extent that different crop hazards exist in the several locations involved, successful selection for resistance to each of these hazards becomes a population characteristics and contributes to improvement in net merit. This can be of value to all collaborators in that any of the hazards encountered in one place may occassionally be present in others. This procedure is diagramatically illustrated in the figure of page 38

The above scheme has been initiated by a group of cooperators in southern South America and preparations are underway for a similar program in the lowland tropics in Central America. Plans are underway to study the quantitative genetic aspects of the selection effects.

High elevation

Several selection methods were initiated in populations adapted to the high plateau region. Modified half-sib and mass selection procedures have been underway. New systems begun were combinations of: 1) Mass, S_1 and reciprocal selection; 2) S_1 and half-sib; 3) reciprocal full-sib intra-variety; and 4) mass selection for high sucrose in the stalk.

Chalqueño populations have been selected at Chapingo (2250m) using mass selection and modified ear-to-row procedures for several years. The mass selection has been subjected to a 5% selection intensity in approximately 7500 plants each year. A selection intensity of 20% of 195 families has been used in the ear-to-row series. The population density used in the plantings for selection has been approximately 25,000 plants per hectare. Seed of each of 5 generations of mass selection and 4 generations of ear-to-row was used in planting a performance trial at Chapingo in 1967. This is the first of a three-year testing sequence for each generation of selection. Plant populations of 30,000 and 45,000 plants per hectare were used with 20 replications at each level. The data are from a single trial and therefore do not provide a critical evaluation of the progress realized. When grown at 30,000 plants per hectare the average regression for gain from selection was 6.70% per generation for mass selection and 8.65% for the modified ear-to-row selection. Thus even though the selection intensity is much greater for mass selection alone, the response was slightly greater for the ear-to-row procedure.

At the 45,000 plant per hectare population density, the rate of gain shown by the two methods was less than half that shown at the 30,000 plant density, being 3.0% and 2.9% for the mass and modified ear-to-row selection, respectively. There is a suggestion therefore, that selection done under low plant densities will sort out types having the capability of more efficiently utilizing extra space in the field; thus the evaluation of progress under low plant densities would be expected to show more progress. When available space for each plant is limited it appears that the higher yielding genotypes may not be those selected under less crowded conditions. Thus different rates of gain would be expected when grown under different plant densities.

Data were collected also on the number of tillers and percentage grain producing tillers. Over a period of 4 cycles of selection the number of tillers increased from 103 tillers per 100 plants to about 120 tillers with both methods at the 30,000 plant density. At the 45,000 plant density (original = 101/100 plants) there was no obvious change in number of tillers. Both mass and modified ear-to-row also gave similar results in terms of grain-bearing tillers. The counts showed an increase over 4 generations of selection of about 100% in the percentage of tillers with ears at both the 30,000 and 45,000 plant densities. Thus heavier rates of planting reduced tiller expression but permitted an increase of tillers with ears.

Lowland Tropics

The characteristic growth habit of tropical maize in the lowland areas is one of excessive height and relatively little grain. The excessive height frequently results in lodging, especially in areas subject to tropical wind storms. Farmers limit the damage from high winds by "doubling" or breaking the plants below the ear before physiological maturity. The effect of this treatment on yield is unknown, but the work involved is considerable.

Attempts to decrease ear height have taken several forms. The dwarf mutant brachytic-2 has been successfully introduced into Tuxpeño varieties and selections have been made for yield in these populations. Critical yield comparisons are now being obtained between the original normal and the new dwarf varieties.

Direct selection for reduced plant and ear height was started in a Tuxpeño composite in 1967. In the subsequent generation the reduction in plant height was 16 cm and the reduction in ear height was 27 cm, as shown in the following table. Selection will be continued to reduce plant and ear height at the same time that increased productivity is sought.

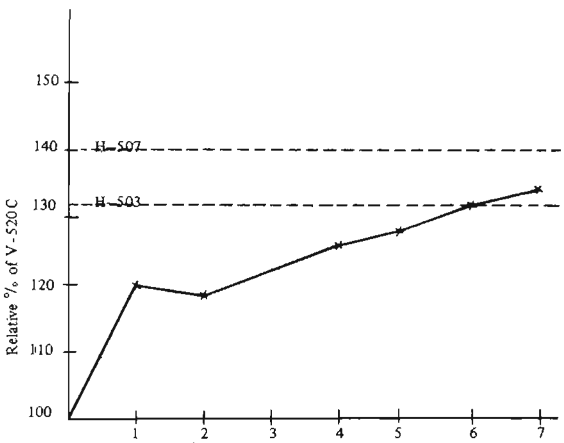
TABLE M12. Plant and ear height reduction following one cycle of selection. San Rafael, Veracruz, Mexico, 1967.

Identity	Height* Plant m	Ear m
Tuxpeño Crema I C0	3.46	2.05
" " I C1	3.30	1.78

* Average of 116 plants in each population.

In the tropics, most varieties grow tall. The high ear placement makes them susceptible to lodging, and difficult to harvest. One way to solve the problem is through selection, saving only the short plant with low ear placement. Through this procedure plant height was reduced by an average of 16 cm and ear placement by 27 cm after one year of selection in Tuxpeño Crema I, shown in the foreground. In the background a population of short-staked Antigua I, which is being used in crosses as a source of dwarfness.

Mass selection for yield per plant has been carried out in V520C (Tuxpeño) for several years. The selections were all evaluated in 1965 and again in 1967. The results are presented in the adjoining figure. The regression for yield on cycle of selection is 4.8% in this population. No change in plant and ear height, nor in days-to-flower is evident. The population now compares favorably with the hybrids H-503 and H-507 which were developed for this general area.



Relative (%) gains in yield from mass selection in V520C through 7 cycles together with relative yields from hybrids H-503 and H-507. Each point is an average of 20 replications in each of two years—1965 and 1967.

Another approach to obtain rapid reductions in plant height is the incorporation of the dwarf gene, brachytic-2, into locally adapted varieties such as these in Nigeria.

Intermediate elevation

Selection methods being studied in the Bajío include the following: mass selection for prolificacy and prolificacy limited to a single culm; area improvement; full sib; standard reciprocal selection; combined mass, half sib, and reciprocal selection; mass, S_1, and reciprocal selection; and S_1 selection. Inasmuch as the populations adapted to the Bajío grow well in the winter planting area near Cuautla (1300 M), results of two generations of selection per year using prolificacy as the selected trait are being compared with those of a single generation per year at Celaya.

Two and three generations of mass selection have been completed at Celaya in Puebla Gpo. 1 and Celaya Comp. II. A system of continuous three-year evaluation of each cycle of selection is being initiated with these and other selected materials.

Indirect Selection for Resistance to Lodging

Corn that remains erect until maturity yields more and is easier to harvest. Most varieties and even some highly selected hybrids lack satisfactory resistance to lodging. However, there is ample evidence that resistance to lodging can be increased by selection. The rapidity of progress depends largely on whether it is possible to identify resistant genotypes. The factors contributing to lodging are storms, plant density, fertility, moisture and other factors, all of which can easily mask genetic differences between resistant and susceptible genotypes.

In the Bajio, the introduced variety Puebla Gpo. 1 has been highly productive but very susceptible to lodging under some conditions. Crushing strength and rind thickness of lower internodes were shown to be highly correlated with field lodging ($r = -0.82$ and $r = -0.81^{**}$ respectively) by Zuber and Grogan in 1961. To a lesser extent, the weight of a 5 cm cylindrical section of stalk was found to be correlated with field lodging also ($r = -0.73^{**}$).

The advantage of indirect selection for resistance to lodging through a trait such as rind thickness is that regardless of the degree of field lodging in a given environment, relative differences in resistance among genotypes can be determined with reasonable precision. Since rind thickness and weight of a 5 cm section of stalk are simpler traits to measure than crushing

Top view of a plant with the character "tallo cuadrado". The plant has two opposite leaves at each node and the leaves at successive nodes appear at right angles. The stalks are strong with an angular shape, a character which is probably associated with lodging resistance. Ears are produced on the axils of both leaves of at least two nodes, suggesting that this material may also useful in selection for prolificacy.

strength the relative value of both traits as a mean of selecting for lodging resistance are being evaluated by a Paraguayan student, Ricardo Suárez, in the variety Puebla Gpo. 1, as a thesis problem for the Ingeniero Agronomo degree at "Antonio Narro", Saltillo.

Five hundred S_1 lines from Pue. Gpo. 1-I (A) were planted in a yield trial with 2 replicates in Roque, Gto. in 1967. Samples of six stalks each were collected for each S_1 line (3 competitive stalks per replicate) and after drying 24 hours at 50°C, 5 cm stalk sections were cut with a specially constructed saw shown in the adjoining figure. The sections were weighed and rind thickness was measured for each stalk of the 197 (39%) most productive S_1 lines. Average weights per line varied from 1.44 to 3.26 gm with an overall mean of 2.31 gm. Rind thickness mean values varied from 1.57 to 2.44 mm with an average of 1.98 mm. The correlation coefficient was r = 0.78** (significant at the 1% level of probability). This should be expected since the rind tissue contributes the major portion of the weight of a stalk section. It is thought, therefore, that a more reliable estimate of stalk strength would be realized by weight of a section. From the 197 line means, 4 groups were selected (the 20 highest and 20 lowest for rind thickness and weight of the cylindrical section) for further study. The averages for both traits in the high and low groups in each case are presented in Table M13.

TABLE M13. Average rind thickness and weight of 5 cm stalk sections for 20 S_1 lines selected as high and low, and the general averages of the population of S_1 lines sampled for each trait.

Direction of selection	Rind thickness; mean of 20 selected lines	Weight of 5 cm stalk section; mean of 20 selected lines
High	2.25 mm	2.93 gm
Low	1.73 mm	1.78 gm
General mean of 197 S_1 lines	1.98 mm	2.31 gm

As expected from the high correlation between rind thickness and weight, nine of the 20 S_1 lines with highest rind thickness were also among the 20 highest in weight of a section and nine of the low lines were common in the lower 20 for each trait. Even though the two traits are highly correlated their relative value as an indirect trait in the selection for lodging resistance will be studied from three points of view: a) the relative precision with which they can be measured, b) their degree of correlation with other important traits like yield, days to flower and ear height, and c) their relative effectiveness in selection for lodging resistance.

Coefficients of variation in the analysis of variance of 1967 data were 12.2% and 7.0% for weight of a 5 cm section and rind thickness, respectively.

The analyses of variance provided the means for calculation of the line component of variance for each trait. The results are shown in Table M14. The larger values for weight of section suggest possibilities for greater selection opportunities using this trait. Subsequent study of the selected groups will provide an empirical test of this possibility.

TABLE M14. The among line components of variance, the ratio σ_L^2/σ^2 and the genetic coefficient of variance for rind thickness and weight of 5 cm section in 197 S_1 lines of Puebla Gpo. 1. Roque, Gto., 1967.

	Rind thickness (mm)	Weight of 5 cm section (g)
σ_L^2	.01235	.0697
σ^2/σ^2	6366	.871
GCV	5.6	11.4

Correlations of rind thickness and weight of section with other agronomic traits in this study were:

	Rind thickness	Weight of 5 cm section
Days to flower	0.16*	0.19**
Yield	0.01	0.02
Tillers/plant	—0.25**	—0.30**
Ear height	0.29**	0.40**
Field Lodging	—0.18**	—0.13*

* Significant at the .05 level.
** Significant at the .01 level.

Correlation with yield were non-existent. Partly due to the selection practiced for yield which greatly reduced the range of yield values. However, the correlation of ear height with weight of section was about 40% higher than that of ear height with rind thickness. The correlation of rind thickness and field lodging was significant at the 1% level of probability whereas, that between weight of section and field lodging was only significant at the 5% level of probability. Relative effectiveness of selection for thickness and weight of rind in changing the correlated trait, lodging, will be studied by comparing the 4 versions of the reconstituted populations with the original variety under high fertility levels and high plant densities which favor lodging.

CENTRAL AMERICAN PROGRAM

In an attempt to determine how much corn might be produced on a given plot of land during one year, a group of technicians working with maize in Central America decided to establish "maximum yield" plots. The plots used were one-half hectare as a minimum. The best cultural practices were used. Only one plot was carried through the 12 month period. This plot was at San Andrés in El Salvador. Three successive plantings of a local hybrid, H-5, were made. The yields for the three crops were 6,048, 5,012 and 7,000 kg/ha or a total of more than 18 tons of grain (12% moisture). This is believed to be the best production per year reported up to now in the tropics.

Breeding programs in the lowland tropics of Mexico are linked with regional programs and problems in Central America. New materials are under development which will be used in a cooperative breeding scheme designed to develop high yielding populations with a wide area of adaptation. The breeding program is oriented toward the twin goals of (1) deriving new information and (2) developing superior varieties for immediate use.

In breeding materials suitable for the tropical and subtropical areas of the world, top priority is being given to productivity together with reduced plant height and resistance to stunt virus. In the Central American region, evaluation of materials is aided through uniform trials planted at one or more locations in each of the six countries. The rainfall distribution pattern results in two separate periods of crop culture. The first crop of corn is planted in May and the second in August. Yields tend to be higher in the first (May) planting as shown for the 1967 summary in Table M15. Lack of adequate rainfall resulted in abnormally low yields in the first planting in 1967. Results of several years also demonstrate a slight superiority for the intermediate maturities. Moisture tends to be a limiting factor for late (long maturity) types in many areas. Under irrigation or where rainfall is adequate, late types can be recommended.

Relative to the entire group of materials included in the trials, El Salvador H-5, an intermediate maturity hybrid, was highest yielding in the first planting (20.6% above the mean). In the second planting it ranked eighth and was 3% above the test mean. A late hybrid, H-507 was second highest yielding in the first planting (12.8% above the test mean) and in the second planting (9.8% above the test mean). It was thus more consistent in performance. Honduras

Uniform yield trials of tropical maizes in Alajuela, Costa Rica. Twice a year in early and late plantings, CIMMYT materials are included in uniform trials throughout Central America and Panama.

CIMMYT works in close cooperation with national corn improvement programs in Central America. Here Ing. Julio Romero, plant breeder of Desarrural in Honduras, shows a high yielding variety developed through mass selection.

H-5, an intermediate hybrid, ranked third and first, respectively.

One of the limiting factors in maize production in Central America is stunt virus. In certain areas, and especially in the August planting, yields may approach zero unless types exhibiting some resistance are used. H-507, El Salvador H-5 and Honduras H-5 were so heavily damaged that they produced no grain in La Calera, Nicaragua second planting in 1967. Similar experience has been had in the coastal area of El Salvador.

The more resistant populations thus far discovered are a Cuban composite and a Dominican Republic composite. These two composites together with their cross are being used in a selection program (modified ear-to-row) to develop high resistance and high yielding populations for the lowland tropics (See Pathology).

TABLE M15. Central American Uniform Trial. Average grain yields in kg/ha at 15% moisture for 12 commercial hybrids or varieties. 1967.

	First Cycle May (10 locs.)		Second Cycle August (8 locs.)	
	kg/ha	% of overall mean	kg/ha	% of overall mean
Early				
El Salvador H-3	4024		3322	
Honduras Comp. early	3259		2490	
Nicaragua H-1	2749		2301	
Group means	3344	(85.1)	2704	(81.3)
Intermediate				
El Salvador H-5	4738		3440	
Honduras H-5	4232		3849	
x 302	4106		3494	
x 304	3897		3518	
Group means	4243	(108.0)	3575	(107.5)
Late				
H-507	4434		3652	
T-72	3976		3494	
T-25	3937		3491	
T-66	3906		3283	
x-306	3895		3569	
Group means	4030	(102.6)	3498	(105.2)
Overall mean	3929	(100)	3325	(100)

In Central America, as in other tropical and subtropical areas of the world, native corn varieties tend to be tall and susceptible to lodging. Here Ing. Adolfo Fuentes shows lodging at Cuyuta, Guatemala. Work is underway to lower ear placement and reduce plant height through selection and by incorporating the dwarf gene, brachytic-2.

The Andean Zone Program has stimulated an active interchange of materials and information among countries of the region, as well as uniform trials of the new varieties. The experiment station at La Molina Agrarian University, Lima Peru, participates in the uniform trials.

ANDEAN REGION

The national corn improvement programs of the individual countries in the Andean Region continue to cooperate with an active exchange of genetic stocks, breeding programs and reciprocal testing. The goal is to stimulate genetic research designed to improve yield, plant type and nutritional values, to evaluate production methods and to study storage and marketing of corn.

Yield Improvement

A measure of the success of the breeding program is the acceptance of varieties and hybrids by commercial producers.

Farmers of the irrigated coastal region of Peru are competing for the presently limited supply of new hybrids from the maize program of the Universidad Agraria, La Molina. In extensive tests PM-204 has shown its adaptability to Peru's northern and central coastal zones with commercial yields of over 9 metric tons per hectare.

In 1967, sales of improved corn seed in Colombia increased 42 percent. Most of the increase was due to the increased demand for seed of the recently released hybrids DH-104 and ICA H-207. These hybrids are adapted to the lower

A seed certification service was atarted in Colombia in 1967. Here Ing. Ricardo Ramirez shows the certification tag which was placed on 22 per cent of the improved seed sold last year.

New double cross hybrids being tested in Colombia are multiple-eared.

elevations of Colombia where two crops per year are possible. Total sale of improved seed in Colombia in 1967 was sufficient to plant 22 percent of the national corn acreage.

While reported estimates of total corn production remain low throughout the Andean Region, there is evidence to indicate that production is increasing. For example, in the period 1960 to 1967, the population of Colombia increased 22 percent. If substantial increases in corn production had not taken place, a severe shortage of corn would have developed. Traditionally, such shortages have brought about sharp price increases. But shortages have not been apparent and corn prices have remained remarkably constant.

During the same period, feeding of corn to animals has increased many fold and a corn-processing industry has developed. These changes in utilization and total consumption were possible only through increased production per unit area inasmuch as little new land was brought into production.

New genetic materials are constantly being introduced into the corn programs of the Andean Region to bring about increased yields. These are tested in cross-combinations with the presently available genetic stocks. The superiority of the inbred lines being drawn from newly formed composites in Colombia is shown in Table M16.

From these results it would appear trat substantial yield increases can be obtained from new

TABLE M16. Average topcross yields of the better inbred lines drawn from newly formed composites are shown as percent of the best locally adapted commercial double crosses.

Composite Source	Location	Average relative superiority (%)
Nariño 330-Cuba	Turipana	149
Eto-Cuba-Tuxpeño West Indian	Palmira	123
Eto-Peru 330	Tulio Ospina	120

hybrids. Some of the new composites are being released as varieties per se. One example is the new variety ICA V-105 released from the Turipana station on the north coast of Colombia by Ing. Agr. Fernando Arboleda. This composite was formed from 10 lowland corn varieties from the region. The yield of ICA V-105 is shown in Table M17.

Corn plants producing more than one ear per plant have been shown to be superior to the single ear types in attaining maximum yields. The populations undergoing selection for prolificacy have been released as varieties. One of the selected populations, ICA V-503, has been found to be a superior parent when used in variety-hybrid combinations. The results of the use of multiple ear stocks in crosses in Colombia and Ecuador are summarized in Table M18.

TABLE M17. Mean yield of the new variety ICA V-105 and the hybrid DH-104 in 20 trials compared to the standard improved variety DV-103.

Genotype	Relative Yield %
ICA V-105	121
DH-104	130
DV-103	100

Regional trials continue to be the principal means of introducing improved seed and new materials to the growers of a region. A greatly expanded program in Colombia, directed by Dr. Climaco Cassalett and Ing. Agr. Julio Toro, clearly indicates the impact that corn breeding can have on commercial production. Data from six distinct regions of Colombia, showed that commercially available improved seeds produced on the average twice as much as the local corn varieties included in these tests.

The genetic potential to double the corn production in the Andean Region already exists. The application of technical know-how and improved seed is the bottleneck to increased corn production

In 1967, Bolivia took steps to expand the genetic base of the existing improvement programs, thus making it possible to evaluate new genetic materials from other Andean region countries. An expanded program of mass selection and varietal improvement is being established.

TABLE M18. Average yields of selected variety-hybrids which include germ plasm selected for prolificacy.*

Genotype		Yield as % of local tester
Harinosa Mosquera (prolific) x DH 501	Tibaitatá, Col.	135
Harinosa Mosquera (prolific) x Chillos	Tibaitatá, Col.	126
Rocamex V-7 (prolific) x Chillos	Santa Catalina, Ec.	134

* Data provided by Ing. Antonio Rivera, Colombia and Ing. Mario Golarza, Ecuador

Agronomic Characteristics

Throughout the Andean region the corn improvement programs are facing common problems. Lodging and harvesting problems necessitate a reduction in plant height. Consequently ear and plant height are being given top priority in selection programs in most populations. The brachytic-2 gene which reduces plant height is also being incorporated into the major breeding materials of the Andean region. In Venezuela Ing. Agr. Pedro Obregón has developed populations of semi-dwarf plants using the brachytic-2 gene.

The need for shorter plants with less vegetative growth is apparent whenever attempts are made to mechanize corn harvesting. Commercial producers in the tropical areas of Ecuador estimate that they can economically accept a 20 percent reduction in yield if this were necessary to permit mechanical harvesting.

Corn Production Methods

Systems of production which form a package of practices in an extension program are not well developed in the Andean tropical regions. The north coast of South America has large areas which are being brought into production through the establishment of drainage and irrigation systems. This controls the water level in the wet season and provides for irrigation during the dry season. These large developmental projects are

Lower ear placement as a result of intense selection for this characteristic is demonstrated by Ing. Daniel Sarria at Palmira, Colombia.

Andean germ plasm is being used in African breeding programs. Mr. Mathias Akposoe, Ghanian plant breeder, inspects Colombian material for possible use in Ghana.

presently being constructed but the factors which affect crop production have not been tested.

Systems designed to be commercially practical were established at the Turipana station in Colombia in May, 1967 by Mr. Paul L. Carson, on leave from South Dakota State University. The project includes the application of modern production systems, the identification of the major barriers to economical corn production, and a cost analysis of the various systems applied.

This project was designed to apply, as nearly as possible, production systems which could be followed by commercial producers of the region. Irrigation was not possible in 1967, so planting at the beginning of the rainy season was attempted. It immediately became apparent that timeliness of all operations, especially weed control, was of paramount importance. Heavy rainfall early in the season contributed to poor stands because of soil crusting and ponding which made standard methods of mechanical and chemical weed control impossible.

One of the treatments included in the chemical weed control trials was the post-emergent application of atrazine with oil. It was not possible to make this application until the weeds were 10 to 12 inches tall; however, it proved to be one of the most successful weed control measures applied. This system of weed control needs to be studied in much greater detail because of the obvious advantage of extending the time period over which the chemical can be applied. This is especially important when long periods of heavy rainfall prevent timely field operations. The results of the weed control treatments are shown in Table 19.

TABLE M19. The effect of weed control practices on yield of silage at the Turipana experimental station. Colombia, 1967.

Produce	Weed Control Treatment		
	0	Two kilos atrazine pre-emergence	Two kilos atrazine in oil post-emergence
	ton/ha	ton/ha	ton/ha.
Corn as silage	18.0	20.6	26.0
Weeds	19.0	14.9	7.2
Total	37.0	35.3	33.2
Percent weeds	51.2%	42.0%	21.7%

Weeds also greatly affect harvesting. Corn planted in May is ready for harvest in 120 days which is still within a period when heavy rains can be expected. Weeds, which are retarded in their growth by early chemical application or by ground shading, begin to grow again when the corn reaches physiological maturity. Systems of early season weed control are of only limited value in controlling the late season weed growth. More effective methods must be found to meet this problem.

Another problem is that of obtaining and maintaining an adequate corn plant population to make high yields of grain possible. Stand losses because of poor seed, soil insects, soil crusting and chewing insects were anticipated and treated

The yield potential of the new maize varieties can be assessed by Colombian farmers at field days organized by ICA scientists. Dr. Manuel Torregroza addresses farmers at a regional corn trial.

as factors in the experimental design. While it is too early to pin-point all of the cause and effect relationships which influence commercial corn production in the humid tropics, it is apparent that the hand technology used in experimental plot production must be modified greatly for large scale production.

Where appropriate cultural practices were employed, yields of more than 5 tons per hectare were harvested. To date, it has not been possible to put an economic value on all of the factors needed to attain maximum yields. This type of information is needed, because in many cases the farmer is not convinced that an economical return is possible with many of the cultural practices being recommended.

These studies are being expanded to provide training opportunities for personnel at all levels of experience and to serve as demonstrations for the extension service.

Corn Storage and Marketing

One of the great deterrents to increased production of corn in many developing areas is the lack of an adequate marketing system at harvest. Inseparably tied to this is the unavailability of storage facilities at the market consolidation points and on the farms. The storage at the market centers is important for a continuous and orderly movement of grain to the consumer. On-the-farm storage is vitally important, especially to a small producer, as this is the only means by which he can gain a bargaining position. In the humid tropics, corn must be put into protective dry storage or sold within 20 days of harvest. Throughout the Andean region, most small producers of corn are served by itinerate corn buyers whose prices for corn may not in any way reflect the national demand.

The effect of over-supply on an inelastic market structure was observed in Peru in 1967. An importation of only 50,000 tons of sorghum as feed grain was associated with a sharp reduction in the price paid for corn in the coastal region. In the following season, at least 40 percent less corn was planted. This sharply affected the total supply available. Adequate marketing systems which could provide reserve storage and more adequate information about supply and price would aid in overcoming market fluctuations which can be costly to the nation and ruinous for individual producers.

INTER-ASIAN PROGRAM

The Inter-Asian Program (IACP), headquartered at the Kasetsart University experiment station (Farm Suwan), has made considerable progress in research, training and experiment station development during the year. The work is integrated with the Thai National Corn Improvement and Training Program (See Training).

The objectives are, through research and training, to improve corn production in Thailand and the tropical and subtropical areas of Asia.

Exchange of staff, materials, and information, as well as annual workshops, have contributed to a higher degree of communication and cooperation throughout the region. Cooperative performance trials are now permitting wide evaluation of better materials from the various national breeding programs. Close cooperation is maintained with the experiment station of Uttar Pradesh Agricultural University (UPAU) in northern India. The Indian station devotes much of its effort to variety improvement for the semi-tropical and high altitude areas of Asia. It also provides some in-service training and through the cooperation of UPAU, a limited amount of degree training.

Thailand

In April 1966, a memorandum of understanding was signed by the Thai Government and Rockefeller Foundation officials in which Kasetsart University's Suwan Farm was designated as the principal experiment station for the National Corn and Sorghum Research Program. A total of 118 hectares of the farm were allocated to this program. By January 1968, a deep well had been improved and a new pump installed which provides 300 gpm; a permanent, plastic lined 3 hectare decimeter reservoir had been constructed; 350 meters of 12" concrete pipeline had been laid with necessary gate stands and alfalfa valve risers; 11 hectares of land had been leveled to grade; and over 11 km of farm roads layed out. All trees, shrubs, stumps, roots and brush had been removed from about 100 hectares and the area smoothed by land planning Areas not devoted to research during the rainy seasons of 1966 and 1967 were used for seed multiplication for the Department of Agriculture.

During 1967, seven duplex houses for laborers plus three houses for Thai staff and three for international staff were constructed at the National Corn and Sorghum Research Center. Architectural plans have been completed and the budget approved for a large service center, a fertilizer and chemical warehouse, and a dormitory.

Development work has been initiated at four outlying stations.

Chinat. Approximately one hectare was surveyed and leveled to grade at the Chinat Agricultural Experiment Station for regional testing. A small open ditch irrigation facility was also constructed.

Korat. Ten hectares of land were surveyed and rough-leveled for the 1967 rainy season planting. This area was chiseled, plowed, and prepared for intensive cropping for the first time.

Takli. Ten hectares at Takli Agricultural Experiment Station were allocated to corn and sorghum research. This area was of very rough profile and covered with small palm trees. In 1967, the areas was cleared surveyed, and ploughed. Soil sampling showed the

FARM SUWAN: CENTER OF RESEARCH AND TRAINING IN SOUTHEAST ASIA. Two years after being designated as headquarters of the Thai National Corn and Sorghum Research and of the Inter-Asian Corn Improvement Program, Farm Suwan has greatly improved facilities for research and training. More than 100 hectares of land have been smoothed and planned for experimental plantings and multiplication plots. There is a new pump and a water reservoir for irrigating experimental plots during the dry season. Pipelines assure more uniform and precise water application.

Research at Farm Suwan serves Thailand's national programs and is also projected to other countries of Southeast Asia. Germ plasm from Latin America and other countries is contributing to varietal improvement—such as multiple-ear varieties and populations to which the dwarf gene, brachytic-2 are being incorporated to reduce plant height and consequently lodging caused by the strong winds in the region.

black, fertile topsoil to be only one meter deep, and this was underlain by the white, calcareous subsoil. Adjacent field areas where the subsoil had been exposed exhibited very poor, highly chlorotic crop growth. Consequently only shallow surface smoothing of the soil, to enhance surface drainage, was done. This area was planted to corn yield trials in May 1967. Due to an unprecedented drought and lack of irrigation facilities the crop failed to mature. The land was then reallocated to the cotton research group.

Uthong. The Department of Agriculture has recently purchased additional land area near the Uthong Agricultural Experiment Station. Development work will be started on this area in the near future.

Breeding

The breeding program is concerned with varietal improvement and development of new gene pools. Screening of introduced germ plasm is continuing to identify adapted genetic materials of potential value in the area. Materials from the Central American and Caribbean region show most promise. Variety crosses involving Veracruz 181, Antigua Gpo. 2, Cuba Gpo. 1, Cuba 40 and Nariño 330 - Peru 330, together with a synthetic variety, Guatemala x Caribbean Flint Composite in 1967 produced yield from 25 to 50% higher than the local variety checks.

Varieties from Japan and Argentina appear to be good sources of earliness. Twenty of the better varieties and crosses are being advanced to a regional testing program in 1968.

Several population improvement schemes have been initiated to further improve the better germ plasms and to provide evidence on the most effective and efficient breeding procedures for this area. Some of these schemes are being modified to permit utilization of three growing seasons per year.

The mutant genes, opaque-2 and floury-2, affecting protein quality in maize, are being incorporated into adapted tropical germ plasm. Efforts are also underway to reduce plant and ear height through the incorporation of materials characterized by reduced plant height.

Three populations of corn with different average plant heights (123, 167, 192 cm) in Guatemalan background were compared with standard Guatemalan (219 cm) in one test. The two shorter types showed more tolerance to drought and greater lodging resistance than the taller plant types. Leaf area indices were somewhat lower in the short types. The greater drought tolerance may have been due to the more compact leaf canopies of the shorter types where less air movement would be accompanied by lower transpiration rates. A significantly higher yield was produced by the plant types that averaged 167 and 192 cm in height, the former producing the highest yield of 2780 kg/ha. Pollination was poor on the shortest plant type where the close spacing of the leaves apparently interfered with pollen movement.

Maize Pathology and Entomology

Potentially serious pests are being identified through field surveys and research has been initiated on control measures for these pests.

The presence of a number of diseases in Thailand possess a serious threat to future maize production. In 1967, a total of 28 different maize diseases were identified in the country; 14 of these were reported for the first time although they were probably here previously Preliminary screening of germ plasm was begun for resistance to the most serious diseases including northern and southern leaf blights, Curvularia leaf spot, Colletotricum stalk rot and charcoal rot. Curvularia leaf spot caused by ***Curvularia lunata*** seems to be more prevalent in Thailand than most other maize areas of the world. Some tolerance has been found in certain varieties which are being used for selection experiments and inheritance studies. The presence of a crown and stalk rot complex reported in other tropical countries, has also caused concern in Thailand. An ear rot caused by ***Botryodiplodia phaseoli*** has also been found.

The major insects attacking maize are the Bombay locust (***Palanga succineta***), corn armyworm (***Pseudaletia separata***) corn earworm (***Helecoverpa armigera***) and European corn borer (***Ostrinia salnelialis***). Attack from these insects seem to be sporadic in different seasons and areas of Thailand. Control measures are being investigated through chemical and genetic means . Various insecticides are being tested for economic control of these pests and screening of genetic materials is being initiated under natural and artificial infestation.

Agronomy

The 1967 season was exceptionally dry at Farm Suwan and all experiments suffered from lack of adequate soil moisture. Experiments in soil fertility showed a very low level of available phosphorous in the soils at Farm Suwan. The addition of nitrogen fertilizer without phosphorous reduced yields in all experiments. High levels of phosphorous fertilizer were needed to satisfy crop needs when the phosphorous was broadcast. Banding the fertilizer greatly improved recovery efficiency, but precision in placement in relation to the seed was important.

Weed control in the tropics is imperative but difficult to achieve by conventional cultivation methods. Chemicals are the answer, if residue problems can be minimized so as not to damage the cotton, peanuts, mungbeans or soybeans which are frequently planted after the corn and soybean harvest.

Weed control experiments in corn were conducted using several chemicals in granular and spray forms and at varying rates. There were no significant differences in yield due to chemical treatments when compared to unweeded and hand weeded plots. This was probably due to a very low weed population as a result of the drought.

Pakistan

Pakistan is moving rapidly ahead with its corn production program. About half of the total corn area of West Pakistan was planted to improved varieties last year. A spring, or off-season, crop has been grown to rapidly build up seed stocks of the improved varieties. During the past year the research program was reorganized into a coordinated corn improvement program. A project director coordinates activities across all three regions. With this reorganization, the Ford Foundation was asked to provide a corn breeder to work with the project director in organizing and implementing the research activities. The Ford Foundation responded through CIMMYT and a consultant is now on location in West Pakistan. This is an important step in West Pakistan's coarse cereal grain program as it will give needed attention to research, education and training.

Philippines

The College of Agriculture at Los Baños, in cooperation with other agencies, has moved ahead with the Philippine corn program. An extensive research program is underway at the College and is now reaching out into various regions of the country. Active cooperation has also been extended in the search for resistance to Downy Mildew (See Pathology).

As reported last year, three new varieties were released in the Philippines. There is now adequate seed of these varieties to plant at least 60,000 hectares. The Philippine workers have continued their active program of demonstration and seed increase blocks with cooperating farmers in the major corn producing areas. Simultaneously with the demonstration and seed program, a vigorous training program has been carried on for extension workers. To date 125 extension workers have gone through 4-8 weeks of intensive training in corn production practices.

The College has obtained funds for building a training dormitory to house up to 30 trainees. A system has been worked out to include a degree program to upgrade the staff of cooperating agencies, colleges and schools of agriculture. In addition to the programs for the Philippines, the College is also providing degree opportunities for Asian scholars.

Afghanistan

The corn workers in Afghanistan have attempted to grow the varieties, J1 and Golden Thoras, with but little success since these varieties are late and poorly adapted. More promising breeding material may come from a series of local varieties crossed onto exotic germ plasm by CIMMYT. After surveying these crosses growing in Afghanistan, CIMMYT made up several composites from which a population improvement program will be initiated by two trainees who returned home after a year in Mexico. Also, considerable breeding material has been sent to Afghanistan from the Indian and Thailand stations.

Nepal

The IACP station in India is working closely with the program in Nepal. This work has resulted in the release of three varieties. New material from the Indian program is also being tested in the search for other potentially useful materials.

Ear rots are a serious problem in parts of Nepal because of the high rainfall at harvest. Selection is underway for corn plants that have a reclining ear at maturity as one means of avoiding water collecting inside the husk and encouraging the development of ear rotting fungi.

India

India has the largest corn research program in Asia and has released over the years several hybrids and synthetics which are presently in production. Seed of high yielding synthetics is available to plant an estimated 600,000 acres.

One of the hybrids released during the past two years by the All India Coordinated Maize Improvement Project are shown here at the Pusa Experiment Station at New Delhi. Six high yielding composites have also been distributed to different areas of the country—from the Himalayan hills to the Indo-gangetic plains. Latin American germ plasm has been used in developing these new varieties.

As in other parts of Asia, the Indian Maize Improvement Program is working on the development of dwarf hybrids to solve problem of lodging and harvesting. The work shown here is at Pantnager.

These new synthetics have been successful, and progress has also been made in developing disease resistant and insect tolerant material.

The Indian program is a good source of in-service and degree training at both the MS and PhD levels.

Indian farmers are greately interested in the new corn varieties. This field is at the Pusa Experiment Station.

EASTERN AFRICA PROGRAM

The CIMMYT regional coordinator in East Africa, headquartered at Kitale, Kenya, works closely with the Kenya Maize research section and the USAID program for that area. Research stations for maize improvement are maintained in Kenya at: Kitale, Katumani and Embu. Each station is concerned with the development of maize populations suitable for a particular ecological set of conditions.

The maize programs are oriented toward the production of a package of recommendations for maximizing maize production. These are passed on by the extension officers to farmers. Considerable use is made of demonstrations planted throughout the country for farmers to see in the field the value of various important cultural practices as well as good seed.

The genetic yield potential of maize populations in East Africa has been increased greatly through the incorporation of germ plasm from corresponding latitudes in Latin America. Broad based composites have been formed which have led to rapid and substantial gains in productivity through various recurrent selection procedures. Some of the results obtained are shown in Table M20.

These populations are being used to evaluate the relative efficiency of different methods of selection. A total of 10 testing locations are being used to provide accurate evaluation of the methods. Preliminary information is being employed in advising maize breeders in other programs in the region.

Improvement in productivity is being coupled with improvement in nutritional quality through use of the opaque-2 mutant; plant height through use of the brachytic-2 mutant; and resistance to blight ***Helminthosporium turcicum,*** through use of the Ht gene. To aid in future seed production of hybrids, cytoplasmic sterility and the fertility restorer genes are being incorporated into the necessary populations.

Strong working relationships have been established with the Kenya Seed Company and with the extension personnel. Thus improved maize varieties are made available for farmer use in the shortest period of time, and the information obtained on important cultural practices is distributed and demonstrated on a wide scale.

The package approach to improved maize production has led to the use of "demonstration diamonds" as shown in the adjoining figure. The demonstration provides a comparison of the importance of various factors involved in maize production and their interactions. Husbandry combines time of planting, plants per acre and weed control. The main observations provided by the four plots "diamonds" are:

1) The first treatment, bad husbandry, local variety and no fertilizer results in a yield representing the area average; 2) Substantial increases in production can be derived from good husbandry alone; 3) Expensive inputs (hybrid seed and fertilizer) yield little profit if applied with bad husbandry; and 4) A four-fold increase in maize production can be obtained with good seed and fertilizer, together with improved husbandry.

Where new programs are being initiated in other countries in the region, strong emphasis is being given to the use of the package approach in the increase of maize production.

The effect of the combined approach (breeding, agronomic research, seed production, and extension) in Kenya is reflected in the amount of land area planted to improved long-season hybrids since 1963. A total of 400 acres were planted to these hybrids in 1963. By 1968 the total acreage planted had increased to 240,000. Commercial farms are now planting virtually all of their acreage to hybrid maize. The small scale subsistence farms, have also shown a substantial increase in use of hybrid seed, the acreage increasing from 10 in 1963 to 140,000 in 1968. Although the hybrids may outyield the local maize by 30 to 50%, their use has stimulated interest in improved husbandry with the result that these yields have been more than doubled where such practices were applied.

Problems have developed as a result of the increases in maize production in Kenya. Excellent crop seasons coupled with improved maize culture has led to a surplus as far as internal requirements are concerned. Lack of adequate transportation and storage facilities and the absence of a market structure has caused wide fluctuations in the price of maize. This has led to concern among farmers as to the advisability of increasing acreages of maize. A stable and reasonable price level is important for any cereal program.

TABLE 20. Mean yields for Kitale Composites at 10 locations in 1966 and 11 locations in 1967.

Variety [1]	Yields in lbs per acre 1966	1967	Mean	% of Kitale II
Kitale II	4,580	3,550	4,070	100
Kitale III	4,890	4,070	4,480	110
Kitale Composite B	4,870	4,520	4,700	115
Kitale Composite C	4,810	4,470	4,640	114
Kitale Composite E	5,170	4,910	5,040	124

[1] Kitale Synthetic II was the best open-pollinated variety previously available.

Kitale Synthetic III was derived from one cycle of S_1 topcross testing from Kitale Synthetic II.

Kitale Composite B is a mixture of a wide range of Kenya Flat White material. Two generations of 25% mass selection during composite formation had taken place before the trials.

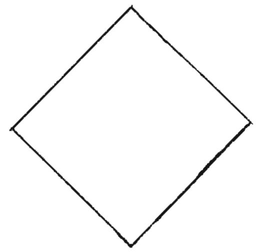
Kitale Composite C is a mixture of selections from Ecuador 573, Costa Rica 76 (both race Montano) and race Comiteco.

Kitale Composite E is a very wide mixture of Composite B and C with an equal amount of 13 other Latin American races.

Eastern Africa Demonstration Diamond

Bad Husbandry plus
Local Maize No Fertilizer
Yield . . . 1,760 lbs/acre

Bad Husbandry plus
Hybrid - With Fertilizer
Extra Cost - 132/-
Yield . . . 2,920
Extra Profit 30/-



Good Husbandry plus
Local Maize - No Fertilizer
Extra Cost - 67/-
Yield . . . 4,360
Extra Profit 297/-

Good Husbandry plus
Hybrid - With Fertilizer
Extra Cost - 224/-
Yield . . . 7,160
Extra Profit 532/-

INTERNATIONAL MAIZE MEETINGS

CIMMYT staff participated in several international meetings to exchange ideas and information, and to develop stronger cooperation among maize programs.

The ALAF meetings were held in Maracay, Venezuela in September, 1967. Maize personnel from throughout Latin America attended and research was reported on all phases of maize breeding, genetics, entomology, pathology and production.

The IV Interasian Maize Improvement Workshop met in Pakistan in October, 1967. It was well attended and a great deal of enthusiasm was shown for progress in research and development to increase maize production.

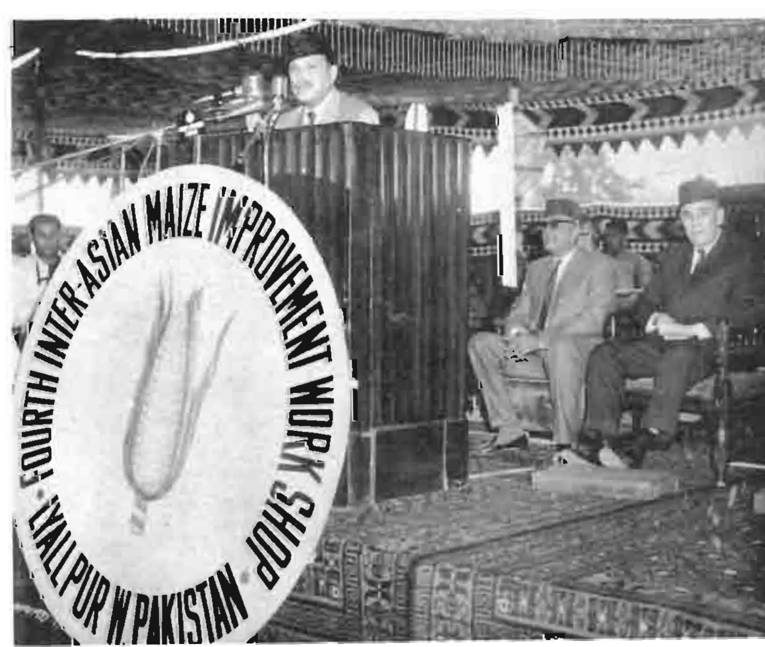
The XIV annual meeting of the Central American Food Crop Program (PCCMCA) was held in Honduras, February 27-29, 1968. This cooperative program, underway since 1954, has been highly effective in increasing production of maize, beans and sorghum throughout the area.

A conference of maize researchers in Argentina, Brazil, Uruguay and Chile was organized in Buenos Aires, March 4-5, 1968. Those invited included both private and experiment station technicians interested in the improvement of maize production. Groundwork was laid for future meetings and cooperative research programs.

The III Annual Andean Maize Workers Conference was held at La Molina, Lima, Perú, March 18-21, 1968. The meeting was well attended and papers were presented on various phases of maize improvement, seed production and distribution in the Andean region.

The maize researchs staff of CIMMYT met in Mexico, April 4 and 5, 1968. Other collaborators invited to participate in these meetings included personnel from Peru, Ecuador, Colombia, Venezuela, Honduras, Kenya and India. A group of plant physiologists (California, Wisconsin, Illinois, Kentucky, New York, and Japan) met with the

Mr. Mohammad Ayub Khan, President of Pakistan, inaugurated the Fourth Asian Maize Improvement Workshop at Lyallpur, a meeting which was attended by delegates from 11 Asian countries. President Khan, delivering his speech, is accompanied by Mr. Malik Khuda Bakhsh, Minister of Food and Agriculture, and Mr. Mohammad Musa, Governor of West Pakistan.



The Fourth Asian Maize Improvement Workshop provided an opportunity for interchange of ideas and information among scientists. Dr. Abdul Ghafoor Bhatti, West Pakistan Maize Project Director, shows an improved variety to delegates from five countries while touring the Yousafwala Maize Farm.

maize group to learn of the research underway and advise on research relating to physiological aspects of maize growth and production. Plans are underway to establish a plant physiology branch in CIMMYT to aid in the development of more efficient plant types for the tropics.

The CIMMYT representative in Kenya participated in a number of meetings held in East Africa during the year. The second Eastern African Cereals Research Conference was held in September, 1967. A total of 39 delegates from 7 East African countries attended.

Dr. B. L. Renfro, Rockefeller Foundation Plant Pathologist in India, along with scientists from Thailand and Malaysia attending the workshop in Pakistan, examines a plant affected by rust at the Okara Maize Farm.

w h e a t

Short-strawed, high-yielding wheat varieties have taken over the irrigated wheat area of India and Pakistan, bringing greater production and betterment in rural living.

wheat

■ FOR TWO SUCCESSIVE crop years (1966 and 1967), India and Pakistan suffered one of the severest droughts in recent decades. Disastrous famines were averted only by the massive importation of food grains, mostly wheat.

Masked by the drought and largely unnoticed was the successful transplant from Mexico into both Pakistan and India of the high yielding, light-insensitive, fertilizer-responsive dwarf Mexican wheat varieties. These, together with a package of intensive management practices that had been developed through research done half-way around the world and modified by research done in Pakistan and India, were setting the stage for an agricultural revolution which is now sweeping the sub-continent.

The first small commercial transplant was made from Mexico into both countries in the fall of 1965. The success of the first transplant was so spectacular that the government of India took bold action and imported an additional 18,000 tons of seed of Mexican dwarfs in 1966. Last year the government of Pakistan took similar action and imported 42,000 tons of Mexican dwarfs, thereby setting the stage in both countries for the production breakthrough that is now unfolding. The chronology of change is clearly indicated in Tables W1 and W2.

The harvest now being completed in Pakistan is officially estimated at 6.2 million tons, compared to a harvest of 4.3 million last year and to the previous all time high of 4.6 million tons in

TABLE W1. The transplant of high-yielding, fertilizer-responsive, semi-dwarf Mexican wheat varieties, together with new technology into the Near and Middle East.

Country	Collaborating technical assistance agency	Seed Year	Imported from Mexico * Quantity	Estimated area planted to Mexican varieties with new technology ** Crop year	Approximate acreage
West Pakistan	Ford Foundation via Grant to CIMMYT	1962	Exp. samples (grams)	———	
		1963	Exp. samples (200 kilos)	———	
		1964		1964-65	10
		1965	350 metric tons	1965-66	11,000
		1966	50 metroc tons	1966-67	600,000
		1967	40,000 metric tons	1967-68	3,000,000
India	Rockefeller Foundation and CIMMYT	1962	Exp. samples (grams)	———	
		1963	Exp. samples (300 kilos)	———	
		1964		1964-65	15
		1965	250 meric tons	1965-66	7,000
		1966	18,000 metric tons	1966-67	700,000
		1967	—	1967-68	6,000,000
Turkey	USAID	1964	Exp. samples (grams)	———	
		1965	Exp. samples (kilos)	———	
		1966	60 metric tons	1966-67	1,500
		1967	22,500 metric tons	1967 68	600,000
Afghanistan	USAID	1966	170 metric tons (from Pakistan)	1966-67	3,000
		1967	—	1967-68	65,000

* During 1966 and 1967 Mexico exported 81,000 tons (3,000,000 bushels) of seed wheat to Near and Middle East countries, including 18,000 tons to India (July 1966); 22,000 tons to Turkey (July 1967), and 42,000 tons to Pakistan (August, 1967)

** The major part of this acreage is heavily fertilized.

TABLE W2. Total cultivated area, production and yield of wheat in West Pakistan and India; area, production andyield of dwarf wheats grown under intensive management.

WEST PAKISTAN

	TOTALS			Dwarf Wheat and New Technology				
Harvest Year	Wheat area Millions of Ha.	Prod. Millions Metric Tons	Ave. Yield Kg/ha	Area Millions Ha.	% Total Area	Prod. Millions Metric Tons	% of Total Prod.	Yield Kg/ha
1956	4.52	3.3	730					
1960	4.88	3.9	802					
1961	4.64	3.8	819					
1962	4.92	4.1	832					
1963	5.04	4.1	831					
1964	5.00	4.1	820					
1965	5.32	4.6	865					
1966	5.28	3.9	379	.005	.01	.017	.043	3075
1967	5.36	4.3	803	.120	2.2	.29	6.7	2416
1968*	6.00	7.0	1167	1.2	20.0	2.94	42.0	2450

INDIA

	TOTALS			Dwarf Wheat and New Technology				
Harvest year	Wheat area Millions of Ha.	Prod. Millions Metric Tons	Ave. Yield Kg/ha	Area Millions Ha.	% Total Area	Prod. Millions Metric Tons	% of Total Prod.	Yield Kg/ha
1957	13.5	9.4	705					
1960	13.4	10.3	783					
1961	12.9	11.0	862					
1962	13.6	12.1	901					
1963	13.7	10.8	804					
1964	13.5	9.9	740					
1965	13.5	12.3	925					
1966	12.7	10.4	836					
1967	13.1	11.5	889	.280	2.1			
1968*	14.0	18.0	1286	2.5	18	6.5	36	2600

* Estimates based on data available, April 1, 1968.

1965. In all probability the final total harvest will be between 7.0 and 7.5 million tons. This production makes Pakistan self-sufficient in wheat for the first time. Pakistan has accomplished in three years —drawing heavily on Mexican seed and scientific know-how— what it took Mexico 13 years to achieve.

India is also completing a bumper harvest. Official estimates indicate a harvest of more than 18 million tons —although it may turn out to be closer to 20 million. This compares with a harvest of 11.5 million tons last year, and an all-time high of 12.3 million tons harvested in 1965. Although India is not yet self-sufficient in wheat production, it has taken a giant stride in this direction and is far ahead of schedule.

Millions of farmers have enthusiastically taken to the new technology. A new optimism fills the air. It has infected the farmer, government officials, scientists and politicians.

Warehouses are overflowing and even stadiums and schools have been utilized during the summer vacation for emergency storage space to get the grain under roof before the onset of the monsoon. Every available railroad car and truck has been regimented to transport the grain to the main centers of consumption, but the grain continues to accumulate and glut the markets in the principal centers of production. Government officials are struggling to maintain the official floor prices and have been surprisingly effective despite many difficulties. Even labor is in short supply for handling the crop, an unheard of phenomenon in India and Pakistan.

The problems associated with this rapid change in production are enormous, but there is no doubt that they can be solved. In Pakistan at the beginning of the 1968 kharif (summer) planting season, there was a shortage of fertilizer and a flourishing black market as the farmers' enthusiasm for the new technology spread to the intensive cultivation of dwarf IRRI8 (IRRI-Pak) rice and to J-1 synthetic maize.

There is now the monstruous job of meeting the exploding demand for inputs such as fertilizer, pesticides, credit, storage facilities, transport

The goal of CIMMYT researchers in collaboration with the scientists of many countries: healthy, high-yielding wheat crops to help solve the world's food problems.

Success in raising production has created a new problem-storage. In the usually dry Yaqui Valley of Sonora, Mexico, this can be solved temporarily by using open spaces surrounded by wheat bags. In Pakistan and India school rooms were used during vacation to add to available covered storage.

equipment, tube wells, and more and better machinery for land preparation, sowing and harvesting. Antiquated systems for distributing these inputs contribute to the bottlenecks which appear at every turn. Above all there is increasing pressure to improve the effectiveness of the announced floor prices. Failure in any of these undertakings will disrupt or slow the revolution in wheat, rice, maize and sorghum production which is now gaining momentum.

The production revolution, triggered by new seeds and technical know-how, can only go forward if the necessary inputs are planned for and provided in ever increasing amounts. The situation in India is very similar to that outlined above for Pakistan.

It must be emphasized that there are two principal factors contributing to the record-breaking harvests in both countries. These are: 1) very favorable winter rainfall and 2) the yield impact of the Mexican dwarf wheat varieties under intensive management practices, including heavy fertilization. An idea of the relative importance of the two factors can be gained by comparing the total production and yield for the 1965 harvest and that for the current year in both Pakistan and India (Table W2). The 1964-65 crop also had a favorable monsoon and favorable winter rainfall. Yields in Pakistan rose from 865 kilos per hectare in 1965 to 1167 kilos in the 1968 harvest, and in India from 925 to 1286 kilos. Most of this increase in yield comes from the intensive cultivation of large acreages of dwarf Mexican varieties under intensive management practices, including especially heavy fertilization. To a lesser extent, increased yields also reflect the use of fertilizer at lower levels on large areas of tall strawed Pakistani and Indian varieties.

The revolutions in wheat production which began in India and Pakistan are now spreading rapidly to other countries.

Turkey is moving aggressively to catch up with Pakistan and India through a two-pronged approach. The accelerated spring wheat program, confined to low elevations along the Mediterranean and Aegean coasts, is built around the dwarf Mexican varieties and the package of intensive management practices used in Mexico, Pakistan and India. The current harvest is very good and is now producing its first small impact on production. During the 1968-69 crop cycle the full impact from this program will be felt.

In the highlands of the Anatolian Plateau where the climate is more severe and winter wheats are grown, the revolution is just beginning. It involves a program of the Turkish Government and USAID to introduce the dry land management practices developed in the low rainfall areas of the State of Washington in the U.S.A., combined with the use of high-yielding, frost-resistant winter varieties.

Afghanistan's effort in increasing wheat production is gaining momentum in the areas where the Mexican dwarfs are adapted. In the colder drier winter wheat areas, a program similar to that for the Anatolian Plateau is needed.

Tunisia has made considerable progress during the past year in laying the ground work for launching a revolution in wheat production. Next year about 25,000 hectares will be sown to Mexican dwarfs with improved management practices.

Currently there is much interest in revolutionizing wheat production in Africa and the Near and Middle East. The countries include Morocco, Saudi Arabia, Lebanon, Iran, Iraq, Kenya, Sudan and South Africa. In South America, Brazil, Paraguay and Uruguay are now interested in developing accelerated production programs.

It is clearly feasible to greatly increase wheat production in many countries of Africa and Asia. The knowledge, materials and trainees developed by the Mexican-CIMMYT wheat program have been decisive catalysts in provoking wheat production revolutions in several countries. It is estimated that during the 1968-69 season the Mexican varieties will be grown on an area in foreign countries that will be 15 times greater than the entire area sown to wheat in Mexico, where these varieties were bred. The investments made in wheat research in Mexico by the Rockefeller Foundation and the Mexican government have paid fantastic returns both in terms of increased food production in Mexico, as well as by improving the well-being of hundreds of millions of people in widely separated areas of the world.

Revolutions in wheat production do not just happen as an automatic by-product of research programs. In the past, various countries have improved varieties and carried out the agronomic, entomological and phytopathological research to produce the information and materials on which wheat production campaigns could be successfully launched, but wheat production and per hectare yields have remained stagnant.

In several cases, fiscal policies built around the importation of low-priced wheat, has suppressed domestic production. Are the expenditures for research on wheat justifiable in these countries if the findings are not to be utilized to improve the lot of the farmers and to help solve food production problems for the country?

Rapid increases in production and yield can only be obtained by launching aggressive, national production campaigns. In such campaigns all important factors affecting production —biologic, soil, economic and psychological— must be manipulated harmoniously and with purpose and urgency.

The CIMMYT wheat program staff has developed considerable experience and competence in helping to organize national wheat production campaigns. Additional information on progress being made in wheat production in countries with which CIMMYT collaborates is briefly summarized in the following sections of this report.

PAKISTAN

The stage is now set for Pakistan to achieve and maintain self-sufficiency in wheat production every year for the next decade, regardless of variation in winter rainfall.

In the 1968 harvest it is estimated that the 20 percent of the 3 million acres that were cultivated to Mexican dwarf wheats under intensive management, produced 43 percent of the total harvest.

Next year Pakistan must double the area under Mexican dwarfs with intensive management, to assure self-sufficiency even though weather is unfavorable. The maintenance of incentive prices for wheat is also essential, as is the availability of fertilizer and an expansion of credit to facilitate its purchase.

The breakthrough in wheat production has created many new problems. These include inadequate: 1) facilities for storage and transport; 2) machinery for land preparation, leveling, sowing and harvesting; 3) supplies of fertilizer and pesticides; 4) organizations for the distribution of fertilizer and pesticides; 5) credits for the purchase of new inputs; and 6) organization and credits for the support of floor prices.

Storage

The storage situation will get progressively worse as the production revolution spreads to rice, maize and sorghum. It will take several years to solve the problem even though both the government and the private sector launch aggressive programs of warehouse construction. Currently wheat is stored in all sorts of inadequate buildings in an attempt to get it under some type of roof before the onset of the monsoon. Much remains outside under temporary improvised storage facilities. Some will be lost or damaged.

Transport

A shortage of railroad freight cars and trucks has contributed to depressing grain prices. This problem will become worse with the anticipated jump in rice and maize production.

Availability of Fertilizer and Pesticides

Up to now fertilizers and pesticides have generally been available in adequate quantities within the country. However, shortages at the village level have been common and distribution often faulty and bureaucratic. Credit for fertilizer purchases is too limited and often difficult to obtain at the village level. This has sometimes restricted use and resulted in lower volumes of fertilizer sales than those programmed.

One bottleneck to expanding fertilizer sales at the targetted rate is caused by the lag in phosphate sales. Potential yield increases from the use of nitrogen fertilizers are greatly depressed in most Pakistan soils unless combined with proper rates of phosphate application. Currently phosphate sales are only running 10 percent of total fertilizer sales, whereas recommendations indicate that phosphate sales should represent 40 percent of the total. Last year, an extension campaign attempted to correct this situation, but met with little success. This problem could be circumvented to a large degree by importations of "complex starter fertilizers" such as diammonium phosphate, nitrophos, etc. Farmers using these fertilizers would automatically be applying both nitrogen and phosphate at sowing. Topdressing with urea at a later date would supply the remainder of the needed nitrogen. The importation of complex starter fertilizers has been recommended to solve this problem but to date no action has been taken.

Need for Better Machinery

Two years ago the Accelerated Wheat Production Program recognized the need for improving the mechanization of Pakistan s agriculture. A Machinery Demonstration Unit was made available to Pakistan under a Ford Foundation grant via CIMMYT to demonstrate the value of modern machinery for increasing yields and production.

The rapid increase in the land area with more than one crop per year focuses attention on the need for tractors to rapidly prepare the land following each harvest. Bullock power is too slow to meet this need. The bumper wheat harvest focused attention on the inadequate of the antiquated hand sickle harvesting and the old fashioned treading and winnowing threshing method. This method is still used to harvest and thresh virtually 15 million acres of wheat. The self-propelled wheat combine of the Machinery Demostration Unit has caught the fancy of both large and small farmers. Large farmers are now trying to purchase combines to thresh their wheat, rice, and sorghum crops. It is hoped that custom machinery companies will come into being soon to perform this service for small farmers on a fee basis.

As crop yields jump, a revolution in farm mechanization will automatically occur if the foreign exchange difficulties do not hinder this development. With an abundance of food and feed grains, part of the areas now in cereals can be shifted to forage crops. Straw will become less valuable. Simultaneously there will be a rush to abandon hand sickle harvesting in favor of the combine, just as occurred in the densely populated Bajio region of Mexico fifteen years ago.

At the wheat seminar in Lyallpur, Pakistan, Dr. S. A. Qureshi discusses with delegates from 17 Near and Middle East countries the methods used to obtain rapid yield increases. Here they observe experimental lines being developed by Pakistani scientists.

The seed of new varieties must be increased rapidly to keep the pace with demand. These are multiplication plots of Mexipak 65 on the farm of Mr. Bashir Ahmed, near Shaikhupara, West Pakistan. On this 125 acre farm, an average yield of 5.3 ton/ha was obtained last year, using a spacing of 60 cm between rows.

Pakistan and India have intensive breeding programs based on crossing local materials with germ plasm provided by CIMMYT and other institutions. Photo taken at the Ludhiana Experimenta Station, Punjab, India.

Support of Floor Price for Wheat

Although the announced floor prices were maintained fairly well by timely government purchases during the current harvest, there were some local areas where prices slumped below the announced floor level. Panic was averted, but the market was wobbly. If market disorders are to be circumvented next year, the government Food Department must organize its purchasing system more efficiently and have established more adequate lines of credit well before harvest.

Varietal Improvement

The Mexican derived dwarf varieties Penjamo 62, Lerma Rojo 64, Indus 66 and Mexipak 65 were grown on 3 million acres during the 1967-68 cycle. All performed well, but yields of Indus 66 and Mexipak were outstanding. There will be a large increase in the area sown to Mexipak 65 and Indus 66 during the forthcoming season. Both are high yielding; Mexipak is preferred because it has white grain, considered to be more desirable for chapattis.

It is known that Mexipak 65 and Indus 66 are susceptible to certain races of leaf rust and one race of stem rust which are present but not prevalent in Pakistan. The anticipated shift toward these varieties by Pakistani farmers indicates the urgency to multiply and distribute other varieties combining better grain quality, different types of rust resistance and high yield potential.

The research program in widespread micro trials during the past season has established the superiority of three new varieties. They will be increased as rapidly as possible. These varieties are:

1. Mangla 68. A white grain type developed by the Pakistan breeding program from the cross (BK8-6 x 3958).
2. Norteño 67. A white grain type developed in Mexico from cross (19008) Lerma Rojo 64 x Sonora 64.

3. INIA 66. A red grain type developed in Mexico as a sister selection of Norteño 67.

The widespread cultivation of these three varieties will diversify the resistance to rusts and reduce the rust hazards. However, it will take two to three years to multiply adequate quantities of seed.

The rust resistance of Mexipak 65, Indus 66, Penjamo 62 and Lerma Rojo 64 will be adequate for the 1968-69 season. Should shifts in rust races threaten during 1968-69 it would be possible to provide protection by imports of Norteño 67 and INIA 66 from Mexico for 1969-70, should this seem desirable, since both varieties are now extensively grown. Such expenditures for imported seed may be excellent investments when necessary. It is estimated that the entire expenditures for seed imported into Pakistan during the past 3 years has been 6.5 million U.S. dollars. This investment increased production during the current crop (1967-68) by 1,700,000 tons with a value of 170 million dollars. These benefits do not include increased income derived during the 1966-67 crop.

The breeding program in Pakistan is broad and dynamic and will provide new varieties as needed. It is also backed up by superior genetic materials which are fed into the Pakistan program semi-annually from the CIMMYT. In the past, lack of adequate summer nursery facilities has reduced the efficiency of the breeding program and slowed the multiplication of new varieties. The government has now committed itself to correcting this deficiency and is searching for an adequate site in the Kalam and Kagan valleys.

Agronomic and Soils Research

The agronomic and soils research programs are still weak. It will take time to correct these shortcomings, since there is a great shortage of trained scientists in these disciplines.

Extension Program

The extension program is improving. It is estimated that the Mexican dwarf wheats were grown on 3 million acres during 1967-68; nevertheless, the intensive management practices were only applied on about 70 percent of this area.

An in-service training program, similar to the one being used successfully by the International Rice Research Institute, is being organized by the Ford Foundation and Pakistan government to correct this weakness.

Effect of Breakthrough in Wheat Production on Other Crops

The breakthrough in wheat production is having a stimulative effect on other cereal crops. Last year there were 10,000 acres grown to the high yielding IRR18 rice (IRRI-Pak). This year there will be 1 million acres. Last year there were 300,000 acres grown to J-1 synthetic maize. This year the acreage will increase to 700,000 acres. It is quite possible that Pakistan will become self-sufficient in all cereal grains during the current kharif (summer) season.

The revolution under way in cereal grain production has had a negative effect, however, on cotton production. Double cropping of wheat and rice, or wheat with maize or sorghum, will drive cotton out of production in many areas. This trend cannot be reversed until research and sanitation programs develop satisfactory insect control measures for cotton. Farmers will not invest in fertilizer for cotton until they can protect their crop. Varieties which respond to improved cultural practices are urgently needed.

Mr. Haldore Hanson, Ford Foundation representative and one of the organizers of the Accelerated Wheat Program in Pakistan, was presented with a golden wheat head by Mr. Mohammed Musa, Governor of West Pakistan, on behalf of the Pakistani wheat scientists. Witnesses of the ceremony were Mr. Malik Khuda Bakhsh, Minister of Food and Agriculture (left), and Dr. Norman E. Borlaug (center), Director of the CIMMYT Wheat Program.

From animal power to mechanization. The wheat revolution is bringing changes in the kind of power used to prepare the land. Farmers know that irrigation water can be applied more uniformly when the land has been leveled. They do it with oxen—and more recently with a modern leveler such as this one in use near Tandojam in the southern part of West Pakistan.

A tractor plows deep in preparation for wheat plantings near Tandojam. A camel turns the wheel to raise water for wheat irrigation, a common source of power in India and Pakistan. Thousands of new tube wells are beginning to replace animal power, but the old and the new work together to raise wheat production in India and Pakistan.

INDIA

India's wheat deficit was much greater than that of Pakistan. India has not yet attained self-sufficiency, despite the large 1968 harvest. Nevertheless, as already indicated, the progress has been every bit as impressive as that achieved by Pakistan.

It is estimated that there were approximately 6 million acres sown to dwarf varieties under intensive management during the 1967-68 season. This, altrough only about 18 percent of the total area, will produce about 40 percent of the harvest.

Although tremendous progress has been made by India in solving its wheat deficit, much remains to be done. It must now rapidly convert the entire irrigated wheat acreage to intensively managed dwarf wheats. It must also develop its underground water resources and expand its irrigated areas. Many thousands of tube wells must be sunk as rapidly as possible. Soil moisture must be conserved and utilized efficiently on the barani (rainfed) areas which constitute two-thirds of the crop land in wheat.

India has encountered all of the problems indicated earlier for Pakistan and in addition a few others. Despite these difficulties its accelerated production program is well ahead of schedule.

Storage and Transport

Storage facilities have been hopelessly inadequate to store the immense harvest. The lack of storage space has been particularly acute in the main centers of production where market gluts have developed because of shortage of trucks and railroad freight cars, resulting in slow movement of wheat to the centers of consumption.

Currently, all warehouses, elevators and available buildings in the main producing areas are jammed. School rooms were used during vacation for temporary storage. Temporary open-air storage topped with canvas and plastic covers was improvised. Despite a herculean effort by all to get the crop under cover, some will be lost. These events indicate clearly the job that must be done to expand warehouse and transport capacity to meet the needs for an awakening and rapidly changing agriculture.

Price Supports

Despite the many difficulties with storage and transport, the state and central governments have done a commendable job of sustaining the floor support price. The appearance in the market of discolored grain (black point caused by saprophytic fungi) resulting from repeated rains during harvest was used by some merchants to drive down prices and provoke temporary panic. However, the market responded to official buying at floor price levels. The red grain Mexican varieties generally brought from 10 to 15 percent less on the free retail markets than the best white grain Indian types.

The abundance of wheat has driven down the retail price from the levels formerly set at the government fair price food stores in the larger cities.

Fertilizers

The demand for fertilizer continues to expand rapidly. During the 1967-68 season India used 1.3 million tons of nitrogen. Consumption has been increasing at 300,000 tons of nitrogen (N) per year, and in all probability will jump again soon. India is now spending 250 million dollars a year in foreign exchange for the importation of fertilizer. It is also expanding fertilizer production capacity as rapidly as possible. By 1971-72, plants call for production of 2 million tons of nitrogen (N), which is estimated to be adequate for self-sufficiency. However, this is doubtful, since demands for fertilizer will climb more rapidly as the full impact of the breakthroughs are felt in wheat, rice, sorghum, maize and millet production.

India must increase food grain production by 4.5 million tons annually to meet its targetted needs. Its ability to expand food production fast enough to cope with population growth and increased per capita consumption, depends heavily on expanded fertilizer production.

During the past year the government has done a commendable job of satisfying the growing needs, and distribution has functioned well.

Hand sickle harvesting becomes a much bigger job in India and Pakistan with the greater production of well-fertilized new varieties. A program has been initiated to demonstrate mechanized harvesting.

The Indian wheat program has a series of new lines in final stages of testing. The aim is to provide varieties which have a diversified base against rust attacks as well as the amber-colored grain preferred by local consumers. These plots are at the Ludhiana Experiment Station, Punjab.

Varietal Performance and Varietal Development

The introduced Mexican dwarf varieties as well as Indian varieties developed by re-selected from introduced Mexican materials performed well during the past season. In general these dwarfs substantially outyielded the Indian varieties they are replacing while showing better resistance to both stem and leaf rust.

The red grain varieties such as Lerma Rojo 64, PV18 and Sonora 64 generally sold at from 10 to 15 percent below the price of the white grain varieties. This will mean a shift to the white grain dwarfs as fast as seed is available. PV18 (red grained 8156) will, however, continue to increase in area because of high yield until there is ample seed of white grain types.

The shift to white grain types is fast becoming feasible because of the vigorous selection and multiplication program that has been carried on by the All Indian Wheat Improvement Program. During the past season (1967-68) the following materials were in semi-commercial multiplication:

S-227 (unselected 8156 white grain) ; 15,000 acres.

Kalyansona (improved 8156 white grain); 20,000 acres.

Sonalika [(1153-388 x Andes) Pitic sib]; white grain, formerly known as S-308; 12,000 acres.

Safed Lerma [(Yaqui 50 x Norin 10-Brevor) Lerma 52] Lerma Rojo^3; white grain; 12,000 acres.

S-331 (Lerma Rojo 64 sib x Huamantla Rojo); white grain; 600 acres.

Triple dwarfs — the next step to increase yields. Dr. W. L. Mc Cuistion demonstrates the difference in lodging between the two gene dwarf Sharbati Sonora (right) and the triple dwarf on the left, at the Indian Agricultural Research Institute, New Delhi.

One of the promising new triple dwarfs obtained by usinq the genes Norin 10, Olesen and Tom Thumb, as sources of dwarfness. These wheats have shorter, stronger straw and resist heavy applications of nitrogen.

Sharbati Sonora developed as a mutation from Sonora 64; white grain; 400 acres.

The aforementioned multiplication probably has provided about 2.5 million bushels of seed for the 1968-69 cycle. The appearance of these new varieties in large-scale production will now begin to provide more diversified resistance to rusts, in the event of shifts in rust races.

In the All Indian Coordinated Breeding Program, a large number of new lines are in final stages of testing. A number of lines from the cross Lerma Rojo 64 x Sonora 64 show outstanding promise.

The double dwarf varieties Sonora 64, Sharbati Sonora, Kalyansona, S-331, and PV18 have straw that is much shorter than the tall Indian varieties or than the semi-dwarf variety Lerma Rojo 64. Nevertheless, the most progressive Indian farmers are now fertilizing heavily and lodging is again becoming a problem even with the double dwarfs. Even shorter varieties —triple dwarfs— are needed.

Several very promising triple dwarf types with good grain have been identified during the past year at stations in India. This promises to be another potential breakthrough which may lift wheat yields to a new plateau. The farmers' interest runs high in this new development. Illegitimate, non-recommended, triple dwarf wheat varieties are selling for $135 (dollars) per kilo on the black market.

Agronomic Research

The agronomic research being done on irrigated wheat under the All Indian Coordinated Wheat Program is the finest being done anywhere in the world. It has laid the basis for sound recommendations for proper fertilization, irrigation, and rates, dates and depths of planting. As a result Indian wheat farmers follow to a high degree the recommendations as laid down by the researchers. For example, no difficulty has been encountered in convincing Indian farmers to use phosphate (as well as nitrogen) on wheat.

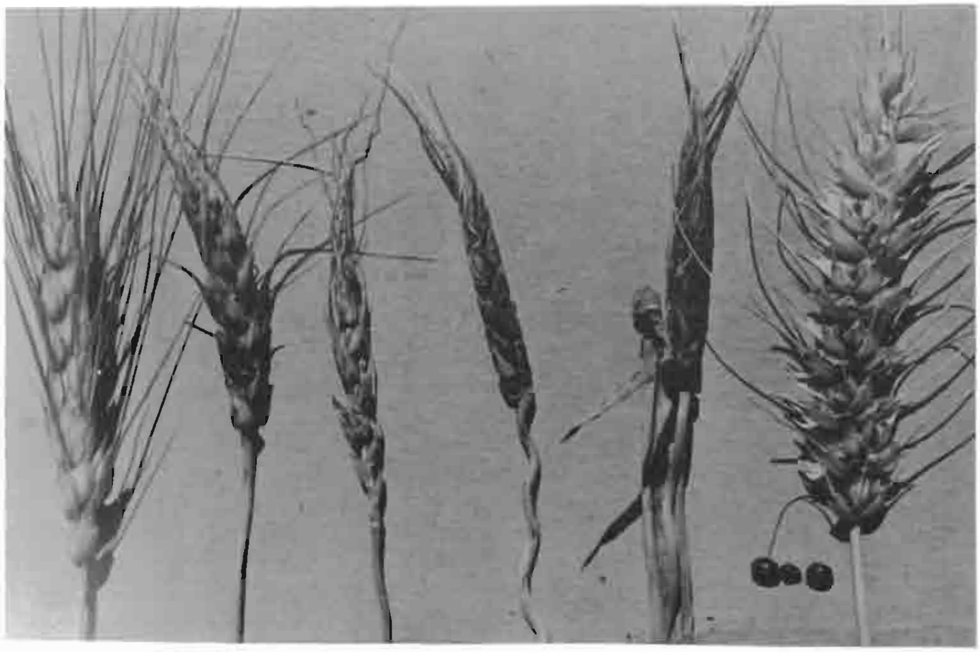
As wheat cultivation is intensified, new problems arise. This dusting at the Ludhiana Agricultural Experiment Station is to control the armyworm.

Indian technicians saw research in the field as part of a seminar at the Ludhiana Experiment Station in Punjab. This station is one of the main wheat research centers in India.

During the past season Indian agronomists began research to develop the best practices for growing triple dwarf varieties. This is research which is absolutely necessary if triple dwarfs are to be exploited commercially. The cultural practices currently used on semi-dwarfs and double dwarfs are not adequate for triple dwarfs.

In the future Indian agronomists will also need to conduct extensive research to develop the best agronomic practices for barani (rainfed) wheat production, which constitutes nearly two-thirds of the area sown to wheat. Although the principles developed for efficient utilization of moisture in the low rainfall areas of the state of

Members of the Indian Parliament have shown their interest in wheat research by visiting the experimental fields. Here Dr. M. S. Swaminathan, Director of the Indian Agricultural Research Institute, explains the work under way.



Tundu and ear cockle attack on wheat in India. Tundu is a disease compounded of the attack of the nematode Anguina tritici and the bacterium Corynebacterium tritici. Ear cockle is the result of Anguina tritici alone. On the left is a healthy head; the next four heads exhibit different symptoms of Tundu in which no seeds are produced. To the right is a head in which the seed have been replaced by black ear cockles, shown below, filled with nematodes.

Washington (U.S.A.) are perhaps valid in India, they cannot be exploited currently because of lack of adequate bullock-powered machinery.

Pathology Research

Until recently the pathology research has been oriented principally toward theoretical ends, rather than application. During the past year there has been a shift in emphasis, to assure a closer collaboration between plant pathologists, breeders and agronomists.

Experiments conducted during the past season have shown that the chemical seed disinfectant "Vitavax" (U.S. Rubber Co.), provides nearly complete protection against loose smut of wheat, a disease that is common on all susceptible varieties under Indian conditions.

TURKEY

There were somewhere between 600,000 to 800,000 acres grown to Mexican dwarf varieties at lower elevations in Turkey during 1967-68 crop season. Virtually the entire area was well fertilized and rainfall was favorable. In a few areas unusually low winter temperatures damaged the seedlings, but most of the damaged fields recovered satisfactorily and reports indicate a good harvest.

Turkey has built its spring wheat production campaign around a diverse number of Mexican varieties and, on the basis of performance in commercial plantings, will this year select those best suited to local needs. The varieties being grown include Penjamo 62, Pitic 62, Lerma Rojo 64, Sonora 63, Sonora 64, Mayo 64, Super X, Siete Cerros, INIA 66, Tobari 66, and Noroeste 66.

During the past two years the Turkish production program has been pushed aggressively through the joint effort of the Turkish government and USAID. During the past year Dr. Orville Vogel of Washington State and Dr. Tom Jackson and Dr. Warren Kronstad of Oregon State have provided part time guidance to the production effort through a USAID contract. Several experienced wheat extension agronomists from the Oregon State extension service have also played active roles in accelerating the program.

On the colder, drier Anatolian Plateau the dry land techniques of wheat production used so effectively in Washington and Oregon also are being successfully introduced by the aforementioned scientists. High yielding winter varieties such as Burt, Brevor, Gaines, Warrior, Gage and Lancer are being evaluated on a semi-commercial basis. A breakthrough in winter wheat production on the Anatolian Plateau will have value in similar ecological zones of Iran and Afghanistan.

AFGHANISTAN

More than 65,000 acres of Mexican dwarf wheats were grown during the 1967-68 season. Harvest is not yet completed but preliminary reports indicate very good results. Although the Mexican dwarf spring wheats and management methods fit the lower elevation very well, Afghanistan will also need to launch a program for the improvement of winter wheat production in the colder, drier, high elevations. Such a program can best be patterned after the program now underway on the Anatolian highlands of Turkey.

TUNISIA

An accelerated program to expand wheat production was launched during 1967-68. Approximately 1500 acres of Mexican dwarfs were grown with good results. The varieties INIA 66, Tobari 66, and Jaral 66 were most satisfactory in commercial plantings. Experimental plantings of Siete Cerros and Norteño 67 also showed good promise. Tunisia hopes to expand the area sown to Mexican varieties to 35,000 acres during 1968-69.

MOROCCO

About 500 acres of Siete Cerros, INIA and Tobari were grown with good success during the past season (1967-68). The area will be expanded to 10,000 acres during 1968-69.

Most of the area devoted to wheat culture in both Tunisia and Morocco is rainfed. There is need for strengthening the agronomic research and production practices to maximize the efficiency of moisture utilization. The research on varietal improvement, agronomy, entomology and pathology of wheat, all need strengthening. Arrangements are now being finalized to station two CIMMYT staff members in these countries. This work will be financed through a USAID grant to CIMMYT.

ARGENTINA

Approximately 350 advanced lines from the coordinated INTA (Instituto Nacional de Tecnología Agropecuaria) breeding program were evaluated in regional yield tests. Record-breaking rainfall in the period from heading to ripening (385 mm in 34 days) reduced the reliability of these tests. Nevertheless, 150 of the experimental lines outyielded the highest yielding commercial variety, Klein Atlas.

Four crosses were outstanding under these adverse conditions. These were:

Sonora 64A x Klein Rendidor cross II 19975 (36 lines).

Sonora 64A x (Tezanos Pintos Precoz x Nainari 60) cross II 18889 (26 lines).

Sonora 64A x Knott^2 cross II 18893 (12 lines)

Sonora 64A x (Selkirk 6_E x Lerma Rojo 64) cross II 18900 (7 lines).

Many of these lines which were high yielding during the 1967 season of excessive rain, were also the best yielders under the extreme drought conditions of 1966. Unfortunately the excess rain

Through the cooperative programs, new wheats are tested in the Andean region. This yield trial, being harvested at La Molina near Lima, Peru, includes outstanding wheats from many countriesh.

Differential lodging of varieties in the International Spring Wheat Yield Nursery at La Molina, Peru. Through a CIMMYT coordinated project, new short-strawed materials resistant to lodging are tested in the Andean region.

during the 1967 season made it impossible to obtain satisfactory grain samples for milling and baking evaluations. Consequently it will not be possible to identify those lines with the best industrial quality until the 1968 harvest.

There is now ample evidence that many of the lines —especially those from the cross Sonora 64A x Klein Rendidor II 19975— are high yielding under a wide range of conditions. During the past three years they have consistently outyielded all of the important commercial Argentine varieties under widely varying conditions. Moreover, they respond well to the use of chemical fertilizer, are resistant to lodging and possess good rust resistance. Several of these lines have also yielded well under irrigated conditions in Mexico.

It is becoming increasingly clear that nitrogen fertilization will produce yield response in many areas of Argentina. However, the acceptance of fertilization as a sound commercial practice on farms is being delayed by the unfavorable price ratio between nitrogen price and grain price. The ratio in Argentina is 9.3 to 1 versus 2.4 to 1 in the U.S.A. Fertilizer use will not increase rapidly until this unfavorable price ratio is corrected.

During the next year the research work on the agronomic aspects of wheat production will be expanded.

OTHER COUNTRIES

Six other Asian and African countries and three South American countries have requested technical assistance from CIMMYT. The number of qualified CIMMYT staff currently limits the degree of assistance that can be extended.

MEXICO: JOINT INIA-CIMMYT RESEARCH

Agronomic Research

The past season (1967-68) was the most unfavorable for wheat production in southern Sonora and Sinaloa since the dwarfs were released in 1961. Yields were consistently low in both the commercial crops and experimental plantings. The national average yield dropped several hundred kilos per hectare because of poor yields in the aforementioned areas, even though good yields were obtained elsewhere in the Republic.

The best farmers, who harvested 4.5 to 6 tons per hectare on large areas in 1967, harvested only 3 to 4.5 tons in 1968. In 1967 experimental yield tests at CIANO of the best check varieties, INIA 66 and Penjamo 62, ranged from 6.5 to 8 tons per hectare depending upon date of sowing and fertilization. This year they ranged from 4.5 to 6 tons per hectare. Similarly other disease resistant varieties such as CIANO 67, Noroeste 66 and Tobari 66, yielded 25 to 35 percent less than last year. Despite their low average yields, the varieties which have exhibited broad adaptation in the past in the International Yield Nursery — Pitic 62, Penjamo 62, INIA and 8156— again tended to outyield all other varieties. What contributed to the relatively low yields in 1968?

In the commercial crop of southern Sonora, adverse climatic conditions, especially at planting, adversely affected yields. Many farmers obtained poor stands of seedlings because of flooding by rains which occurred when the seed was germinating, but before the seedlings had emerged. Poor stands of seedlings and severe weed infestation resulted. Many of these fields should have been disked and replanted. This was generally not done.

Other farmers who did obtain good stands handled subsequent irrigations unwisely and suffered yield reductions. Rains occurred during December, January, February and March, and although the total precipitation was less than 150 mm, it confused most farmers, who are not used to having rain during the wheat cycle. Many discontinued irrigation for a month following a light rain, believing that the rain was the equiv-

Trainees along with staff members of INIA and CIMMYT compare the relative merits of advanced lines of T. durum. These lines are user for crosses with rye in the formation of Trlticales because they are more fertile than the bread wheats. Work is under way simultaneously to develop better durum varieties.

alent of an irrigation, which practically never was the case. The result was that many of the plantings suffered from drought effects before the next irrigation was applied, at one period or another. Nevertheless, even in irrigation experiments where some soil moisture treatments were kept at or near the optimum throughout the crop cycle, yields were 20 to 30 percent lower than anticipated.

Severe winds and rain when the wheat was being irrigated at the time of heading contributed to widespread lodging, something that had not occurred for the past 6 years.

A few farmers also suffered yield reductions as the result of planting non-recommended varieties that became seriously infected with leaf or stem rust, especially when planted late. Yet, disease was not the primary factor in reducing yield on the vast majority of the farms. Neither was it a problem in the experimental plantings since Sonora 64, which is susceptible to leaf rust and developed moderately severe infection late in the season, was consistently the second highest yielding variety, outyielded only by INIA 66. Tobari 66, a variety highly resistant to all three of the rusts, yielded about 33 percent less than last year.

It is known that the minimum temperatures, especially during January and February, were significantly higher than in ordinary years. It is also known that the number of cloudy days during December, January, February and March was much greater than in most years, yet no measurements were made.

It is becoming increasingly apparent that we need to develop more basic information concerning the interaction of all factors that influence yield. Recognizing the aforementioned weakness, CIMMYT plans to add a physiologist and a soil scientist to its staff to work on these and other interdisciplinary factors affecting wheat yields.

Performance of Commercial Varieties

The varieties INIA 66, Noroeste 66, Tobari 66, Siete Cerros, Super X, Jaral 66, Penjamo 62, and Lerma Rojo 64 represented most of the commercial area sown to wheat in Mexico in 1967-68. The latter two varieties are now being rapidly replaced by the newer varieties. INIA 66 appears to be the highest yielding, and most widely adapted of the new varieties. The varieties CIANO 67, Azteca 67, and Norteño 67 were grown on a commercial basis for the first time during the past season with good success.

In all probability INIA 66, Noroeste 66, and CIANO 67 will become the principal commercial varieties for the next several years. They are consistently good yielders and have very good milling and baking characteristics. Tobari 66 will become popular in areas of high rust hazard, since it is highly resistant to all three rusts. However, it consistently yields less than INIA 66, Noroeste 66 and CIANO 67.

The other aspect of the wheat revolution underway in Mexico in the past few years is quality. It should be emphasized that the baking quality of the commercial varieties INIA 66, CIANO 67, Noroeste 66, and Azteca 67 is the full equivalent of the best hard red spring wheat varieties of Canada or the U.S.A. when they are grown under conditions that produce grain of similar protein levels.

Promising Advanced Generation Lines

The most promising advanced generation crosses, based on disease resistance, preliminary yield performance, grain quality and gluten strength during the past wheat cycle were:

[CIANO x (Sonora 64-Klein Rendidor) 8156] cross II 23584 (75 lines).

(CIANO x Sonora 64) cross II 23582 (53 lines).

(CIANO x Chris) cross II 23583 (21 lines).

(CIANO x INIA "S") cross II 23959 (11 lines).

(INIA x Napo) cross II 22392 (9 lines).

The cross II 23584 is particularly promising for there are many superior, diverse types represented in the 75 lines. Many of these have phenotypes similar to Super X and Siete Cerros. Among these particularly promising lines are several triple dwarfs, some with good red grain and others with good white grain. All are superior in disease resistance to 8156.

Many of the lines from cross II 23582 are very similar to Sonora 64 in phenotype. However, they possess far superior resistance to all three rusts, and have very good milling and baking quality.

Lines from II 23582, and II 23584 are also showing outstanding promise in both Pakistan and India.

Most Promising Early Generation Lines

The most promising early generation lines based on phenotype, disease resistance, grain and gluten quality are shown in Tables W3 and W4.

More Dwarfness in Commercial Varieties

For the past six years unsuccessful attempts have been made to develop high yielding triple dwarf varieties. All lines in the triple dwarf height class have had inferior grain. Without exception the grain has been partially shriveled, of low test weight and with weak gluten. Nevertheless, in the CIMMYT conventional breeding program, as well as in the hybrid program, research has been continued toward developing a high yielding

Sterile wheat plants are bagged to prevent undesirable pollination as part of the breeding program with hybrid wheats at CIANO.

TABLE W3. The best F_2 population identified at CIANO, Ciudad Obregon, Sonora, Mexico in 1967-68.

Pedigree	Cross No.	No. of F_2 plans selected	No. of selections replanted in Toluca in summer 1968*
(CIANO x 8156 (B) [CIANO (Sonora 64-Kl. Rendidor x 8156)]	II 25876	40	31
(CIANO x Jaral) [CIANO (Sonora 64-Kl. Rendidor x 8156)]	II 25913	35	31
(CIANO x Siete Cerros) (Tobari x Sonora 64-Kl. Rendidor)	II 26252	50	26
(Yaqui 50-CIANO x Olesen) (Centrifen x 8156 (B)	II 26397	116	33
INIA 66 x CIANO "S"	II 26475	96	61
INIA 66 x (Sonora 64 x Penjamo)	II 26476	71	43
INIA 66 x [F_3 CIANO x (Sonora 64-Kl. Rendidor x 8156)]	II 26478	114	93
Noroeste 66 [F_3 CIANO x (Sonora 64-Kl. Rendidor x 8156)]	II 26480	80	49
$CIANO^2$ x Chris	II 26520	53	31
[(Sonora 64-Kl. Rendidor x 8156)] INIA 66	II 26531	62	34
(F_3 CIANO x Chris) [F_3 CIANO (Sonora 64-Kl. Rendidor x 8156)]	II 26558	82	28
[F_3 CIANO x (Sonora 64-Kl. Rendidor x 8156)] CIANO	II 26572	122	69
(Pitic x T. Thumb-Sonora 64) $CIANO^2$	II 26745	94	27

* Number of lines surviving laboratory screening test for grain characteristics and gluten quality tests.

triple dwarf type. This becomes absolutely necessary at the present time, for the best farmers in Mexico, Pakistan and India have learned the value of using extremely high rates of fertilization. Such applications become economically feasible only if lodging can be avoided. However, when more than 120 to 140 kilos of nitrogen per hectare are applied to the commercially available varieties such as 8156 and Sonora 64, there is likely to be severe lodging at the time of the last irrigation when the grain is filling, with a depression in grain yield.

TABLE W4. The outstanding F_3 families* identified in the CIANO nursery, Ciudad Obregon, Sonora, Mexico, during 1967-68.

Pedigree	Cross No.
CIANO "S" x Tobari 66	II 25079
CIANO "S" x Penjamo 62	II 25093
CIANO x Noroeste 66	II 25011
CIANO x Lerma Rojo 64	II 25329
[(Lerma Rojo 64 x Sonora 64) Napo 63] [(Tezanos Pintos Precoz-Sonora 64) x (Lerma Rojo 64A x Tezanos Pintos Precoz-Andes E)]	II 25477
(Lerma Rojo 64-Sonora x Napo 63) x Ciano "Sib"	II 25483

* Only the crosses are indicated rather than the families involved.

During the past four years, the CIMMYT program has tried to overcome this problem by searching for other sources of dwarfness that might be used effectively in the breeding program. In addition to the Norin 10 genes, the so called "Olesen dwarfing" from Rhodesia, and "Tom Thumb" dwarfing have been used both separately and in combinations with one another. All three sources of dwarfing produce "triple dwarf" types.

The Olesen dwarf types produce a high percentage of segregates with excellent phenotype and good disease resistance but most have chlorophyl defects, shriveled grain and bucky gluten. The Tom Thumb derivatives produce segregates of extremely short stature and good phenotype, but most are extremely susceptible to rusts and very late in maturity. All have shriveled grain with weak gluten.

By continuing to select and recross between triple dwarf Norin 10 derivatives, considerable progress has been made within the past two years in India, Pakistan and Mexico. Triple dwarfs have been identified that show extreme promise. They tiller profusely and have heads with many of the spikelets producing 4 to 6 fertile florets under favorable conditions. Many lines with good rust resistance have been found. Some of these plump grain with good test weight as well as good gluten strength. Little is currently known about their yield potential because of lack of knowledge on how best to cultivate them.

It will be necessary to carry out a whole series of agronomic trials to determine the yield potential of these new types, since the sowing methods —density, spacing, fertilization, irrigation— currently in use with semi-dwarfs and double dwarfs are certainly inappropriate for these new types. This work is already underway in India and will be initiated in both Mexico and Pakistan in the 1968-69 cycle.

It has become evident that the greatest contributing factor to improvement of triple dwarfs is the cooperation between the breeding programs in Mexico, India, Argentina and Pakistan. This ap-

These odd looking wheat plants are being used to incorporate disease resistance into advanced lines. Here Dr. Bill Roberts make crosses between hexaploid bread wheat species at CIANO.

proach permits the evaluation of large numbers of segregating individuals in many populations. As a result, lines have now been isolated which show definite promise of being able to raise yields to a higher plateau, once the agronomic research has been done which will determine how to permit their most efficient utilization.

Although a number of different crosses have produced promising triple dwarf lines, perhaps the best at present have been isolated from the cross II 23584 [CIANO x (Sonora 64-Klein Rendidor) x 8156 (W)]. Superior triple dwarf types with either red or white grain have been isolated.

Large numbers of promising triple dwarfs will be evaluated in yield trials in the 1968-69 season.

Improvement in Milling and Baking Quality

The original spring habit, Mexican, semi-dwarf wheat varieties Penjamo 62 and Pitic 62, had definite defects from an industrial standpoint, despite their high yield. Pitic 62 had low grain test weight and weak gluten. Penjamo 62, although possessing grain of high test weight and good milling characteristics had weak gluten and poor bread making characteristics.

The Milling and Baking Laboratory of the Mexican program was not installed until 1958. It took several years more to train a staff. By 1964 a technique had been worked out for early generation screening. The method involves the use of the micro-Pelshenke (whole wheat fermentation) test on an individual plant basis in the F_2, F_3, and F_4 generations. It also involves the use of alveographs and mixographs in the F_3 and F_4 generations to identify lines that show promise for baking quality. The Pelshenke value, mixograph score, and alveograph P/g and W values are also determined for all parental varieties and high yielding lines. These indexes of quality are used as a guide for planning future crosses. Special emphasis is given to the P/g and W values of the alveogram.

Since this method has been evolved and used, the quality of the wheat varieties emerging from the Mexican breeding program has improved markedly. Varieties such as CIANO 67, INIA 66, Azteca 67, Noroeste 66, are fully as good in milling and baking quality as the better spring wheat varieties of Canada and the U.S.A., when they are grown under conditions that produce grain with adequate levels of protein. The Mexican milling and baking industry now states that they have available for the first time strong wheats with excellent milling quality.

The white grained variety, Norteño 67, a soft white spring wheat, is also a substantial improvement quality-wise over Lerma Rojo 64.

Within the next two years one or more varieties of high yielding, hard, white spring wheats will be released. Several outstanding lines representing a number of different crosses have already been identified. These are superior in preliminary tests, both yield-wise and quality-wise to the better Australian white spring wheat varieties. Some will undoubtedly find widespread use in the vast area from Morocco to India, where white grained, strong gluten types are preferred.

The program also plans to continue developing high yielding, soft (weak gluten) red and white grained varieties.

There is no longer any doubt about the effectiveness of the methods used in the Mexican program in breeding for combined yield, industrial quality and disease resistance. Progress can be made simultaneously on all three fronts with the techniques now in use. This is a point of view that has not been accepted by cereal chemists, plant pathologists and plant breeders in the past.

Improvement in Protein Quality and Protein Level

The discovery of the opaque-2 and floury-2 genes on the lysine level and nutritional value of corn has had profound repercussion on research on other cereals. For the past year and a half the University of Nebraska, in collaboration with the U.S. Department of Agriculture and under a USAID contract has been surveying the U.S.D.A. World Wheat Collection, searching for varieties with high lysine levels. Three years ago Dr. Evangelina Villegas of CIMMYT's technical staff, while at North Dakota State University, also studied and found differences in a considerable number of wheats, ryes and Triticales from the standpoint of lysine levels.

CIMMYT scientists and trainees from 11 countries take part in a field seminar at CIANO. So far, over 62 technicians, mainly from the Near and Middle East, have received training in Mexico in techniques of wheat production.

Considerable variability in lysine content has been found by the Nebraska team. The varieties with high levels of lysine have been crossed at Nebraska with the high yielding, broadly-adapted Mexican spring wheat semi-dwarfs. Double crosses also have been made with lines or varieties carrying the Atlas 66 and other genes for high protein level. Currently a considerable number of F_1's from the aforementioned crosses made at Nebraska and others made by CIMMYT in Sonora, are growing in Chapingo, Mexico. Segregating populations from these crosses will be grown in Sonora during 1968-69. This entire program is a cooperative effort between the University of Nebraska, the U.S. Department of Agriculture and CIMMYT.

A chemical test, specific for lysine, is being developed in the CIMMYT Protein Laboratory.

This test, although still imperfect, shows promise of being useful for screening segregating populations for lysine. There is reason to hope that this method, when used in combination with a rapid test for total protein, will identify segregates combining high protein level and high lysine. The amino acid analyzer will be used to check the lysine content of lines showing promise in the screening test.

The development of varieties with high protein levels and high lysine content will have particular significance for the developing countries from Morocco to India, where wheat represents the most important source of protein in the diets of hundred of millions of people.

Spring-Winter Varietal Breeding Program

In certain areas of the world the climatic patterns favor the use of facultative or semi-winter varieties. Included in such areas are southern Chile, Argentina, and the highlands of Turkey, Afghanistan and Iran.

Dr. J. A. Rupert of the CIMMYT staff is being transferred to California where he will develop an intensive breeding program to cross superior spring and winter varieties. The program will be carried out cooperatively with the University of California, Washington State University, CIMMYT and the aforementioned countries.

In addition to developing varieties of intermediate habit, adapted to these more severe climates, it is highly probable that spring habit segregates will be isolated with higher yield potential than those currently available in the spring habit varieties of the world.

Hybrid Wheat Research

1. Yield of Experimental Hybrids with *T. timopheevi* Cytoplasm

In previous years all of the CIMMYT studies on heterosis in wheat have been conducted with F_1 hybrids made by hand pollination, in the absence of sterile cytoplasm.

However, during the 1967-68 crop season, 9 experimental F_1 hybrids and two F_2 hybrids, with cytoplasm of ***Triticum timopheevi*** were evaluated in replicated yield trials at CIANO. The seed of these F_1 hybrids was produced in CIANO during the 1966-67 winter season. The seed of the two F_2 hybrids that were studied —1A (F_2) and 2A (F_2)— were harvested from F_1 hybrids grown at Chapingo during the summer of 1967.

The F_1 hybrid seed of each of the aforementioned hybrids was produced in isolated crossing blocks, employing sterile lines containing *T. timopheevi* cytoplasm. Six different restorer lines were involved in these hybrids. It was known when these crosses were made in 1966-67, that none of the restorer lines were completely homozygous for restoration, based on their performance in previous test crosses. Nevertheless, all of the F_1 hybrids except one showed heterotic increases in grain yield, ranging from 3.8 to 15.6% above that of the highest yielding parent entering the hybrid. Most hybrids showed yield increases of 11 to 12 percent above that of the highest yielding parent, despite partial sterility (Table W5).

The restorer lines used in producing hybrids —V-102, V-107 and V-122— have been reselected twice during the past year. They now appear to

The wheat training program includes practical experience in all steps of the breeding sequence from planting to harvest. Here the trainees are threshing and packing the spring wheat yield trials at CIANO.

TABLE W5. Grain yields of nine F_1 hybrids and two F_2 hybrids containing. *T. timopheevi* cytoplasm when grown in replicated yield trials at CIANO during the 1967-68 crop season.

Hybrid variety No.	Hybrid pedigree	Fertility based on Anthers	Fertility based on Grain	Grain yield Kg/ha	Female parent (without cytoplasm) ♀	Grain yield Kg/ha	Restorer pollen parent ♂	Grain yield Kg/ha	Grain yield of hybrid as % ± of highest yielding parent
V-122	[(30009 (3) x T. tim²) x Pj62²] x LR64A E⁵	***	***	6,808	LR64A	5,983	[(3009 (3) x T. tim²) x Pj62²]	2,850	+ 11.4
V-116	(Wn 1001 x Pj62) x LR64A E⁵	**	**	6,641	LR64A	5,983	(Wn 1001 x Pj62)	3,266	+ 11.0
V-102	[(Wn 1001 x Nad 63) (LR64 x Son 64)] LR64A E⁵	***	***	6,209	LR64A	5,983	[(Wn 1001 x Nad 63) (LR64 x Son 64)]	3,350	+ 3.8
V-110	[(3009 (3) x T. tim²) x Pj 62] Son 64 E⁶	**	**	5,758	Sonora 64	4,641	(3009 (3) x T. tim²) x Pj 62	2,950	+ 12.4
V-114	(Wn 1001 x Pj62) x LR64A E⁵ (F_2)	**	**	5,475	LR64A	5,983	(Wn 1001 x Pj 62)	3,266	— 8.5
V-113	[(3009 (3) x T. tim²) x Pj62] x (TzPP-Son64) E⁶	**	**	5,200	(TzPP-Son 64)	3,341	[(3009 (3) x T. tim²) x Pj 62]	2,950	+ 15.6
V-107	[(Wn 1001 x LR64A) x 8156] x (TzPP-Son64) E⁶	***	**	4,891	(TzPP-Son 64)	3,341	[(Wn 1001 x LR64A) x 8156 (R)]	4,050	+ 12.1
V-124	[(3009 (3) x T. tim²) x Pj62²] x (TzPP-Son 64)]E⁶	**	*	4,641	(TzPP-Son 64)	3,341	[(3009 (3) x T. tim²) x Pj 62²]	3,933	+ 11.8
V-104	[(Wn 1001 x Nad 63) (LR64 x Son 64)]	**	**	4,275	Sonora 64	4,641	[(Wn 1001 x LR64A) (LR64 x Son 64)]	3,350	— 7.9
V-119	(Wn 1001 x Pj62) x TzPP-Son 64) E⁶	**	*	3,791	(TzPP-Son 64)	3,341	(Wn 1001 x Pj 62)	3;266	+ 11.3
V-120	[(3009 (3) x T. tim²) x Pj62²] x LR 64 E⁵ (F_2)	**	*	3,333	LR64A	5,983	[(3009 (3) x T. tim²) x Pj 62²]	2,850	— 44.3

* = 20% of the florets sterile (in the row). ** = 10% of the florets sterile (in the row). *** = All plants completely fertile.

be homozygous for restoration and are being multiplied.

The two F_2 hybrids which were studied, showed very different yield performances. The F_2 hybrid designated V-114 yielded 17.5% less than the corresponding F_1 hybrid V-116, and only 8.5% less than the highest yielding parent involved in the F_1 hybrid. The F_2 hybrid designated V-120 yielded 51 percent less than the F_1 hybrid V-122 and 44% less than the highest yielding parent. These huge differences in response indicate that the reduction in yield of the F_2 over that of the F_1 hybrid is very unlike for two different hybrids. This indicates the need for further study of this phenomenon.

2. Specificity of Restoration

Data accumulated over the past two years indicate that there are now several restorer lines which appear to be homozygous for restoration of fertility to various cytoplasmic sterile lines. Some restorers transmit complete restoration of fertility to certain cytoplasmic steriles, while they only partially restore fertility to others under the same environment. The performance of several restorer lines on various steriles is shown in Table W6.

3. Ease of Restoration of Fertility of Cytoplasmic Sterile Lines

It is becoming increasingly apparent that a scientist attempting to develop hybrid wheat varieties must not only consider specificity of restoration, but must also recognize that some cytoplasmic sterile lines are relatively easy to restore, whereas others are very difficult to restore regardless of the restorer line that is used.

One cytoplasmic sterile line —(21931-Chapingo 53 x Andes) x Yaqui 50 "S"[5]— is easily restored to fertility. It can be restored to complete or nearly complete fertility by a considerable number of restorers that are ineffective on other steriles. However, this line itself is a stable sterile and remains completely sterile over a wide range of ecologic conditions. It also appears to provide a high degree of heterosis in many crosses. (Table W7).

4: Multiplication of Restorer Lines and Cytoplasmic Steriles

Currently three restorer lines that are believed to be homozygous for restoration, based on their performance in crosses with a number of different steriles, are being increased. Eight cyto-

TABLE W6. Fertility restoration observed in F_1 hybrids grown in CIANO in 1967-68.

No. of restorer line	Restorer line (♂) used as pollen parent in hybrid	Crim "S"			INIA 66 "S" [3]			(LR64 x S64) "S" [5]			(TzPP-S64) "S" [7]		
		B[2]	C[2]	T[2]	B	C	T	B	C	T	B	C	T
1	(T. tim-Mq^2 x Lerma Rojo 64A) x 8156 (Red)	RRR	RRR	RRR				RRR	RRR	RRR	RRR	RRR	RRR
2	(T. tim-Mq^2 x Lerma Rojo 64A^1)										RRR	RRR	RRS
3	(T. tim-Mq^2 x Lerma Rojo 64A^2)												
4	(T. tim-Mq^2 x Nad 63) (Lerma Rojo 64 x Sonora 64)												
5	(T. tim-Mq^2 x Sonora 64) Huelquen												
6	(T. tim-Mq^2 x Sonora 64)												
7	T. timopheevi-Marquis^2-2Y-108Y												
8	T. timopheevi-Marquis^2-2Y-110Y				RRR	RRR	RRR						
9	(Ti tim-Marquis^2) Dirk^3				RRR	RRR	RRS						

No. of restorer line	Restorer line (♂) used as pollen parent in hybrid	(S64-TzPP Y-54) "S" [5]			Bonza 63 "S"			(8156 "S" [3] x TzPP-S64)			Sonora 64 "S" [5]		
		B	C	T	B	C	T	B	C	T	B	C	T
1	(T. tim-Mq^2 x Lerma Rojo 64A) x 8156 (Red)												
2	(T. tim-Mq^2 x Lerma Rojo 64A^1)												
3	(T. tim-Mq^2 x Lerma Rojo 64A^2)	RRR	RRR	RRR									
4	(T. tim-Mq^2 x Nad 63) (Lerma Rojo 64 x Sonora 64)				RRR	RRR	RRR	RRR	RRR	RRS	RRR	RRS	RRS
5	(T. tim-Mq^2 x Sonora 64) Huelquen												
6	(T. tim-Mq^2 x Sonora 64)												
7	T. timopheevi-Marquis^2-2Y-108Y												
8	T. timopheevi-Marquis^2-2Y-110Y												
9	(Ti tim-Marquis^2) Dirk^3												

Cytoplasmic sterile lines used as female parent in forming F_1 hybrids.

[1] Cytoplasm obtained in most cases from **T. timopheevi** x Marquis^2 line acquired originally from DeKalb Agricultural Association.

Part of the training consists of grading wheat for commercial appearance and quality, then classifying the grain as "hard" or "soft". Grain is packed accordingly for shipment from CIANO.

All cyto-plasmic sterile lines and F_1 hybrids possess *Triticum timopheevi* cytoplasm.[1]

Cytoplasmic sterile lines used as female parent in forming F_1 hybrids														
(Hua R-Pix Pj62) E[4]			Pitic 62 "S"[4]			(TzPP-S64) "S"[6]			CIANO "S"[3]			(TzPP-64) "S"[7]		
B	C	T	B	C	T	B	C	T	B	C	T	B	C	T
			RRR	RRS	RRS	RRR	RRR	RRS				RRR	RRR	RRS
						RRR	RRR	RRS						
RRR	RRS	RSS							RRS	RSS	RSS			
RRR	RSS	RSS							RRS	RRS	RSS			
RRS	RRS	RSS												

Cytoplasmic sterile lines used as female parent in forming F_1 hybrids														
8156 (R) "S"[6]			Lerma Rojo 64 "S"			C-273 "S"[3]			(21931-ch x An) Y50 "S"[4]			Noroeste "S"[3]		
B	C	T	B	C	T	B	C	T	B	C	T	B	C	T
RRR	RRR	RRR												
			RRR	RRR	RRR	RRR	RRR	RRR	RRR	RRR	RRR			
RRR	RRR	RRR										RRR	RRR	RRR
									RRR	RRR	RRS			

(3) B, C, and T refer to florets of the basal, central and tip spikelets of all primary and secondary spikes in the row: RRR = completely fertile; RRS = 10 percent of sterile florets in the row; RSS = 20 percent of sterile florets in the row.

plasmic sterile lines are also being increased. With these materials available it will be possible to conduct preliminary studies on several aspects of the hybrid seed production problem during the 1968-69 crop season in Sonora.

Promising New Durum Wheat Varieties

The only durum wheat variety currently grown on any sizeable area in Mexico is the dwarf Oviachic 65. In certain years and from certain dates of planting this variety approaches the yield of Penjamo 62 or Pitic 62, but in some years yields drop 40 percent below that of the best vulgare varieties. Oviachic is day-length sensitive and also develops considerable sterility under some environmental conditions.

During the past two years six experimental durum wheats have consistently outyielded Oviachic 65. During the 1967-68 crop cycle, these six experimental lines were placed in preliminary

The second part of the field training is carried out in the Toluca valley where summer plantings are made with the seed packaged at CIANO. In this way two crops of the breeding materials are obtained each year.

TABLE W7. The specificity and ease of restoration of fertility in certain sterile lines with based on the F_1 hybrids grown at CIANO in 1967-68.

Restorer number	Restorer line (♂) used as pollen paren in F_1 hybrids	Cytoplasmic sterile lines used as female parent in forming F_1 hybrids: 21931-Ch 53 x AN) Y50 "S" (2)			CIANO "S" 3 (2)			8156 (R) "S" 6		
		B(1)	C(1)	T(1)	B	C	T	B	C	T
1	(T. timopheevi x Marquis²) x Sonora 64 H11-64-3Y-3M-1Y-1C-1Y-1M									
2	(T. timopheevi x Marquis²) x Penjamo 62 H55-64-2Y-4C-5Y-1C-1Y-1M	RRR	RRR	RRR						
3	(T. timopheevi x Marquis²) x Nadadores 63	RRR	RRR	RRR						
4	(T. timopheevi x Marquis²) x Penjamo 62² H707-65A-3C-2Y-3C	RRR	RRR	RRR						
5	(T. timopheevi x Marquis²) x (LR64 x Son 64² H-2-65-9Y-1C-2Y-1C				RSS	SSS	SSS			
6	[(T. timopheevi x Marquis² x LR64A)] x 8156 (R)H107-65-3Y-1C-1Y-1C				RRS	SSS	SSS			
7	(T. timopheevi x Marquis²) x Penjamo 62 H4-64-1Y-26M-1Y-3C-1Y-1C				RRS	SSS	SSS			
8	[(T. timopheevi x Marquis²) x Nad 63] (LR64 x Son 64) H411-65-1Y-3C-4Y-1C	RRR	RRR	RRR						
9	[(T. timopheevi x Marquis² x Nad 63] (LR64 x Son 64) H411-65-2Y-1C-1Y-1C							RRR	RRR	RRR

(1) Fertility in florets of B (base), C (center), T (tip) spikelets of the primary and secondary heads; RRR = completely fertile; of all heads sterile.
(2) "S" = cytoplasmic sterile.

Partial sterility is a serious problem in the breeding of Triticales; fertility is a prime consideration when selecting promising crosses between wheat and rye to form the new species. Scientists mark the crosses and later select visually in the field for high fertility. Here Dr. Frank Zillinsky and Ing. Joaquín López select promising individual spikes from the numerous crosses made earlier.

T.timopheevi cytoplasm when crossed with a number of different restorer lines. Observations

Cytoplasmic sterile lines used as female parent in forming F_1 hybrids																	
Sonora 64 "S" [5]			Pitic 62 "S" [4]			Lerma Rojo 64 "S"			TzPP-S64 "S" [6]			El Gaucho "S" [3]			8156 x TzPP S64 "S" [3]		
B	C	T	B	C	T	B	C	T	B	C	T	B	C	T	B	C	T
									RRR	RRS	RSS						
			RRR	RRR	RRR	RRR	RRS	RRS	RRS	RRS	RSS						
												SSS	SSS	SSS			
									RRS	SSS	SSS						
RRS	SSS	SSS				RRR	RSS	RSS	RRR	RRS	RSS						
RSS	SSS	SSS															
RRR	RRS	SSS															
															RRR	RRS	RSS
RRS	RSS	RSS													RRR	RRS	RSS

RRS = 10 percent of spikelets sterile in whole row; RSS = 20 percent of spikelet sterility in whole row; SSS = all florets and all spikelets

multiplication. At harvest two were found to be sufficiently promising to be considered as replacements for Oviachic 65. The performance of these two varieties is indicated in Table W8.

Even though these two varieties out-perform Oviachic 65, there is need for a vigorous expansion of the durum breeding program. CIMMYT plans to expand this work during 1968-69. The expansion and diversification has a twofold purpose:

a) To develop higher yielding, light-insensitive dwarfs that have more yield stability.

b) To develop a diverse group of high yielding, light-insensitive dwarf durums than can be used to breed new Triticales.

Research on Triticales

Two new members were added to the CIMMYT staff in January 1968, primarily to expand the breeding and research work on Triticales. Dr. Frank Zillinsky will be in charge of the breeding aspects, while Dr. George Varughese will be in charge of all cytological work and will assist with other phases of the program. They will also assume much of the responsibility for the durum breeding program, since durum wheat is one of the components used to develop new Triticales. A large collection of ryes, (the other parent of Triticales), has been obtained by CIMMYT for use in diversifying the rye genome component of Triticales.

The two principal defects of Triticales continue to be: a) partial sterility and b) shrunken endosperm. These two defects will receive much attention in the next several years. Considerable progress has been made in improving the plant type. Many early maturing dwarf lines are now available that did not exist three years ago.

Within the past crop cycle (1967-68), a number of F_4 plants were found which were both highly fertile and had endosperms that showed only slight shriveling. These selections are now being grown to determine whether they are true breeding.

During the 1968 summer season a large number of new Triticales are being made, using many different wheats and ryes as progenitors. With these new Triticales of diverse parentage, a vigorous breeding program will be established to intercross the new types with the best ones presently available.

Based on two years of comparative yield experiments, it is apparent that the best Triticales now available yield considerably less than the best varieties of dwarf bread or durum wheats. However, the opportunities appear good for achieving a

Tcl. X 1044 F2
Wt. 56.0

Tcl. V-65 F6
Wt. 71.1

Tcl. S-1025 F4
Wt. 74.0

yield breakthrough in Triticales within the next four or five years.

It appears that simultaneous improvement can be made in grain yield, grain quality (correct shriveling and test weight), nutritional properties, and plant type. CIMMYT is launching a vigorous program to achieve this objective within the next five years.

Experimental seed

One of CIMMYT's most vital contributions to wheat research and production are the small samples of experimental seed that it makes available to scientists in many parts of the world.

These seeds come from the complex gene pools in bread wheats, durum wheats and Triticales that are currently available in Mexico and constantly being modified. Last year experimental seed was shipped to 60 different countries; in many cases various scientists in a country received samples. The present practice is to provide F_2 bulk seed to qualified collaborators around the world. This opens up vast new possibilities for further improvement in both yield and disease resistance, because larger populations of each cross can be examined for valuable segregates.

The countries to which seed was shipped and the type of material involved are indicated in Table W9.

Training

During the past seven years 65 wheat scientists from many countries of Asia, Africa and Latin America have received training in the CIMMYT program in Mexico. Much of the current progress in research and wheat production in the Near and Middle East, is possible because of this corps of young scientists. The interest in this type of training is growing rapidly but the number of trainees is restricted in order to assure personal attention and quality of instruction. Currently there are 17 trainees in Mexico, as follows:

Hayder Omar Hayder	- Iraq
Dafalla Ahmed Dafalla	- Sudan
Hossein Tajaddod	- Iran
Bradi Nath Kayastha	- Nepal
Erdogan Indelen	- Turkey
Ali Mohammad Salen El-Masa'Deh	- Jordan
Ato Demissie Damte	- Ethiopia
Issam Naji	- Syria
Syed Muhammad Afzal	- Pakistan
Abdus Sattar	Pakistan
M. Shaffi Qari	- Pakistan
Abdul Samad	- Pakistan
Ghulam Siddiq	- Pakistan
Valentín Azañon	- Guatemala
Abdul Wakil	- Afghanistan
Mohammed Sofi	- Afghanistan
Shirindil Safi	- Afghanistan

NEAR AND MIDDLE EAST SEMINAR

A seminar covering all aspects of wheat research and production was held at Lyallpur, West Pakistan from March 22-28, 1968. The seminar was sponsored jointly by the government of West Pakistan, the FAO and the Rockefeller Foundation. It was attended by delegates from 17 countries.

This seminar was unique in that it provided the delegates an opportunity to view personally the revolution in wheat production taking place in Pakistan. This first-hand experience of observing the changes underway, as well as participating in the stimulating seminar session, will probably lead to other countries launching accelerated wheat production programs in the next few years.

Many of the delegates attending the seminar were young scientists who had studied and trained in the CIMMYT program in Mexico.

TABLE W8. The yield of two promising new dwarf durum varieties compared with Oviachic 65 under Sonora conditions in 1966-67 and 1967-68.

Sonora plot No.	Pedigree	Yield in Sonora 1966-67 Kg/ha	Yield in Sonora 1966-67 % of Oviachic	Yield in Sonora 1967-68 Kg/ha	Yield in Sonora 1967-68 % of Oviachic
PM 3	[(Pitic "S" x Barrigon Yaqui^2) x Tehuacan 60] [(Pitic "S" x Tacur 125) x Tehuacán 60^3] D 21570-9M-6R-1M	6409	133.2%		
PM 7	[(Pitic "S" x Barrigon Yaqui^2) x Tehuacan 60] [(Pitic "S" x Tacur 125) x Tehuacan 60^3] D 21563-2M-2R-2M	5744	119.4%	4250	134.9 %
PMX	Oviachic 65	4811	100.0%	3150	100.0 %

TABLE W9. Experimental seed shipments from September, 1967 to June, 1968.

Countries	International yield nursery	Screening nursery	Commercial varieties	Advanced lines	F_2 bulk	Triticales
North America						
United States	X	X	X	X	X	X
Canada	X		X	X		X
Alaska	X					
Latin America						
Argentina	X	X	X	X	X	X
Brazil			X	X	X	X
Bolivia			X			
Colombia	X	X				X
Chile	X	X	X		X	
Ecuador	X	X		X	X	X
Guatemala	X			X	X	X
Paraguay			X			
Uruguay	X		X			
Guiana			X			
Dominican Republic			X			
Near and Middle East						
Afghanistan	X		X	X	X	
Cyprus	X					
Iran	X		X			
India	X	X	X	X	X	X
Iraq	X		X			
Israel	X		X	X	X	
Jordan	X					
Lebanon	X		X	X		
Pakistan	X	X	X	X	X	X
Saudi Arabia	X					
Syria	X		X	X		
Turkey	X			X		
Europe						
Belgium			X			
Denmark	X		X			
England			X			X
Finland			X			
Greece			X			
Germany			X			
Holland			X			
Ireland			X			
Italy			X			
Poland			X			X
Portugal	X		X	X		
Spain	X		X			
Sweden	X					X
Yugoslavia			X			
Africa						
Algeria	X					
Angola	X					
Egypt	X					
Ethiopia	X					
Kenya	X	X	X			
Libya	X					
Morocco	X		X			
Nigeria	X					
South Africa	X		X	X		
Sudan	X					
Tanzania			X			
Tunisia	X		X	X	X	
Others						
Australia	X		X	X	X	
Ceylon			X			
Hawaii			X			X
Korea	X		X			
Nepal	X		X	X		
Thailand			X			

Optimum yields are the result of planting an adapted variety at the right time with an adequate population and an appropriate fertilizer application. By obtaining information on optimum levels of the variables which can be manipulated, agronomic research contributes valuable knowledge to the farmer.

soils and plant nutrition

soils and plant nutrition

■ AGRICULTURAL DEVELOPMENT programs in most countries have as their primary goal a rapid increase in average crop yields. An important objective of adaptive research in these countries is to generate and make available to farmers information on optimal levels of the agronomic inputs such as fertilizers, insecticides and herbicides. There is no general consensus of opinion as to the most efficient procedures to follow in studying the reaction of a crop to different levels of the agronomic factors. Consequently, studies have been conducted for the purpose of obtaining a better understanding of some of the problems involved in carrying out agronomic experimentation and to develop improved procedures for use in these studies.

Two questions, specifically related to fertilizer use experimentation, have been investigated during the past year. (1) What is the best way to select the treatment combinations for an experiment in order to minimize the bias error in the estimated yield function? (2) What is the best procedure to employ in combining the yield data obtained at a large number of experimental sites into a general yield equation useful for predictive purposes? These studies were conducted in cooperation with Dr. Foster B. Cady, who was Visiting Professor at El Centro de Estadística y Cálculo, Chapingo, México, under a joint Chapingo, Iowa State University, and Ford Foundation arrangement. Dr. Cady is presently Professor of Experimental Statistics at the University of Kentucky, Lexington, Kentucky.

Two reports were prepared from the results obtained in these studies and have been submitted for publication in the Agronomy Journal, published by the American Society of Agronomy and in the SSSA PROCEEDINGS, published by the Soil Science Society of America.

BIAS ERROR IN YIELD FUNCTIONS

Yield data produced in fertilizer experiments are commonly used to calculate yield equations from which interpretations are made as to optimal levels of fertilization. Some postulated model, frequently the quadratic polynomial, is assumed by the investigator to provide an adequate represensation of the relationship between yield and rates of fertilization. The experimental treatments are selected and the resulting yields used to estimate the parameters for this model. The appropriate variances are estimated and the regression coefficients are tested for statistical significance along with tests of significance of the overall model and lack of fit.

The numerical difference between a response, predicted from an estimated postulated model, and the true response depends upon the magnitude of errors originating from two sources. If the postulated model is the true model, the deviation of the estimated postulated model from the true model, expressed in the appropriate manner, is defined as the variance error. The second source of error, called bias error, arises from the deviation of the postulated model from the true model. As used in this study the bias error is the area or volume between the true and postulated models. It is illustrated in the figure on page 90 as the shadded area between the two curves. Thus, it is the integrated area or volume between the true and postulated models over a given range of values for the fertilizer variables.

The objective of this study was to evaluate the effect to treatment design on bias error, and to compare the magnitude of this effect with the bias error introduced on selecting different postulated models. Treatment design refers to the set of fertilizer treatments selected for a study and is varied by changing either the spacing (allocation) of the number of treatment combinations. The procedure followed and the conclusions reached in this study are summarized in the following paragraphs.

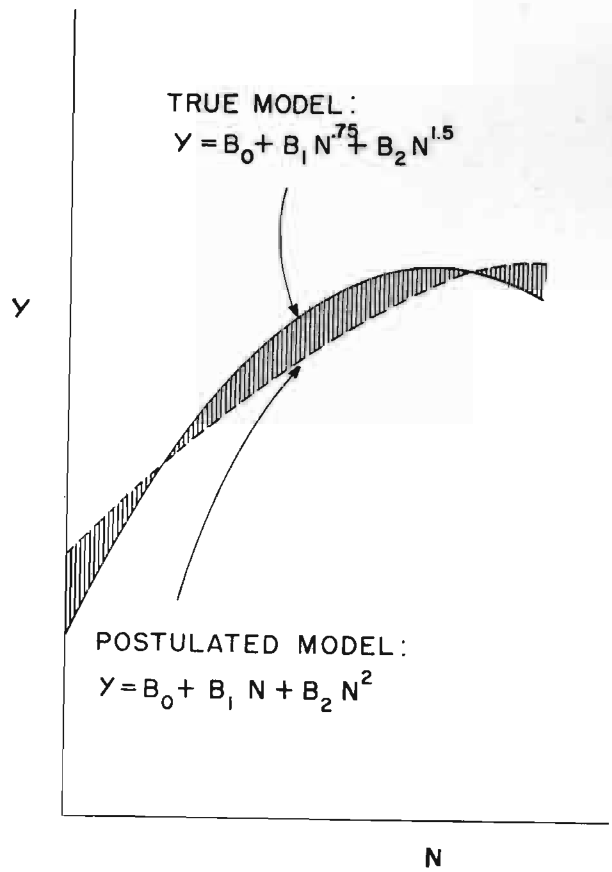
Procedure

The second order polynomial given below was arbitrarily selected as the true model:

$$Y = 1500 + 110^{.75} - 0.7N^{1.5}$$

Yield, Y, and rate of nitrogen fertilization, N, are expressed in terms of kilograms per hectare. Six second order polynomials were selected as postulated models. The exponents of nitrogen in the second terms of these equations were 1.0, 0.9, 0.8, 0.7, 0.6 and 0.5. The exponents of nitrogen in the last terms were always twice the size of the second term exponents. Thus, the exponents for the postulated models included a range from the quadratic to the square root.

Symmetric and asymmetric treatment designs were selected for studying the effect of allocation. The levels of nitrogen in kilograms per hectare were: 0, 60, 120, 180, 240, 300, and 360 for the



Curves illustrating the deviation of a postulated model from the true model. Bias error is the shaded area between the two curves.

symmetric design and 0, 40, 80, 120, 160, 260, and 360 for the asymmetric. The effect of varying the number of treatments was studied using symmetrical distributions of 3, 5, 7, 11, 15, and 19 levels of nitrogen.

The true values of Y, corresponding to the levels of N selected for study in each design, were calculated. These values were used to estimate the six postulated models for each treatment design. These prediction equations were employed to calculate values of Y corresponding to N values from 0 to 360 in increments of one kilogram. The absolute differences between these predicted values, calculated at the midpoints of the one-kilogram increments of N, were summed to give bias error.

Conclusions

1. A symmetric distribution of treatments in the factor space minimizes the bias error of the yield function when evaluated over the entire range of values for the independent variable(s) studied. If the major interest of the investigator is limited to a portion of the factor space, bias error in this region may be reduced by concentrating in it a greater part of the treatments.

2. Bias error is reduced markedly by increasing the number of treatments. With one independent variable the magnitude of bias error increased rapidly as the number of treatment levels was decreased from seven to three.

3. The most effective way to reduce bias error is by making a good selection of the postulated model. Unfortunately, too little is known about the nature of yield functions to provide a basis for making a good choice.

COMBINED ANALYSIS OF DATA FROM FERTILIZER EXPERIMENTS

The crop yield data used in this study were collected in 76 fertilizer trials conducted with unirrigated maize in Central Mexico during the four-year period 1962-1965.[1] The soils in this region respond to applications of both nitrogen and phosphorus. The fertilizer treatments used in the experiments, however, did not permit an adequate estimate of the effect of phosphorus on maize production. Therefore, only yield data for four treatments —0, 40, 80 and 120 kilograms of nitrogen per hectare plus a uniform phosphorus application— were used in the combined analysis.

The productivity factors measured at each site were the plant, soil, climatic, and management factors believed capable of differentially influencing yield and response to fertilization. Ten of those measured appeared sufficently important to be included in the combined analysis. These ten factors, referred to subsequently as site variables, were total soil nitrogen, excess moisture, drought rooting depth, soil slope, texture, previous crop, hail, leaf blight *Helminthosporium turcicum*, and weeds.

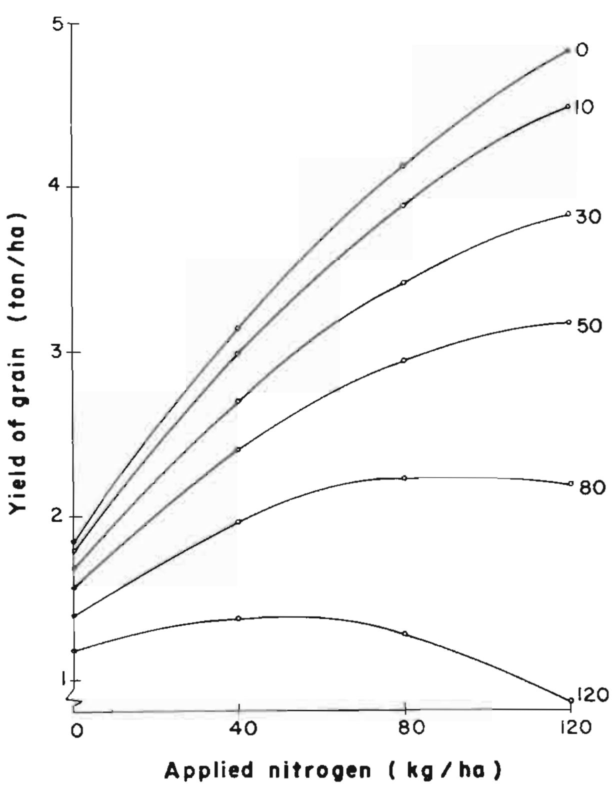
The independent variables selected for the regression analysis consisted of the linear and quadratic effects of applied nitrogen, the ten site variables, and interactions among these. As shown in Table S1 there were a total of 36 X-variables.

The first step in the combined analyses was to simultaneously regress yield on all 36 independent variables. The analysis of variance for the full regression model is given in Table S2. The 36 regression coefficients were tested for significance using experimental errors calculated from the individual analyses of the 76 experiments. Fourteen of the regression coefficients were not significant at the 5% level. This suggested that a regression model with fewer independent variables might be found without significantly increasing the residual mean square.

The stepwise and backward elimination procedures were first employed in an effort to produce an adequate reduced model. Regression equations containing 18 and 25 independent variables were

[1] The field trials were conducted jointly by the Instituto Nacional de Investigaciones Agrícolas, Chapingo, México, and CIMMYT.

Fertilizer trials, spread throughout a region on various soils and under differing climates, make it possible to estimate optimum fertilization levels and make specific recommendations. This photo shows the planting of an unirrigated corn fertilization experiment with a cooperating farmer in Central Mexico where the data were collected for the study reported here.



Yield curves estimated from the general yield function for six different indices of drought and average levels of the other site variables.

obtained using the stepwise and backward elimination procedures, respectively, without discarding significant variables. Neither of these solutions was agronomically satisfying however, as several important variables —quadratic effect of applied nitrogen, linear effect of soil nitrogen, interaction between applied nitrogen and soil nitrogen, main effects of excess moisture and drought— were absent from each of them.

Therefore, a new attempt was made to produce an acceptable regression equation by employing the following steps based mainly on agronomic considerations:

1) The main effects of each of the ten site variables were tested for significance at the 5% level with the other nine, plus the linear and quadratic applied nitrogen variables, present in the model. Insignificant site variables, together with their interactions, were discarded.

2) A model was formed comprising N, N^2, the main effects of the remaining site variables, any quadratic effects of these factors that were present in the full model, and all interactions among nitrogen source variables (N, A, and B)

3) Each of the interactions between applied nitrogen and the site variables (less A and B that were treated as nitrogen sources) were added separately to the model, regression analyses were made of the new models, and the resulting increases in the regression sum of squares were tested for significance.

Soil scientists are collaborating in the Puebla Project to estimate optimal levels of nitrogen and phosphorous fertilization. Here Ing. Armando Puente shows the vegetative response to nitrogen in one of the experiments planted in 1967.

TABLE S1. The independent variables in the full regression model and the regression coefficients for the reduced model.

Independent variables	Symbol	Regression coefficients for reduced model
Constant		—1.2479
Applied nitrogen (linear)	N	1.4405
Total soil nitrogen (quadratic)	N^2	—0.0154
Total soil nitrogen (linear)	A	0.0411
Total soil ntrogen (quadratic)	A^2	—0.0246
A x N	AN	—0.0119
A x N^2	AN^2	—0.0086
Previous crop (linear)	B	0.3526
Previous crop (quadratic)	B^2	—0.0526
B x N	BN	0.0054
B x A	BA	—0.4279
B x N^2	BN^2	—0.0405
B x A^2	BA^2	0.3089
Excess moisture	C	—0.2646
C x N	CN	
C x A	CA	
C x B	CB	
Drought	D	0.0093

Independent variables (cont.)	Symbol	Regression coefficients for reduced model
D x N	DN	—0.0091
D x A	DA	—0.0007
D x B	DB	—0.0095
Depth of rooting zone	E	
Soil slope	F	—0.0064
Soil texture (linear)	G	
Soil texture (quadratic)	G^2	
Hail	H	—0.2325
H x N	HN	
H x A	HA	
H x B	HB	
Blight (*H. turcicum*)	J	—0.0789
J x N	JN	0.0214
J x A	JA	—0.0167
J x B	JB	—0.0032
Weeds	K	
K x N	KN	
K x A	KA	
K x B	KB	

4) All significant applied nitrogen x site variable interactions together with the interactions between these same factors and the other nitrogen source variables, were added to the variables mentioned in (2) above to give the final regression model with 23 independent variables.

Yield was regressed on the 23 variables in the agronomic model and the regression coefficients are given in Table S1. The coefficients corresponding to 11 of the variables —N^2, AN, AN^2, BN, BN^2, D, DA, DB, J, JA, JB— had t values that were not significant at the 5% level. The analysis of variance for this regression is given in Table S2. The reduction in regression sum of squares corresponding to the 13 discarded variables was significant at the 1% level.

The regression equation obtained by employing the agronomic approach was used to calculate the yield functions for different combinations of values for the site variables. The curves corresponding to yield functions calculated for six different indices of drought and average levels of the other six site variables are shown in the figure in page 91. The relationship shown here between response to nitrogen fertilization and intensity of drought agrees well with general experience. Likewise, the predicted yield functions for varying levels of the other site variables agreed reasonably well with expectations. Thus, there was considerable evidence in favor of accepting this general yield equation as a reasonably accurate representation of the relationship between the yield of maize and the applied nitrogen and site variables.

TABLE S2. The analysis of variance for the full and reduced regression models.

Regression Model	Source of variation	Degrees of freedom	Sum of squares	Mean square
	Regression	36	458.6839	12.7412
Full	Residual	267	101.9642	0.3819
			$R^2 = 0.818$	
	Regression	23	441.8715	19.2118
Reduced	Residual	280	118.7766	0.4242
			$R^2 = 0.788$	

F (for 13 discarded variables) = 3.39; Significant at the 1% level.

This general yield equation is a summary of the information obtained in 76 fertilizer experiments conducted during a period of four years. With computer facilities available this equation can be employed to estimate specific nitrogen recommendations for farmers' plantings of maize. For this purpose the advisory service responsible for supplying farmers with specific fertilizer recommendations would need information on the seven site variables in the equation, corresponding to each field for which a recommendation was needed. Part of this information on site variables could be supplied by the farmers part of it would have to be compiled and made available by the service organization, and available nutrient levels could be determined by analyzing representative soil samples from each field.

communications

The work in communications is aimed at converting experimentally proven yield possibilities into higher yields on the farm. Visual aids such as low-cost educational movies are one way to bring new information to the attention of farmers. In the scene above, two Colombian trainees are receiving in-service training while helping to produce a movie on corn storage.

communications

■ THIS ACTIVITY SHARES a common objective with the plant breeders, soil scientists, entomologists and plant pathologists, namely to bring about more productive and profitable cultivation of maize and wheat. The special interest of the communications program is to convert the experimentally demonstrated yield possibilities into higher yields on the farm. This is being approached at two levels: 1) through leaders at the research and policy levels, and 2) at the farm level. At the research and policy level, the communications department provides visual and printed channels for disseminating research results among scientists around the world who are working on related problems.

At the farm level the primary focus is on research questions related to requirements for bringing about rapid yield increases on the millions of farms currently producing maize and wheat. As mentioned in the 1966-67 report, CIMMYT research and that of other investigators has reached the point where it is possible to identify the important variables limiting maize yields on farm plantings. It was mentioned that the main focus of communications research for 1967-68 would be to field tets a model for gaining rapid adoption among farmers of more productive practices. This research interest is now centered primarily in the Puebla Project, where an integrated approach is being used combining plant breeding, agronomy and communications. The Puebla Project is described in a separate report and thus will not be covered here.

INFORMATION EXCHANGE

Publications

The publications program attempts to gain systematic distribution of CIMMYT results on a world wide basis.

CIMMYT News. During the past year the bimonthly newsletter provided a continuing progress report as well as news of persons, institutions and events related to maize and wheat research. Distribution was expanded to include 1,900 addresses for the English edition and 1,950 for the Spanish edition. The newsletter goes to investigators, institutions and libraries in 85 countries.

Because of the role of the newsletter in making known the kinds of research in progress as well as the results, many requests have been received for additional information. These are answered with available publications or by referring the question to specialists in the Center.

Research bulletins. During the year four new research bulletins were added to the CIMMYT series; three were published in English and one in both English and Spanish, as indicated in the following list:

Res. Bul. 8. "Results of the First International Spring Wheat Yield Nursery 1964-65". Charles F. Krull, Ignacio Narváez, Norman E. Borlaug, Jacobo Ortega, Gregorio Vázquez, Ricardo Rodríguez and Carlos Meza, March 1968.

Res. Bul. 9. "Técnicas de campo para experimentos con fertilizantes". Reggie J. Laird, Marzo 1968.

"Field Technique for Fertilizer Experiments", March 1968.

Res. Bul. 10. "Variability in the Lysine Content of Wheat, Rye, and Triticale Proteins". Evangelina Villegas, C.E. McDonald and K.A. Gilles.

Res. Bul. 11. "Results of the Second International Spring Wheat Yield Nursery 1965-66". Charles F. Krull, Ignacio Narváez, Norman E. Borlaug, Jacobo Ortega, Gregorio Vázquez and Ricardo Rodríguez.

This makes a total of 11 bulletins in the research series, which have been distributed to the mailing list mentioned earlier.

No systematic attempt has been made to measure the impact of these bulletins, but correspondence, personal comments and requests for permission to reprint, indicate the value of the material.

Translations and reprints. This series was initiated during the past year to disseminate valuable technical information which has received only limited circulation or is currently available in only one language. Reprints are ordered directly from the publisher or permission is obtained to reprint by the CIMMYT. The following reprints were obtained directly from the publishes during the past year:

"New Wheat for India and Pakistan", by Grant Cannon in The Farm Quarterly.

In the case of grain production on small holdings, important yield increases will come about only through the decisions of a large number of individual operators. The task of the agronomist is two-fold: to develop the package of tested agronomic practices from which dramatically higher yields can be obtained, and to assist and convince the farmer that it will be to his advantage to invest in new seeds, fertilizers and other purchased inputs. This photo was taken during a bench mark survey for the Puebla Project.

"The Impact of Agricultural Research on Mexican Wheat Production", by Norman E. Borlaug in the Transactions of the New York Academy of Sciences.

"Integración del mercado rural a la economía nacional en México", (Integrating the Rural Market in to the National Economy of Mexico), by Delbert T. Myren in Comercio Exterior.

In addition the CIMMYT reprinted "Producción de maíz en Centroamérica" from the Proceedings of the 13th annual meeting of the Central American Food Crop Improvement Program.

In the case of translations the communications department will request permission from the authors and publisher, then do the translation, publish and distribute the material.

In addition to its own series of publications, the Department collaborated in the edition, publication and distribution of the proceedings of the 13th meeting of the PCCMCA, held in San Jose, Costa Rica in March 1967. This collaboration is part of CIMMYT involvement in raising corn yields in the area and is closely tied with the Central American Program mentioned in the maize report.

Providing information for other media

The Center does not copyright its publications; quite the contrary, other media are encouraged to use or reprint sections or complete bulletins. Important sections of the first annual report were reproduced and distributed throughout Latin America in farm magazines and reference was made to the work of the CIMMYT in a large number of magazines and national newspapers around the world. In this was, the information first released in CIMMYT bulletins reaches a much broader audience than the original publication. Numerous reporters have also visited CIMMYT and have written original reports on their observations, presenting a highly favorable description of the approach and the activities underway.

Visual Aids

The work in visual aids and photography continued during the past year through a cooperative arrangement with the National Institute for Agricultural Research (INIA).

The film team collaborated with the Colombian Agricultural Institute (ICA) to produce three films and simultaneously train two technicians in the production of low cost films and visual aids. During the training period in Mexico, this Colombian team participated in various stages of editing, completed three movies filmed in Colombia and also took part in filming the "The Granary" for the INIA and the National School of Agriculture. This last film shows how to construct simple, low-cost storage for corn.

The film team is presently producing a 16 mm movie to be used intensively with farmers in the Puebla area. This film demonstrates the package of technology —planting procedure, adequate and correct application of fertilizer, optimum plant population— needed to obtain sharply higher yields under the conditions of this specific area.

Work has also been initiated on other visual aids. A film strip and a series of transparencies, both on methods for increasing corn yield are currently being completed. These are the first of a series which should cover all of the technical aspects needed to obtain a more efficient production of corn and wheat and which should be useful in various countries for training agronomy students, extension agents and other development workers.

TRAINING

Earlier training activities have laid the ground work for broader Mexico-based training in communications. Although only one of the graduates in the communications, Dr. Gregorio Martínez is employed full-time in the CIMMYT, others with advanced training are working in cooperating institutions and taking a strong initiative in development programs. Abdo Magdub (MS) is in charge of information and promotion at the undergraduate level in Chapingo; Jesús Martínez Reding (MS) is secretary of the Graduate School; Dr. Leobardo Jiménez is director of the new graduate field of Agricultural Communications and coordinator of the Puebla Project. These three men also form the committee in charge of the communications specialty in the Chapingo Graduate College. Along with others who have obtained advanced training, they are laying the ground work for a solid graduate program of applied and theoretical work to train agronomists who wish to learn how to become more proficient in bringing about increases in crop yields at the farm level.

In the case of communications, it is hoped to handle CIMMYT training activities in collaboration with this graduate program. CIMMYT staff in communications will be among the faculty providing courses and research guidance to graduate students, and the Puebla Project will serve as a research and action area to complement the theoretical work in the classroom.

SOURCES OF SUPPORT FOR 1968

I. CASH RECEIPTS

	Dollars
A. General Support	
1) The Ford Foundation	527,500
2) The Rockefelier Foundation	385,000
3) Sales	9,000
Sub-Total A	921,500
B. Restricted Grants and/or Contracts	
1) The Ford Foundation	
a) Pakistan Wheat and other cereals projects	214,574
2) The Rockefeller Foundation	
a) Central America and Caribbean Food Crop Project	15,000
b) Puebla Pilot Program	56,400
c) Equipment and Vehicles	60,000
d) Eastern Africa Maize Program	14,644
Sub-Total B	360,618
Grand Total	1,282,118

II. OTHER

A. Number of scientists commissioned to the Center (man years)

The Ford Foundation	2½
The Rockefeller Foundation	8¾