1966-67
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CENTRO INTERNACIONAL DE MEJORAMIENTO DE MAIZ Y TRIGO
INTERNATIONAL MAIZE AND WHEAT IMPROVEMENT CENTER
Londres 40 Apartado Postal 6-641 México 6, D. F., México
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INTRODUCTION

This first annual report of the International Maize and Wheat Improvement Center has a two-fold objective: 1) to set down in type the objectives, philosophy and broad policy outline of the Center and 2) to report on progress and results obtained during the past year.

The CIMMYT evolved from many years of cooperative effort between the Rockefeller Foundation and the government of Mexico, Central America, Colombia, Ecuador, Chile, and more recently India, in the improvement of quantity and quality of maize and wheat. The history of this cooperative work is adequately described in the Annual Reports of the Rockefeller Foundation’s program in the Agricultural Sciences covering the years 1959-65.

The Center was originally established in 1963 as a cooperative program with the Mexican Ministry of Agriculture. However, by early 1966 the growing demands on this program by the ever-widening food gap around the world indicated the need for a restructuring and expansion of activities. As a result, the Center was reorganized and established on April 12, 1966, in accordance with Mexican law, as a non-profit scientific and educational institution by Mexico’s Ministry of Agriculture and the Rockefeller Foundation to be governed by an international board of directors.

This new organizational structure provides the CIMMYT with the necessary freedom for operation of its world-wide programs and for receipt of funds from all agencies interested in advancing its goals.

The board in its first meeting on September 19, 1966, approved the programs for the calendar year 1967; major financial support was provided by the Ford and Rockefeller Foundations.

HEADQUARTERS

Plans have been made to locate the headquarters of the Center in close proximity to Mexico’s National Center for Agricultural Education, Research and Extension. A physical plant will be constructed to provide office space and facilities for research and to give the Center identity and character. Facilities already available at cooperating institutions in Mexico and other countries will be taken into consideration in planning its requirements.

THE OBJECTIVE: RAPID AND CONTINUED YIELD INCREASES

The main purpose of CIMMYT is to assist nations throughout the world to increase the production of wheat and maize. Such help is particularly needed in the tropical and semi-tropical regions where these

1 Letters of the official title — Centro Internacional de Mejoramiento de Maiz y Trigo.
two crops can be efficiently grown for food or feed but where yields are presently very low. Priority will be given to those countries that need and request help in increasing yields.

Although in its initial stages the activities of the Center will be concentrated mainly on wheat and maize, work with other food crops may eventually be included in its programs.

In the realization of its broad objectives the CIMMYT will:

• Conduct and promote research to develop new information, genetic materials and practices needed to bring about substantial advances in yields of maize and wheat.

• Assist in the education and preparation of people —scientists, extension workers, administrators, industrialists and farmers— who can be influential in moving elite materials and improved production practices into general application.

• Develop cooperative programs which will help national governments and institutions to gain rapid application of research results which will bring about economic increases in wheat and maize yields.

• Assist whenever indicated with the development of key national agricultural research and educational institutions that can solve local production problems.

• Sponsor relevant scientific and technical meetings as well as other activities which foster cooperation among scientists.

• Publish and disseminate the results of research and generally promote the more rapid application of important research findings.

THE SCIENTIFIC STAFF AND ITS FUNCTIONS

To carry out its task, the Center will assemble and maintain a hard-core staff of highly competent scientists, of various nationalities and scientific disciplines, to act primarily as program leaders and directors. Most of these scientists will be employed on a career basis to serve as innovators and pace setters in promoting and applying the high quality research and training needed to catalyze greater production of maize and wheat wherever feasible and desirable.

The efforts of this experienced group will be supplemented by research assistants and trainees as well as specialists who may be temporarily affiliated with the Center while on leave from other institutions or who may be employed directly to deal with a specific research, teaching or production problems. They may work in the central facilities in Mexico on basic research projects of world wide importance or may be assigned to aid cooperating national institutions in solving specific problems. In certain cases several persons may join forces in a large cooperative project without leaving their respective countries and only meet periodically to analyze accomplishments and plan future procedures.
Although the staff will consist primarily of research scientists, other specialists may operate more broadly as wheat or maize production specialists. As a team they will serve as catalysts in the attempt to bring about accelerated economic progress of agricultural areas through a greater production of maize and wheat.

The principal thrust of the Center will be through its most experienced scientists. To plan and guide strategic research and production programs, these scientists must be sufficiently competent to diagnose problems limiting yields. They must be able and willing to help national scientists to identify factors limiting progress and bring them to the attention of the principal decision makers within their own countries. The various nations cooperating with the Center will be helped to build up their own facilities and competence to solve their own special problems in food production. The scientists must be flexible, modifying their operations in accordance with responses and capabilities of cooperating institutions.

In planning their work, CIMMYT staff will take into account the activities of other international institutions concerned with problems of increasing food production in order to avoid unnecessary duplication. Wherever feasible, the CIMMYT will complement or help to implement the activities of such organizations.

Research results in themselves do not accelerate production. Therefore, scientists of the Center will assist wherever they can in the direct application of both old and new knowledge to bring about the necessary changes in traditional agriculture. Ways will always be sought to promote desirable progress in the overall economic and social development of a country striving toward a better life for its people.

Above all else, the CIMMYT staff is committed to learning and taking advice as well as to giving it. An attempt will be made to instill in all with whom they have contact a desire to improve, a spirit of change and an attitude of experimentation, innovation, and adaptation of new ideas.

TRAINING SCIENTISTS

One of the important functions of the Center will be to improve the knowledge and skills of others as related to agricultural improvement. Two kinds of training will be promoted, both closely integrated with research and its applications.

The most thorough training will be provided through a procedure allowing a student to become associated with the Center for three to five years as a research assistant. He will be given responsibility for the operation and development of a specific phase of a research project under the supervision of one of the hard-core staff. In certain cases he may use part of his research work to prepare a graduate thesis. Students of this kind will be held in the program long enough to acquire the need-
ed skills to provide leadership for research or production programs in their native countries.

It is hoped that much of the advanced training leading to a higher professional degree, especially for Latin Americans, can be done in collaboration with outstanding graduate schools in Mexico, Central and South America. In certain cases CIMMYT staff members may become adjunct professors in these schools to help round out a solid professional program; similar arrangements may be made with leading institutions in the United States of America or in other countries where good M.S. and Ph.D. degree programs are offered.

In the second kind of training the student will be associated with the Center for a maximum period of one year as an “in-service” trainee. He will participate directly in all phases of the work and learn the mechanics and the more practical aspects of maize or wheat improvement. After returning to his home country he may continue his development with the aid of his more experienced colleagues and with the continued guidance of CIMMYT staff members involved in regional cooperative projects.

Most, but not all, of the training will be done in Mexico. Part of both the in-service and the degree training can be promoted with competent scientists in other countries or with CIMMYT staff involved in the development of regional cooperative programs. In such collaborative training programs, special attention will be given to arrangements that will not only accomplish the training objectives but will also help to strengthen the institutions involved.

A MULTI-PRONGED ATTACK ON YIELD LIMITATIONS

The research effort in both maize and wheat will be directed principally toward the achievement of ever higher yields and production. Development of superior gene pools and widely adapted varieties will be undertaken on an international scale through more complete exploitation of the germ plasm reserves in both maize and wheat. Concurrently, research in soil fertility, water utilization, plant protection, plant physiology and agricultural economics will be closely coupled with the breeding programs. The aim will be to develop packages of inputs integrating the benefits of good seed, fertilizer, water, pest control and other factors which are prerequisites to higher and more profitable production in the major ecological and farming areas to be served.

Research is of little value unless it is applied. Therefore, to facilitate the dissemination of new techniques, the Center will build a communications program to assist in getting useful information to the right places at the right time to do the most good in changing the behavior of people, especially those in leadership positions who can bring together the proper combination of factors to double, triple or quadruple production on each hectare of tillable land now inefficiently used.
Because of the desperate urgency in many areas of the world to raise production as quickly as possible, an immediate first step will be to aid in extending available material, information and experience to needy countries through adaptive research and experimentation. Emphasis will be given to measures that can bring about immediate improvement in wheat and maize in specific areas. However, longer term projects will be undertaken simultaneously to expand basic knowledge and to develop new varieties and production practices which will assure continued progress in increasing yields and improving quality. Such projects may be conducted at the Center or elsewhere in collaboration with competent individuals and private or public institutions.

REGIONAL COOPERATIVE PROGRAMS

Insofar as possible, needed research will be promoted through cooperative programs, thereby strengthening national research and educational institutions. The Center will establish or cooperate in the establishment of sub-centers as may be indicated in regions where maize or wheat are important food crops. In such projects the staff will be primarily concerned with adaptive research and the application of research results to specific areas and farmers’ fields. In this way it should be possible to help in building competent teams of maize and wheat specialists that will be able to solve the agricultural problems of their own countries and also extend a hand to their neighbors when invited to do so.
Higher yielding varieties — the goal of plant improvement. Yield trials at Palmira, Colombia.
MAIZE

About 225 million tons of corn are produced in the world according to the FAO production yearbook of 1964. Among the 10 leading producers were the USA, which produced nearly half of the maize harvest, followed in order by the USSR, Brazil, Mexico, Rumania, Yugoslavia, Argentina, India, France and Italy.

Countries with a temperate climate produced approximately 78 per cent of the total world production on less than 56 per cent of the total area harvested. In contrast, the tropical and sub-tropical countries produced 22 per cent of the total world production on 44 per cent of the total acreage harvested.

The large difference in average yields between maize producing regions, suggested by the above figures, is clearly illustrated below. Average yields per unit area in Latin America, the Near East, the Far

Footnote: The terms "maize" and "corn" are used interchangeably in this report to refer to Zea mays.
East and Africa have improved but little, if at all, since 1950. These are the areas of the world in which the CIMMYT is concentrating its efforts.

That yields can be increased in individual countries of the tropics and semi-tropics is shown in the adjoining figures.

Actually Mexico’s average yield in 1965 (1,050 kg/ha) was 85 per cent more than it was in 1930-34. Thailand’s average corn yield in 1964 (2,190 kg/ha) was 141 per cent greater than during the period 1948-1953.

In general, the cooperative work leading to a further acceleration of maize production in the vast areas where low yields are a serious problem, consists of two principal types of activities:

1. The development of research and training programs with emphasis on those factors which actually limit production.

2. The fostering of programs to increase the rapidity of acceptance and widespread use of new and proven technology.

In moving ahead with these two closely related efforts, a number of cooperative regional programs have already been established; namely, the Central American and Caribbean Cooperative Maize Improvement Program (Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica, Panama, Dominican Republic and Jamaica); the Andean Zone Cooperative Program (Venezuela, Colombia, Ecuador, Peru and Bolivia); the Inter-Asian Program (including the countries of Southeast Asia plus India and Pakistan); and the East African Program (Ethiopia, Kenya, Tanzania, Uganda) which is in the process of being established. A director has been named for each of these regional programs to help individual countries to strengthen their own programs and work together as a team for the mutual benefit of all in the solution of the major production problems of the region.

In addition to these regional programs, certain specific cooperative projects have been initiated with the INIA and the Productora Nacional de Semillas in Mexico, with the INTA in Argentina, with the Institute of Genetics in Piracicaba, Brazil, with the Ministry of Agriculture in Egypt, with the Agricultural School of the University of Ibadan, and with the University of Nebraska and the University of Kansas in the United States. These cooperative projects involve a wide range of activities including the evaluation of breeding methods and materials, formation of elite germ plasm pools, studies of the origin and relationships of races of maize in Latin America and the isolation and fixation of genes for such specific characters as disease, protein quality, and insect and drought resistance.
Among the tropical and semi-tropical nations, Mexico in Latin America and Thailand in Southeast Asia have demonstrated that the introduction of improved germ plasm and better cultural practices can bring about substantial increases in maize yields.
Six maize germ plasm complexes are revolutionizing the varietal improvement programs around the world. In this map, capital letters indicate the center of origin of each complex and lower case letters the areas where the material is currently in use. Coastal Tropical Flint = F; Corn Belt Dent = B; Cuban Flint = C; Eto = E; Salvadoreño = S; Tuxpeño = T.

COOPERATIVE ACTIVITIES IN MEXICO

Research promoted in Mexico by CIMMYT has been primarily concerned with the evaluation of the vast range of variation existing in Latin America and the identification of outstanding breeding materials. The corn banks in Mexico and Colombia have turned out to be virtual gold mines for the further improvement of maize throughout the tropics.

Five outstanding germ plasm complexes for the further improvement of maize in the lowland tropics have now been isolated from the over 250 different races of maize identified in Latin America. These five elite complexes — Tuxpeño of Mexico, the Cuban and Coastal Tropical Flints of the Caribbean, Salvadoreño of Central America and Eto of Colombia— alone or in various combinations, are providing the basic raw materials for the next big jump in varietal improvement throughout the lowland tropics and semi-tropics. Studies with these five complexes have advanced to a point where recipes can now be written for proper germ plasm combinations to be used in the development of superior yielding varieties for almost any kind of environment in the lowlands of the tropical belt around the world.

In the northern and southern semi-tropical latitudes, germ plasm from the Corn Belt of the USA has been found to be extremely useful in combination with the Cuban and Coastal Tropical Flints. Both INIA
and the Productora Nacional de Semillas have contributed greatly in the identification and evaluation of these important genetic materials.

Seed of outstanding varieties and various composites made from them have been widely distributed throughout the world. New greatly improved varieties are rapidly being developed from these raw materials by local breeders in various countries throughout the tropical and semi-tropical belt. The maize breeders in India have just released a series of open pollinated varieties which are equal in yield capacity to the best hybrids developed in past years. These varieties and their pedigrees are indicated below:

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<th>Variety</th>
<th>Pedigree</th>
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<td>Sona</td>
<td>J 1 × Cuba 11 J (Cuban Flint)</td>
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<tr>
<td>Jawahar</td>
<td>A 1 × Antigua Group 1 (Coastal Tropical Flint)</td>
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<tr>
<td>Kisan</td>
<td>J 1 × Composite of Coastal Tropical Flints</td>
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<td>A 6</td>
<td>Basi × Eto Amarillo from Colombia</td>
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<td>JML 1</td>
<td>J 1 improved through mass selection</td>
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The variety J 1 itself is a composite of Cuban and Coastal Tropical Flint with an introgression of a certain amount of germ plasm from the Corn Belt of the United States. This variety is also well adapted to much of the corn area of West Pakistan and is now being increased for wide scale production in that country.

The Cuban and Tropical Coastal Flint materials are also serving as basic raw materials for the further improvement of corn throughout Southeast Asia. Along with the Tuxpeño race they have also been very useful in the breeding programs of West Africa.

The five elite races described above are presently being tested in Egypt in hybrid combinations with local and Corn Belt varieties. Preliminary tests have indicated that these materials can contribute greatly to the improvement disease resistance and yield of the present local and improved varieties.

Recent accomplishments in Brazil provide the most outstanding example of what can be done with the right kind of exotic germ plasm. The first improved hybrids developed and released by the Brazilian corn breeders were made from the local Cateto Flints. These were subsequently improved through the substitution of certain Cateto lines with lines developed from the variety Tuxpan of southern Texas. More recently another significant increase in yield has been obtained through the use of inbred lines derived from the Yellow Tuxpeño race of northern Vera-cruz. Work now under way indicates that the biggest increase yet will be obtained by improving the Cateto Flint side of the hybrids through the incorporation of germ plasm from the Cuban and Coastal Tropical Flints.

Cuban and Coastal Tropical Flint materials are also revolutionizing the corn breeding programs in Argentina in combination with the local flints and recently introduced materials from the Corn Belt of the USA.
The corn breeders of Peru and Ecuador have found them to be extremely useful in the development of high yielding disease and insect resistant varieties for the coastal lowland area of South America.

In Venezuela the combination of Eto × Tuxpeño has proven to be superb. Hybrids and improved open pollinated varieties being developed by the Venezuelan corn breeders from this combination are replacing present improved varieties. A recent test involving combinations between Tuxpeño and the Cuban and Coastal Tropical Flints has indicated that the latter germ plasm complex will also be very useful in the further improvement of corn for the lower Amazonian slopes of the Andes.

Most of the improved high yielding varieties of maize now being distributed in Central America were derived from various combinations of Tuxpeño, Salvadoreño, Eto and the Cuban and Coastal Tropical Flints.

These germ plasm complexes are clearly providing a new base for most of the breeding programs throughout the tropics. From this base a whole new series of improved open pollinated varieties are rapidly appearing which, together with adequate fertilization and improved cultural methods, could double the present corn production in the tropics during the next 5 to 10 years.

These basic breeding materials are not only markedly raising the yield levels almost everywhere, but also contributing greatly to the control of diseases and insect pests. In India and Egypt, bacterial stalk and ear rots present a major problem. Resistance is being obtained from these exotic varieties. Also, as will be indicated later in this report, a variety of Coastal Tropical Flint from Antigua has been found to contain genes for resistance to a number of devastating insects.

Training Scientists

As noted earlier in this report, the corn program has provided both in-service and graduate degree training during the past year. The following persons received in-service training:

<table>
<thead>
<tr>
<th>Name</th>
<th>Country of Origin</th>
<th>Starting Date</th>
<th>Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ghulam Haider Asady</td>
<td>Afghanistan</td>
<td>One year</td>
<td>3/1/67</td>
</tr>
<tr>
<td>Rafael A. Barrios B.</td>
<td>Guatemala</td>
<td>Six months</td>
<td>7/3/67</td>
</tr>
<tr>
<td>Emilio Salvador Bonilla A.</td>
<td>Salvador</td>
<td>One year</td>
<td>7/18/67</td>
</tr>
<tr>
<td>José Eduardo Bontín López</td>
<td>Dominican Rep.</td>
<td>Six months</td>
<td>7/30/67</td>
</tr>
<tr>
<td>Mathias Kojo Akposoe</td>
<td>Ghana</td>
<td>Five months</td>
<td>6/30/67</td>
</tr>
<tr>
<td>Marcos Santos Sarmiento</td>
<td>Guatemala</td>
<td>Three months</td>
<td>7/3/67</td>
</tr>
<tr>
<td>Federico Augusto Thomas</td>
<td>Dominican Rep.</td>
<td>Six months</td>
<td>7/30/67</td>
</tr>
<tr>
<td>Abdul Wasai</td>
<td>Afghanistan</td>
<td>One year</td>
<td>3/1/67</td>
</tr>
<tr>
<td>K. Mandloi</td>
<td>India</td>
<td>Six months</td>
<td>4/1/66</td>
</tr>
</tbody>
</table>
Abdul Wasai and Ghulam Haider Asady of Afghanistan are spending a year in Mexico working with CIMMYT maize scientists as on-the-job trainees. During the course of the year they will prepare seed, then plant, cultivate, harvest and summarize data. On the breeding side they are learning modern mass selection procedures.

A group of agricultural specialists from Afghanistan visited CIMMYT research at Tepalcingo, Morelos, in early May 1967. Here they are viewing maize collections sent from Afghanistan for crossing with germ plasm available at the CIMMYT. This is a short stalk variety selected by farmers in Afghanistan over the past two or three centuries for planting broadcast without cultivation. Seed of the crosses was sent back to Afghanistan for observation at two intermediate altitude locations.
In addition, the following individuals completed the requirements for an M.S. degree at the Graduate College in Chapingo, using data from the corn research program in the elaboration of their theses.

<table>
<thead>
<tr>
<th>Name</th>
<th>Country of Origin</th>
<th>Date M.S. Completed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fidel Berlanga F.</td>
<td>Mexico</td>
<td>March 1967</td>
</tr>
<tr>
<td>Juan Carlos Colazo</td>
<td>Argentina</td>
<td>June 1966</td>
</tr>
<tr>
<td>Gonzalo A. Fletes</td>
<td>Guatemala</td>
<td>January 1967</td>
</tr>
<tr>
<td>Daniel Sarria</td>
<td>Colombia</td>
<td>June 1967</td>
</tr>
<tr>
<td>Humberto Tapia B.</td>
<td>Nicaragua</td>
<td>September 1966</td>
</tr>
</tbody>
</table>

**COMPARISON OF BREEDING METHODS**

In addition to the evaluation, formation and distribution of elite germ plasm, CIMMYT's corn breeders are deeply involved in the evaluation of breeding methods. The hybrid method used by breeders in the Corn Belt of the USA and elsewhere has provided marked advances in corn productivity but its use in the tropics is limited due to a number of problems, such as lack of trained personnel and the need to educate farmers in its use.

CIMMYT's maize specialists believe that simpler methods can be used for maize improvement in the tropics, especially in the early stages of a breeding program. Consequently, different procedures for the improvement of open pollinated varieties and composites are being compared to determine relative efficiency. The work is being carried on in three locations: Chapingo at 2,250 meters elevation, the Bajio near Celaya at an elevation of about 1,750 meters, and near Veracruz at sea level. Obviously, the program is a long term effort and evaluations of relative effectiveness of new methods will require time.

**Highland Areas**

Data from a twenty replication yield trial comparing mass selection and half-sib family selection in Mexico Group 10 (Chalqueño) has indicated the two methods to be approximately equal. The materials have undergone four cycles of selection with yield gains per cycle of three to seven per cent. Data for composite CH61 (Chalqueño) are similar, with the average gain per cycle ranging from 5 to 6 percent.

Data were also obtained from a similar trial conducted in El Roque and Juventino Rosas in the Bajio region, comparing the first cycle synthetics from four methods with the respective originals in Celaya II and Puebla Group 1. These data are summarized in Table 1.

These results are from one year's data and one can only speculate as to the reasons for the differences in gain between methods in the two
TABLE 1. Progress made with different methods of breeding in two populations.

<table>
<thead>
<tr>
<th>Population</th>
<th>Method of selection</th>
<th>Yield(^1) kg/plot</th>
<th>% of original</th>
<th>% gain per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Celaya</td>
<td>SMC Syn. I</td>
<td>6.92</td>
<td>109</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>SMP Syn. I</td>
<td>7.03</td>
<td>111</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>SFS Syn. I</td>
<td>7.09</td>
<td>112</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>SS(_1) Syn. I</td>
<td>6.50</td>
<td>104</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Original</td>
<td>6.33</td>
<td></td>
<td></td>
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<tr>
<td>Puebla Group I</td>
<td>SMC Syn. I</td>
<td>8.74</td>
<td>122</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>SMP Syn. I</td>
<td>8.78</td>
<td>123</td>
<td>23</td>
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<tr>
<td></td>
<td>SFS Syn. I(^1)</td>
<td>9.20</td>
<td>129</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>SS(_1) Syn. I</td>
<td>9.56</td>
<td>134</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>Original</td>
<td>7.14</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^1\) Syn. I = First cycle of selection  
SMC = Mass Selection (wt/plant)  
SMP = Mass Selection (Prolificacy)  
SFS = Selection among Full Sib families  
SS\(_1\) = Selection among S\(_1\) lines  
Ear corn at 0.0% moisture

It is clear that all methods with the exception of SS\(_1\) in Celaya II have resulted in significant increases in yield. In fact, the SFS Syn. I in Puebla Group I was equal in yield to the best new hybrid recommended in the region, H-366.

Lowlands of Mexico

In general it appears that flint corns yield less than dent corns. A study is under way to determine whether the apparent lower yield is due to the flint characteristic itself or to the origin of the flint germ plasm and the relatively narrow inherent genetic variability. As a basis for the study, three populations have been developed: (1) a broad based yellow Tuxpeño, (2) a broad based yellow flint from the Caribbean and Central America and (3) the cross between them.

Experience has shown that the Tuxpeño corns from Mexico and the Eto variety from Colombia are broadly adapted throughout the tropics of the world and that they contribute high productivity in crosses to numerous other races and types. A project is under way to study the value of mass selection for yield in Eto Blanco, Tuxpeño (Mix. 1 × Collima Group 1) and in the cross between the two.

In a few cases corn breeders have found that mass selection for yield in regions where corn is grown twice a year has not resulted in increased productivity. During 1966 a project was initiated at San Rafael,
Veracruz, in a Tuxpeno composite to study this problem. Two systems of selection were initiated: one involves selection during both winter and summer cycles while the second system involves selection during only the winter cycle (the main corn growing season within the region).

Tropical corns generally grow much too tall and have relatively high ear placement. The physical difficulty in harvesting such plants, as well as losses in yield and quality due to lodging, has led to the development of programs aimed at solving this problem. The methods being used involve the introduction of germ plasm from a variety of Coastal Tropical Flint named Antigua, and the Brachytic 2 gene into a population known as Tuxpeno Crema I—a composite of various Tuxpeno collections and lines. Subsequently, plant to plant crosses between short plants with good ear placement in the population have been made as a means of developing a shorter stunted population with high yield potential.

Some of the corns collected in the Caribbean area, especially of the Coastal Tropical Flint type, have shown a tendency towards prolificacy and resistance to the fall army worm, *Spodoptera frugiperda*. In an attempt to improve or concentrate these desirable characteristics, a study is under way in a composite of these varieties to compare the effectiveness of mass selection and breeding procedures make it possible to design the corn plant most convenient for each situation. At the left Juan Cisneros of CIMMYT and K. K. Mandloi of India indicate the ear placement of a Chalqueño variety at Chapingo, Mexico. The breeding trial at the right is focused on reducing plant height and lowering ear placement to avoid serious lodging problems which reduce yields.
The first year of mass selection in the composite Puebla Group I resulted in seed that produced up to 34 percent more than the original seed. Through different variations of mass selection, maize specialists have found it possible to consistently increase yields from 5 to 10 percent per year over a prolonged period. This is one of the highly promising techniques for improving genetic material.

of visual selection among inbred lines and a combination of visual selection with evaluation of full-sib progenies (plant to plant crosses).

Other tropical populations are in various stages of development as adjuncts to the Central American and Caribbean programs. Inbreds, both white and yellow, flint and dent, have been developed and increased to meet demands of various national programs. Several of these are proving to be valuable base materials for tropical corn breeding programs in Asia, Africa and the Middle East.

CHROMOSOME MORPHOLOGY

Previous studies have shown that the origin and relationships of the different races of maize in Latin America can be determined through a study of their chromosome morphology. If the wide range of variation in Latin America is to be efficiently exploited in the development of the super varieties of the future, it is extremely important that we learn more about its evolution. For these reasons, a three way cooperative project for the study of the chromosome morphology of all the different races of maize in Latin America was established among Dr. Almiro Blumenschein of the Institute of Genetics at Piracicaba, Brazil, Ing. Angel Kato of CIMMYT and the Post Graduate School at Chapingo, Mexico, and Dr. Barbara McClintock of the Carnegie Institution of Washington, Cold Spring Harbour, New York. Dr. Blumenschein is presently working on the races of maize in Brazil and Ing. Kato is working on the races in the middle American area.
At a certain stage of development the reproductive parts of the maize plant lend themselves particularly well to the study of their chromosomes under the microscope. Angel Kato demonstrates the taking of sporocyte samples of corn for cytological study. This study should help to delineate the origin and relationships of the different races of maize in Latin America and thereby provide clues for future genetic improvement.

Eighty collections of the Tuxpeño race and 137 other collections from northern Mexico, some of these not yet classified as races, were studied in 1966. The Tuxpeño data indicates this to be a new germ plasm complex carrying medium-size knobs with a probable center of origin somewhere in the State of Veracruz, on the eastern coast of Mexico. These studies also indicate that this complex has migrated to the Gulf Coast of southern USA, the Yucatan Peninsula, the interior of Mexico westward to the Pacific Coast and through Central America to central Panama. Furthermore, some strains and races from the West Indies and the northwestern Antilles (Cuba, Jamaica, Haiti and Dominican Republic) can be traced to the Tuxpeño and the southern Guatemala complexes.

This latter complex has been named the Northwestern Caribbean Secondary Complex. According to the data collected in Mexico and Brazil, it is now possible to trace the influence of this secondary complex through the Caribbean Islands to southern Brazil, Uruguay, northeastern Argentina and southeastern Paraguay.

These studies when completed will provide a much clearer understanding of the migration of the different germ plasm through Latin America.

Kato's observations indicate that large knob size is associated with homozygosis. Studies have been initiated to detect preferential segregation. Also the data obtained up to this point indicate that some strains of maize tend to accumulate a large number of B-chromosomes and studies have been initiated to determine if the number of B-chromosomes has any influence or frequency of nondisjunction.
PROTEIN QUALITY

The recent discovery by scientists of Purdue University that the Opaque-2 and Floury-2 genes increased the lysine content of the Corn Belt Dents is one of the most striking discoveries ever made from the standpoint of human nutrition in the underdeveloped areas of the world.

Dr. Ricardo Bressani of the Institute of Nutrition for Central America and Panama recently reported that the biological value of the protein in the Opaque-2 corn is about 90 per cent the value of the protein in milk. Considering that most of the protein for human food in the majority of the Latin America countries is supplied through maize, this is a tremendous breakthrough.

Certain nutrition experts have indicated that if the quantity of protein in maize could be raised to 15 per cent and made equal in quality to that produced by the two above named genes, then children would grow.

The protein laboratory is linked with both the wheat and maize breeding programs in such a way that it will be possible to handle vast numbers of samples on time to assist the plant breeders in making selection of nutritionally better materials during the second generation. Toward this goal, studies are under way to develop more rapid testing methods. Nearly any type of enzymatic or wet chemical method can be automated on the analyzer shown. Here it is being used for a semi-automatic micro-kjeldahl determination.
normally on a diet of corn as the sole source of carbohydrates and protein, supplemented only with vitamins and minerals.

This opens up new possibilities for the corn breeders throughout the world. CIMMYT corn breeders have under way a large scale program for the incorporation of both the Opaque-2 and Floury-2 genes into the most important races and varieties of maize in Mexico and Central America as well as the many different composites being sent around the world as basic breeding materials. Seeds, homozygous for the Opaque-2 and Floury-2 genes of second and third back-cross generations of certain of the populations, are being widely distributed.

A laboratory well-equipped for the determination of both protein quality and quantity has been established at Chapingo in cooperation with INIA and the Graduate School. As soon as the proper methods can be developed for the analysis of a large number of samples in a relatively short period of time, CIMMYT will initiate a systematic survey of world maize germ plasm for both protein quality and quantity. It is hoped to find additional genes affecting these two characters which can be manipulated more or less at will.

The newly discovered possibilities for breeding and selecting plants with better quality protein in sharply higher amounts, engendered the inclusion of a protein laboratory near the central headquarters of CIMMYT. The equipment includes this automatic amino acid analyzer which provides the most accurate values attainable. Housing for the laboratory is provided by the National Center for Agricultural Education, Research and Extension at Chapingo, Mexico.
INSECT CONTROL

It is a well-known fact that various species of insects cause sizeable losses in the field as well as in stored grain. In general, such losses are much more important in the tropics and sub-tropics than in the temperate zones. Although pest control through the use of insecticides is the most effective means available at present, this method has serious limitations. The development of insect resistant or tolerant varieties is one promising alternative.

One specific example of such a possibility involves resistance to the fall army worm. Resistant sources have now been substantiated by tests and observations in varieties from the island of Antigua in the West Indies.

In view of the wealth of germ plasm available in the corn germ plasm banks and the fact that a great deal of this has evolved in areas of natural infestation of certain of the detrimental insects, it should be possible to find genes for insect resistance much like genes are being found for disease resistance. To this end CIMMYT has initiated a three way cooperative project with the INIA and Kansas State University for the systematic evaluation of the wide range of germ plasm existing in Latin America for resistance to insects. A number of Mexican and North American graduate students are participating in this project and will use portions of the data obtained as theses in fulfillment of the requirements for advanced degrees at Kansas State University.

Particular attention is being given to the identification of varieties resistant to the fall army worm Spodoptera frugiperda (E. J. Smith); corn borer Zeadiatrea spp.; thrips Frankliniella occidentalis (Pergande); earworm Heliothis zea (Boddie); corn rootworm germs Diabrotica; and the rice weevil Sitophilus zeamais Mots. which does most of its damage on the mature grain.

Most of the work on insect resistance is done at Tepalcingo in the State of Morelos where land, water and other facilities are supplied by the Productora Nacional de Semillas. Here during the last two years 70 varieties from Mexico, 54 from Central America, 40 from the Caribbean region, 14 from South America and 9 from the United States of America were evaluated under field conditions for resistance to the fall army worm, stalk borers, thrips and earworm.

The reaction of the different varieties to injury by the fall army worm was estimated on the basis of the percentage of damaged plants and the amount of damage, during the season of highest infestation which occurs from December to March. The information obtained in 1966 indicated that germ plasm from the Caribbean area possesses a relatively high degree of resistance to the fall army worm.

As a result of this, during 1966 a total of 388 first generation inbred lines derived from the collections Antigua 2D and Antigua 8D were eval-
uated against fall army worm injury. The least injured lines were Antigua 2D 160-4, 160-7, 160-80 and Antigua 8D 161-6, 161-52 and 161-72. Also a mass selection plot of approximately one fourth of an hectare was planted with seed of Antigua Group 2 with the objective of developing a population highly resistant to the fall army worm.

The reaction to injury by corn borers was estimated on the basis of percentage of damaged plants, number of holes or damaged internodes per plant and number of egg masses per plant. Of importance in evaluating this kind of result has been the additional finding of significant correlation between diameter of the stalk and average number of Zeadiatrea holes per plant as well as the correlation between diameter of the stalk and number of damaged internodes per plant. This makes it clear that number of holes and damaged internodes are meaningful measures only if considered in relation to diameter of stem and total number of internodes.

The reaction to injury by thrips was estimated on the basis of percentage of plant mortality and amount of damage during the season of highest infestation (September and October). Several varieties showed a fair degree of tolerance.

The reaction to injury by earworms was estimated on the basis of percentage of injured ears and amount of injury per ear using a scale going from 1 for free of injury to 6 for severely damaged. The least injured varieties were Oaxaca Gpo. 35, Oaxaca Gpo. 18, Nicaragua Gpo. 75 and Nicaragua Gpo. 76-A, all varieties of the Zapalote Chico and Salvadoreño races prevailing on the lowland Pacific coast areas of Mexico and Central America.

The adults of the corn rootworm feed on the silks as well as on the tassels, the leaves, and the developing kernels. The search for varieties resistant to this insect requires measuring techniques such as this scale to grade the damage done to the corn silks in the field.
Feeding on the silk by corn rootworm adults may also cause a serious reduction in seed set. The above scale is used for grading the ears.

Both field and greenhouse methods have now been perfected for screening for resistance to fall army worm. More than 1,500 lines, hybrids and races were evaluated for resistance in greenhouse plantings during the last two years in Mexico and Kansas. Field tests under natural conditions at Tepalcingo, Mexico and St. John, Kansas, and under artificial infestation at Manhattan, Kansas, generally confirmed the greenhouse results.

Among 240 selections of Latin American corns tested at St. John, Kansas, infestation by second generation southwestern corn borer, Zea diatrea grandiosella (Dyar), ranged from 46 to 100 per cent of the stalks; from 0 to 89 per cent of the infested stalks were girdled. Among the 10 least infested selections, four were from Haiti, one from the Dominican Republic, two from Puerto Rico, and one each from Guadalupe, Tobago and Guatemala.

Differential Damage to Female Inflorescence of Maize by Rootworm Adults

Some of the most important pests of corn are species of the genus Diabrotica (corn rootworm). For a time, effective control was attained through the use of organic synthetic insecticides. However, in recent years large scale soil treatments using chlorinated hydrocarbons, have resulted in the development of strains of the insect which are resistant to these insecticides.
The ability of a plant to regenerate roots has been the only known type of resistance. The only exception to this is the inbred Indiana 38-11, which is believed to have an antibiotic effect on the larvae of southern corn rootworm. The introduction of this type of resistance into corn populations might bring about an overall reduction of the insect population over a period of years.

The larval stages of the rootworm are generally the most harmful because they feed in and on the corn roots. As a result, a heavy infestation will cause the plants to lodge, resulting in poorly filled kernels, rotted ears and difficulty in harvesting.

Since the adults feed on the tassel, on the leaves, on the silks and developing kernels, the search for resistant varieties to corn rootworm includes silk and kernel damage as well as root damage.

Evaluation for resistance to rootworm was done mostly in Kansas. This work was organized to obtain information about the extent and differential damage to the silks by the adults of corn rootworm, *Diabrotica* spp. principally *virgifera* LeConte. A total of 356 different corns were tested under field conditions in the summer of 1964, at the Belleville and Scandia Experimental fields both in Republic County, Kansas, and at the Agronomy Farm near Manhattan, Kansas. The strains of corn included: Kansas inbred lines, crosses of corn belt × Mexican collections, lines derived from Mexican races × corn belt materials, Mexican collections and U.S.D.A. corn rootworm uniform nursery inbred lines.

The silk feeding by corn rootworm adults was graded seven days after silking started.

Thirty entries, selected from the 1964 test of silk feeding, were planted in the summer of 1965 at the Belleville Experimental field and at the Agronomy Farm 4 miles north of Manhattan, Kansas.

In 1965 data were taken on number of corn rootworm adults present on the different corn selections made on the basis of silk damage in 1964.

The statistical analysis of the data obtained from these studies indicated significant differences among entries for silk damage, ear damage and number of corn rootworm adults present on each line (attractiveness). Correlation coefficients between these possibly related variables were calculated. The fact that the correlation coefficient between silk and ear damage was positive and significant at the 0.05 per cent level (r = 0.416) suggests that the damage to the silks by corn rootworm adults was an important factor in determining the poor seed set observed. A non-significant correlation coefficient between number of adults per plant and silk damage (r = 0.284) was obtained. Since no recuperation was observed when the silk damage was graded five days after the first
grading, it would seem that tolerance is not the mechanism responsible for resistance. The corn material classified as resistant to adult feeding included one Kansas inbred line, K166, a Kansas hybrid, K1859, a U.S.D.A. corn rootworm uniform nursery inbred line, SD10, and nine selections from crosses between Mexican and corn belt lines.

Resistance of Stored Corn Grain to the Rice Weevil

The potential value of research on stored grain insects is clear when one takes into account the general seriousness of these pests on stored grain as well as the damage to unharvested corn in the tropics.

The purpose of this study was to search for possible sources of resistance to the rice weevil *Sitophilus zeamais* Mots. in a number of corn collections by observing the rate of reproduction (number of the first generation progeny), the damage caused by parent weevils, and the attraction of parent weevils to the different corn samples.

In the search for resistance to the rice weevil, important differences were found after five months in: 1) damage, 2) the number of insects emerged and 3) amount of frass produced, between four collections of corn after being originally infested for seven days with six male and six female weevils.
The variability encountered in the shape, size and color of the kernels of corn, as well as in other characteristics not generally obvious, such as hardness, and the chemical composition of odor and flavor about which relatively little is known, may be important aspects in determining genetic resistance.

The methods of testing were developed with seed of Palomero Toluqueño, Cacahuacintle and the Mexican hybrid H-24 using the Mexican strain of the larger rice weevil. Six male and six female weevils gave the best information and this was the number used later with 40 kernels from each sample, for all the no-choice tests. When kernels from several kinds of corn were mixed together in a free-choice test, the total number of weevils emerging increased as the number of parent weevils increased. However, the relative order of susceptibility remained quite constant.

Seventy-four open-pollinated and 65 sib-pollinated Latin American corn collections were tested on a free-choice and no-choice basis. It was found that weevils are able to detect differences in individual kernels, but it was not clear whether the differences in number of weevils which emerged was due to differences in oviposition or to larval survival.

Most of the tests showed statistically significant differences among strains of corn. The best measure of resistance in both free-choice and no-choice tests was the number of weevils which emerged.

An approach to biological analysis of resistance was carried out by using tests in which the weevils emerging from different corn collections were deprived of food to determine the length of life under starvation conditions and to determine the body weight of weevils on emergence.

The corns showing some resistance to rice weevil were: Palomero Toluqueño, Chiapas Gpo. 18, Antigua 2D, Antigua 8D and Yucatan 108.
The range of problems confronted in maize production around the world called for a central research establishment and coordinating headquarters, supplemented by regional programs and cooperative national activities. This map shows central headquarters (HQ) and present regional programs in the Andean zone (AR), East Africa (EAR), inter-Asian region (IAR) and Central America and Caribbean region (CAC). The slender lines emanating directly from HQ indicate the cooperating national and international programs.

CENTRAL AMERICAN PROGRAM

Cooperative work in the improvement of maize was started in Central America in 1954. The progress made in this program during the last 13 years is a striking example of what can be done by a few trained men in different countries when they work together as a team. Through the cooperative efforts of a relatively small group of maize specialists, and with the aid of materials, technical assistance and leadership provided by the Rockefeller Foundation through its Mexican and Colombian agricultural programs and more recently through CIMMYT, improved varieties greatly superior to the native ones are now available in all of Central America and Panama.

The maize work has been so successful that other basic food crops are being included in the program and the name has now been changed to Central American Cooperative Basic Food Crop Improvement Program. The success of the work in varietal improvement is stimulating a similar pattern in soil fertility, control of insect pests and plant diseases. The positive research results have led each country to initiate some form of production program to convince and assist farmers to adopt the new practices.
CIMMYT is continuing to supply basic material and technical assistance and has expanded the cooperative work to include Jamaica and the Dominican Republic in the Caribbean area.

Each year a meeting of all participants is held in one of the cooperating countries. More than one hundred people attended the annual regional meeting held in March, 1966, at Managua, Nicaragua and a similar group attended the 1967 meeting in San José, Costa Rica. The reports at these meetings covered both research results and promotional campaigns to increase the rapidity of farmer adoption of new techniques.

Within the cooperative trials, new varieties of corn are evaluated in a three-step sequence. Promising new hybrids or varieties are first planted in an unreplicated uniform observation trial. The next year those that show promise are included in a regular yield trial of "experimental varieties". Those varieties which will be released or readied for commercial use are then included in a second uniform trial and tested in the six Central American countries for two successive years. The following table summarizes data from Central American trials grown at 15 locations during 1965 and 1966.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Origin</th>
<th>Kg/ha</th>
<th>Days to flower 1</th>
<th>% of tester 2</th>
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<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
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<td>Mexico</td>
<td>4172</td>
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<td>103</td>
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<tr>
<td>H-507 (Tester)</td>
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<td>4035</td>
<td>61</td>
<td>100</td>
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<tr>
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<td>Venezuela</td>
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<td>Local Variety</td>
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1 Averages for first planting cycle (spring) for 1965-1966.
2 Averages within the three groups of varieties—late, intermediate and early.
In experimental plantings, successful hybrids from other regions often suffer severe loss in Central America through damage by the corn stunt virus. This photo shows Humberto Tapia taking observations on resistance and susceptibility in plantings at La Calera experimental station in Nicaragua. A program is also under way in Salvador to select for resistance to this virus.

One CIMMYT staff member works closely with the corn breeders in the countries of Central America and the Caribbean. The success of the Salvadorian program is exemplified by these variety yield trials at San Andres conducted by Jesus Merino Argueta.
The late varieties are unable to express their true yield potential when tested over all stations due to moisture stress. The intermediate maturity varieties seem to be generally indicated for most areas. The hybrid H-5 from El Salvador has proven to be an excellent compromise when considering all locations in the area. Its pedigree involves two inbred lines from Tuxpeño from Mexico and one each from Cuba 23 and Cuba 18 derived in El Salvador.

The hybrids from Mexico are the most productive in areas with favorable moisture, but tend to be high risks in those areas with a short rainy season. They are also relatively susceptible to the stunt virus disease. The semi-flint hybrid was formed in Mexico to meet the demand for slightly harder endosperm characteristics in Central America. The Poey hybrids, T-23 (white) and T-66 (yellow), are widely sold in the area and have been giving good results.

Among the experimental varieties tested during 1966 were groups of hybrids from Pioneer and DeKalb. The Pioneer hybrids performed very well. The DeKalb hybrids appeared to carry germ plasm not well suited to tropical conditions. Also tested were varieties from Colombia including Amarillo Theobromina, Blanco Theobromina and Amarillo de Monteria. These materials were poorly adapted in the lowland tropics of Central America. Several experimental hybrids from Venezuela of the FM 6 series looked very promising from the standpoint of maturity and agronomic characteristics but were susceptible to the stunt virus.

The recurrent selection program to concentrate resistance to stunt virus was continued at Santa Cruz Porrillo in El Salvador. Present levels of field tolerance appear to be of practical value in stunt-affected areas. Whether variants strains of virus occur in different areas that may affect the apparent field tolerance of these varieties is not known. This problem will be investigated by growing the populations developed in El Salvador in all six countries during the coming year.

In the Dominican Republic seed is being distributed to farmers from two varieties developed by mass selection from a local corn and from a mixture of Cuban and Mexican germ plasm. Here Leon Smith and Juan Henderson inspect variety trials at the Agricultural School near Santiago.
Seed distribution is a key problem in the use of hybrid corn. Here Jesus Merino Argueta, El Salvador, and Adolfo Fuentes, Guatemala, inspect seed produced at San Andres which will be certified by the Salvadorian Ministry of Agriculture and sold to farmers.

In Jamaica CIMMYT is cooperating with the Ministry of Agriculture in the improvement of open pollinated varieties and in the development of more suitable agronomic practices. Nearly all of the corn is grown on small hillside plots. Low yields result from generally poor cultural practices, including lack of fertilization, insect and weed control. Along with the varietal improvement work, a research and demonstration program is under way which is showing farmers how yields may be improved.

Two improved varieties show considerable promise. One was derived from a composite of a large number of varieties from the Caribbean and the other from a composite of local Jamaican and introduced Cuban corns.

In the Dominican Republic CIMMYT is cooperating with both the Ministry of Agriculture and the Fundación Dominicana de Desarrollo. The cooperative breeding program is concerned primarily with the improvement of open pollinated varieties. Mass selection is currently under way in three composites. One composite is entirely of local corns, a second of Cuban and Mexican varieties and the third is made up of half local and half Cuban germ plasm. Seed of two improved varieties developed from this material is now being distributed to farmers and is being used in demonstration plots throughout the country. Yield trials in several locations have shown the Cuban by local germ plasm composite consistently more productive than the local varieties, and it has been rapidly increasing as a commercial variety on the Island.

In the Dominican Republic, as in Jamaica, the greatest need is for improvement in cultural practices. An extensive demonstration program in which improved seed is combined with adequate fertilization and proper control of insects and weeds is showing striking increases in yields over the traditional methods.
The CIMMYT representative in the Andean zone has his base at Bogota and works closely with the maize breeders of the Instituto Colombiano Agropecuario. These experimental plantings for the improvement of maize in Colombia are at the Tulio Espino station near Medellin.

Basic seed stocks produced in Colombia have been supplied to five countries in South America and Africa for direct use in the production of commercial seed. Some 20 other countries have received seed for testing. Corn plots at Tulio Espino, Medellin.
ANDEAN ZONE

The maize breeding program in the Andean region of South America is helping to weld together into cooperating units the various national research programs. Scientists in each national program have become conscious of the problems of their neighbors. The manifestations of this mutual concern are found in the free exchange of information as well as in the willing interchange of basic genetic stocks, tested inbred lines and seed of promising new improved varieties for cooperative testing throughout the area.

Research Activities

Extensive regional testing of basic breeding stocks of maize was possible in 1966. These experiments were designed to assist the plant breeders in the selection and evaluation of the best genetic materials available. One of these experiments consisted of 14 varieties, each known to have certain valuable traits and the 91 possible crosses among them. Yield data were summarized for various environments in Venezuela, Colombia, Ecuador and Peru. These results continue to support previous data which have indicated that the Cuban Flint variety from Colombia, Nariño 330, is highly useful. The averages of crosses to this variety were the highest over all environments and were never lower than fourth place when any one experiment was considered. The highest specific combinations were also with this variety in five out of the eight environments sampled.

As a result of the data obtained from this series of regional trials, new composites of basic breeding stocks are being disseminated widely to maize breeders throughout the tropical areas of South America, Africa and Southeast Asia.

Unfortunately, yield is not the only factor to be considered in maize improvement at any specific location. Plant type, grain type and resistance to yield reducing factors, such as attacks of disease and insects, all enter into the final worth of a variety or hybrid. Ing. Julio Cabrera, maize breeder in Ecuador, has made significant progress towards decreasing the ear and plant height of the maize being grown in western Ecuador by crossing the adapted local variety V.S.-2 to genotypes of Cuban and Coastal Tropical Flint origin. In the advanced generation of these crosses it was found that ear height had been reduced as much as 50 to 60 centimeters while the yield of the mixture was equal to that of V.S.-2. This lower ear and shorter plant makes it easier to harvest, more resistant to lodging and permits a higher plant population per unit area, thus tending to increase yields. Mild mass selection pressure has been combined with a simultaneous seed increase program to rapidly make available these improved materials. This material will also provide the Ecuadorian program with useful genetic stocks for future breeding and selection.
For Peruvian hybrids Ing. Federico Scheuch also has utilized Cuban materials as a source of inbred lines to maintain acceptable plant types in conjunction with high yield.

On the north coast of South America, particularly in Venezuela, the greatest increases in yield have come through the use of Eto Blanco germ plasm from Colombia in combination with the Tuxpeño race of Mexico. Work with these stocks started in Venezuela by Dr. Alfredo Carballo is being continued by Ing. Pedro Marcano within the Foremaiz organization.

A new variety derived from these materials through mass selection was recently put into commercial production in Venezuela. This variety designated EX-1 is widely adapted to the central part of the country and has already received enthusiastic reception from maize producers. In yield trials conducted by Foremaiz in 1966 at 11 locations in Central Venezuela, it has yielded nearly as well (4.3 ton/ha) as the two double cross hybrids F.M. 4 (4.4 ton/ha) and Obregon (5.0 ton/ha).

Varieties of the races Cuban Flint from the Oriente province of Cuba, Eto of Colombia and Tuxpeño of Mexico have proven to be most useful in the further improvement of maize throughout the lowland areas of the Andean zone. Inbred lines developed from composites of these varieties have consistently outyielded inbred lines from other sources in topcrosses tested in the lowlands of Colombia. In the Peruvian lowlands the highest commercial yields have been obtained with hybrids resulting from crosses between lines derived from Cuban and Perla Flint varieties.

In the highlands at the Santa Catalina experiment station in Ecuador, Ing. Alex Paez obtained substantial increases in yield from crosses among a highland Flint variety, Blanco Rubí from Colombia, a variety of the Chalqueño race in Mexico, Rocamex V-7, and the multiple ear selection from the floury variety Harinoso Mosquera from Colombia. The five best crosses involving these varieties averaged 20 per cent higher yield than the commercial varieties now grown at high elevations in Ecuador.

Corn breeders at Tibaitata in Colombia have worked with this combination of germ plasm for a number of years and have developed from it two varieties which appear to be widely adapted to the high altitudes of both Colombia and Ecuador. These varieties are ICA V-503 and ICA V-552.

ICA V-503 is a product of mass selection for multiple ear plants in the local variety Harinoso Mosquera. The multiple ear version of this variety yields 20 percent more than the original. This is a relatively simple and inexpensive method of utilizing yield components in maize breeding.

ICA V-552 was produced by mass selection in the advanced generation progeny of a cross between Blanco Rubí, a white Flint variety from Colombia, and Rocamex V-7 from Mexico.
In 1966 Manuel Torregroze (left) was named director of the national maize breeding program of Colombia. Dale Harpstead (right) who previously held this position, is now dedicating full time to the Andean regional program.

Distribution of Seed from Colombia

During 1966 basic stocks of maize produced in Colombia were supplied to five countries in South America and Africa for direct use in production of commercial seed. In Liberia the variety known as Cuba 312 was immediately put into production as a commercial variety. Prior to its production in Liberia the only seed available was that maintained as a part of the germ plasm collection in Colombia. The varieties Eto Blanco and D.V. 254 developed by Colombian breeders are now being commercially grown in Ghana.

Approximately twenty other countries of the world have received seed from Andean regional program for testing and use for varied purposes. Some of these uses have been highly specialized such as the use of Andean highland varieties to increase the cold and frost tolerance of maize in Europe, Canada and northern United States. Also many of the Andean varieties have proven to be good sources of genes for producing a thick stalk rind, a trait closely associated with resistance to stalk lodging in maize. Some of these genes have been brought together in a special variety with the help of Dr. P. L. Crane who spent a year in Colombia on sabbatical leave from Purdue University. This variety is available to any one interested.

Rust Resistance in Colombian Maize

Data on resistance to maize rust _Puccinia polysora_ has been reported from Nigeria and Jamaica. In both countries lines and varieties tracing
to germ plasm which evolved in the north coast area of Colombia were highly resistant to prevalent races of this fungus. In Colombia these materials have now been combined into composites designed to provide a more useful base for further selection in areas where this disease seriously limits maize production.

**High Lysine Maize**

Considerable interest has developed in the use of the Opaque-2 and Floury-2 genes to increase the lysine content of the maize grain. In Colombia a backcrossing program to incorporate these genes into the lines of the best adapted hybrids was begun in 1964. By 1966 a total of 1200 kilos of seed had been produced of a locally adapted hybrid, D.H. 253, containing the Opaque-2 gene in all of its component inbred lines. This seed was released for planting by various commercial organizations and industrial consumers of maize to permit them to become familiar with the production and proper utilization of the high lysine product.

The Opaque-2 gene has also been incorporated into some of the outstanding open pollinated varieties and composites which are widely adapted in the lowland tropics. Seed of this converted material is already in use in the Andean region, Argentina and Brazil. Furthermore, Nigeria and Uganda have incorporated these stocks into their breeding programs.

A field day to demonstrate maize with the Opaque-2 gene drew about 100 interested persons to the Palmira station in January 1967. Among those attending were representatives of the National Institute of Nutrition of Colombia, professors, research nutritionists, students from major universities, a delegation from the U.S.A.I.D. Mission to Colombia, members of the Medical Faculty of the Universidad del Valle, Cali, representatives of the major industrial consumers of maize in Colombia and members of the Colombian Agricultural Research Institute (ICA).

**Regional Conferences**

In May of 1966 twenty-five maize breeders from Venezuela, Colombia, Peru and Ecuador assembled in Quito to review their progress and to prepare future cooperative plans. Invited guest speakers to this program included Dr. J. H. Lonnquist from the University of Nebraska, Dr. J. E. Grafius from Michigan State University and Dr. R. D. Osler from the CIMMYT headquarters in Mexico.

Dr. Lonnquist presented two formal lectures in which he developed the theoretical concepts of genotype by environment interactions and how these could be handled in an applied breeding program. Since certain factors of the environment can be controlled, Lonnquist emphasized the importance of adequate testing under conditions in which the final production will be used. He pointed out the danger of selecting genotypes highly specific to experimental conditions if these same conditions do not exist in the areas of commercial production. The danger may be
avoided by: (1) testing the materials in several seasons, (2) testing the materials in regional tests away from the experiment station and (3) planting experimental units earlier or later than the normal growing seasons to sample a greater segment of a particular environment.

Dr. Grafius outlined the ways in which the various parts of the plant, both morphological and physiological, contribute to yield. Within the plant these can be determined by different genetic systems which function at different times during the ontogeny of the plant. Grafius compared the yield of a particular plant to the volume of a cube which is determined by the length of the sides of the figure. If one component determines a larger proportion of the yield than another, or is more stable over varying environments, this is valuable information for the plant breeder to recognize and utilize. He proposed several plant breeding models through which a breeder could take advantage of yield components and apply them to the problems of breeding and selection.

Dr. R. D. Osler outlined the projected areas of activity of the International Maize and Wheat Improvement Center in Mexico and emphasized the need for cooperative programs to enable maize specialists to be effective over a much wider geographical area.

Participants in this conference agreed to establish further cooperative breeding and testing activities designed to make maximum use of the wide range of environments which exist within the Andean region. Three new germ plasm pools were established to augment those already in use in the region. Seed from these pools will be sent to locations where it is most likely to be useful.

Representatives of governments, universities and industries attended a field day at Palmira, Colombia, to learn about the Opaque-2 gene being made available in commercial maize seed for planting and testing. Daniel Sarria, who recently received an M.S. degree from the Graduate College at Chapingo, Mexico, explains the backcrossing technique used to transfer the Opaque-2 gene to inbred lines.
Training Activities

Colombia has served as host country for trainees from other areas in the Andean region and has shared with them both the theoretical and applied achievements attained within the various maize improvement programs. These students have received their training by entering into the total activities of the national maize program.

Substantial progress has been made in the integration of teaching and research activities at the university level. Approximately 15 students from Colombian universities are working on undergraduate theses at the various research centers. An estimated 30 additional students are working on similar projects in other countries of the Andean region. Formal university classroom instruction is also provided by personnel from the maize breeding programs in Venezuela, Colombia and Peru.

The inter-Asian program now headquartered in Thailand includes South-east Asia, India and Pakistan. Here, A. G. Bhatti (left) and one of his assistants check ear formation on an experimental yellow synthetic. Yusuf-wala, West Pakistan.
INTER-ASIAN PROGRAM

The headquarters for the Inter-Asian Maize Improvement Program (IACP) was shifted from India to Thailand during 1966, where its work in research and training is being merged into the Thai National Corn and Sorghum Improvement Program.

The IACP station located in northern India on the lands of the Uttar Pradesh Agricultural University, at Pantnagar, will continue to function as an important part of the inter-Asian research and training. The climate of Thailand is typical of the lowland tropical areas whereas that of northern India is more representative of the higher altitudes and drier semi-tropical plains of Asia. Efforts at Pantnagar will be devoted primarily to the development of genetic materials for the higher altitudes and dry plains of Pakistan, Nepal and northern India. Work in Thailand will be directed principally toward the development of materials adapted to lowland tropical areas such as those in the Philippines, Vietnam and Malaysia. Also by alternating the planting of certain materials between these two areas, more broadly adapted varieties may be developed.

Most tropical corn is too tall and matures at a time when heavy rains and strong winds often cause severe lodging. For this reason an effort is being made to develop shorter materials through selection for short types and through the incorporation of the br2 (brachytic) gene. This program was started several years ago and has now progressed to the point where a wide range of comparison tests can be made in 1967 to evaluate the effect of the br2 gene in various germ plasm backgrounds.

The br2 gene has been incorporated into the better tropical germ plasm complexes and a series of inbred lines in India is now in a position to produce br2 versions of several hybrids.

Over the years it was noted that heterozygous Br2/br2 genotypes were slightly shorter and stronger stalked than the homozygous Br2/Br2 forms. This observation prompted the breeders to develop stocks which would make it possible to compare Br2/Br2, Br2/br2 and br2/br2 genotypes within five different germ plasm complexes. Certain varieties of the Coastal Tropical Flint race of the Caribbean have also been used extensively in the attempt to reduce plant height. One of the varieties that has been found to be especially useful for this purpose is Antigua 2D.

Tests were conducted during 1966 to determine the degree of heritability of the multiple ear character and the ease or difficulty of transferring it into one eared types. Sp2 and Georgia Cow Corn were used as multiple eared parents. Amarillo-de-Cuba and Cuba 11J served as the predominantly single eared parents.
The new J1 synthetic variety developed by the coordinated maize scheme in India from a composite of Cuban and Coastal Tropical Flint combined with a certain amount of germ plasm from the Corn Belt of the United States, appears to be well adapted to most of the corn area of West Pakistan. Here a West Pakistani farmer demonstrates his field of J1.

**Evaluation and Multiplication of Germ Plasm**

Since the inception of IACP in 1964 a total of 1917 types of material have been received from different parts of the world and are being maintained and evaluated. From this germ plasm pool, 246 types of field corn, 52 types of sweet corn and one type of pop corn were multiplied and 310 new introductions were planted at Pantnagar for observation and maintenance during the Kharif (rainy) season of 1966. Types which were outstanding in yield performance, disease resistance and other desired characters are being utilized in further breeding programs.

**Selection for Earliness in High-Yielding Composites**

Cuba 11J, Antigua 2D and J1 have proved to be well adapted across large areas of the tropics and semi-tropics; however they are later in maturity than preferred by most growers. An attempt is being made with special breeding methods to increase yield and uniformity in each of these populations and to shorten their growing period.

**New Synthetics and Composites**

The IACP station in Pantnagar is stressing the development of broad based composites for high altitude areas. A large amount of material is being tested at high altitude stations in India in cooperation with the Coordinated Maize Improvement Scheme and in other similar areas of Southeast Asia.
The following material has been released for cultivation in Nepal through the cooperative efforts of the IACP: (1) Advanced generation progeny of Antigua 2D × Guatemalan, a variety developed in Guatemala from a mixture of Cuban and Coastal Tropical Flint, (2) Advanced generation progeny of Antigua Gpo. 2 × Guatemalan and (3) J1. J1 was developed by the Coordinated Maize Scheme in India and has also been released in West Pakistan where it is reported to be doing very well.

Introduction of the Opaque-2 Gene

A conventional backcross program was initiated in 1964 to introduce the Opaque-2 gene into many of the materials adapted to Southeast Asia. After two generations of backcrossing, many of the populations show real promise.

New Philippine Varieties

The College of Agriculture of the University of the Philippines conducted field evaluation tests on a group of materials that had been involved in a population improvement program. From this material three varieties

M. Shaw (left) and E. W. Sprague, director of the inter-Asian program of CIMMYT, check the harvest of a new white synthetic developed for the Peshawar area of West Pakistan.
were released in 1966. UPCA-Var 1 is a yellow variety developed from Caribbean yellow flint; UPCA-Var 2 was developed from intermediate white Syn III and UPCA-Var 4 was developed from a late white synthetic population. These three varieties are superior to any previous released hybrids or varieties in the Philippines.

Downy Mildew continues to be a serious problem in the Philippines and Taiwan and now threatens the corn industry in both countries.

Workshop and Training

The third Inter-Asian Corn Improvement Program Workshop was held in New Delhi, India, in October of 1966. Participants from seven Asian countries joined in a week of discussions and field trips. At the meeting Pakistan invited the group to meet in Lyallpur in 1967.

Training has been initiated by the Inter-Asian Corn Program in maize breeding and production technology including seedbed preparation, weed control, water management, use of farm equipment and collection and summarization of data.

During 1966 six staff members of the research project of Nepal were enrolled for six months of in-service training. The trainees are considered as part of the research team and have important responsibilities in developing the program.
Through a combination of local and Latin American varieties, the yield capacity of Kenyan corn has been increased by 40 percent. The photo shows ears of an inter-varietal cross between the local dent, Katali II, and the Ecuadorian flint, EC573.

OTHER REGIONAL AND INDIVIDUAL COUNTRY PROJECTS

East Africa

Maize is one of the basic food crops of the nine million inhabitants of Kenya in East Africa. Since 1963 the maize breeding program of the Kenya Department of Agriculture has been expanded with funds provided by the Rockefeller Foundation. Outstanding progress in varietal improvement has been achieved through crosses of local materials with those obtained from Mexico and Colombia. The new hybrids developed from a combination of these materials are yielding up to 40 per cent more than the improved varieties developed from the local Kitale Flat White variety.

The successes in Kenya in the development of superior varieties and improved cultural practices are forming the base for a new regional cooperative maize improvement program in East Africa. This broader

Varieties of the Mexican Tuxpeño race are providing a new base for maize improvement in Nigeria. These trials are being conducted by the Department of Agriculture of the University of Ibadan.
Although the principles of successful corn production are the same the world over, the yield limiting factors vary greatly between locations. Field testing of a wide variety of germ plasm is a rapid way to locate materials with needed disease resistance and yield capacity. When the most promising material has been located, selection and crossing may give additional yield increments.

The improved varieties in Kenya are getting rapid distribution through seed producers such as this one, proud of his product.
program will be coordinated by Michael N. Harrison who joined the CIMMYT staff in March 1967. Mr. Harrison has worked in maize improvement in Kenya since 1955 and is well acquainted with the problem of maize production in East Africa.

Nigeria

CIMMYT is continuing to collaborate with the University of Ibadan, Department of Agriculture, in the development of better maize varieties for Nigeria. A large number of tropical varieties from Mexico, Central America, the Caribbean, Colombia and Venezuela are being evaluated separately and in combination with local materials. Results indicate that many of these exotic varieties can significantly increase corn production in Nigeria and in other areas of Tropical West Africa if grown under proper management.

Egypt

A cooperative maize improvement program was initiated in Egypt in 1966. This is a three-way cooperative program among the Ministry of Agriculture, CIMMYT and the Ford Foundation. The CIMMYT provided an agronomist on loan from the University of Wisconsin as coordinator of the project, FAO provided a corn breeder and the Ford Foundation provided the services of an irrigation specialist. These three scientists joined with a number of competent Egyptian scientists to form a team which should double corn production through a well integrated program of varietal improvement, adequate fertilization, efficient water use and control of insect pests and diseases. The program was off to a good start when war broke out in 1967. A large number of promising varieties developed from combinations of local and Latin American germ plasm are in yield tests planted in June 1967. Experiments to determine fertilizer and water requirements for high yields under prevailing climatic conditions were planted at the same time.

South America

In addition to helping with the improvement of corn in the Andean area, CIMMYT's geneticists and soils specialists are collaborating with scientists in Chile, Argentina, Uruguay and Brazil. Different breeding methods are being evaluated in a cooperative project with the Institute of Genetics at Piracicaba, Brazil. Promising new composites of various Latin American maize races are being formed in collaboration with maize breeders at Pergamino in Argentina. The maize breeders at the Instituto Agronomico at Campinas, Brazil, have used germ plasm received from Mexico and Colombia to make striking advances in improving the yield capacity of Brazilian hybrids.
Mexican dwarf wheat varieties are becoming potent arms in man's war on hunger. Although these varieties originally were developed by the Cooperative Wheat Improvement Program of the Mexican Ministry of Agriculture and the Rockefeller Foundation to solve Mexico's wheat production problem, within the past few years they have "gone international". They are now being grown in many different countries. Their outstanding yield performance when properly cultivated is now bringing new hope to farmers and governments in food deficit countries in many parts of the world.

During the 1967-68 crop year the Mexican dwarfs will be grown on an estimated 12 to 15 million acres in fifteen different countries. The total area that will be sown to these varieties next year in different countries of the world will be six times greater than the area sown to them in any given year in Mexico, their country of origin. It is significant to find that varieties which were developed to solve a national food production problem may have even greater direct application in many distant countries where hunger is a chronic and ever more acute problem.

During the 1967-68 crop cycle it is estimated that approximately 14 million acres will be sown to Mexican dwarf varieties in India, Pakistan and Turkey. Moreover, considerable commercial acreage will be sown in Guatemala, Afghanistan, Kenya, Nepal, Rhodesia, South Africa and southwestern U.S.A. Smaller commercial plantings, which will serve primarily for seed multiplication, will be sown in Cyprus, Denmark, Iran, Iraq, Lebanon, Libya, Morocco and Tunisia.

The establishment of CIMMYT in 1963 formalized the responsibility for extending the plant materials and knowledge which had been developed in Mexico to other parts of the world. This was not entirely a new departure. The preparation for this change in program orientation had evolved gradually over the years. Many young scientists from Asia, Africa and Latin America had been trained in the Mexican and Colombian wheat programs. Numerous lots of experimental wheat seed had been distributed to other countries. The International Spring Wheat Yield Nursery, which is now grown in more than twenty countries, had been launched. These activities were all part of this preparation. During the past two years, however, CIMMYT has worked directly or indirectly with the scientists and governments of 28 different nations on wheat research.

The goal — more and better quality food. In the Near East, unleavened wheat bread fills the same nutritional role as the corn tortilla in Latin America.
and production problems. In this effort it has collaborated with international agencies such as FAO and U.A.S.I.D., with universities and with many national agencies engaged in wheat research and production activities.

PROSPECTS FOR INCREASING WHEAT PRODUCTION IN ASIA, AFRICA AND THE AMERICAS

The Mexican dwarf wheat varieties have now clearly demonstrated their catalytic value for changing the wheat production in both Pakistan and India. Approximately 800,000 acres of Mexican varieties were grown in India and 500,000 acres in Pakistan during the past season. This included the varieties Penjamo 62, Pitic 62, Lerma Rojo 64, Sonora 64 and selections from Cross No. 8156. Results were highly favorable. The full impact of this development will become evident during the 1967-68 crop cycle in both countries.

Seed of the Mexican dwarf wheats alone will not solve wheat production problems in a traditional agriculture in a developing country. All of the important interacting production factors must be manipulated simultaneously and favorably before yields can be increased appreciably.

CIMMYT wheat breeding material has been extended around the world. On this map the small dots, each representing roughly one million bushels of wheat production, indicate the major producing areas. The large black dots show the locations of the CIMMYT international yield trials during 1966-67. The shaded areas are countries using materials of CIMMYT origin on commercial acreages.
This includes the introduction of proper land preparation, the use of the proper kinds and amounts of fertilizer, proper method, rate and date of seeding, adequate control of weeds and insects, and adequate and timely irrigation.

Pakistan and India imported, along with the seed of the Mexican dwarfs, the scientific information and wheat production experience that had been acquired by the CIMMYT technical staff over the past two decades in Mexico, Colombia and Chile. Supplemented by limited adaptive local research that was conducted in both Pakistan and India to check the validity of the Mexican data under local conditions and to improve on their efficiency, this experience has saved many years of time. By this procedure these two countries have the possibility of increasing their wheat yields in five years to a level that required 15 years to accomplish in Mexico.

CIMMYT scientists have insisted on applying the entire package of improved cultural practices wherever the dwarf varieties were being introduced. Heavy rates of fertilization, such as 120-40-0, were used instead of the maximum of 40-40-0 that was used previously by progressive farmers on the tall Pakistani and Indian varieties. The yield results have been spectacular wherever the package of recommendations has been applied. Many “package plot” demonstrations have produced yields of 5,000 to 8,000 kilos per hectare in contrast to yields of 600 to 2,000 kilos in the plots grown with tall varieties and employing traditional methods. The traditional ideas concerning wheat culture and wheat yield potentials, that have been held by peasant farmers, government officials and even scientists, have come down in shambles in the light of the past season’s results. Enthusiasm is now rapidly replacing despair. The governments are being pressured by the farmers for more fertilizer and more credits.

Both governments are committing themselves to the whole-hearted support of the package programs. They have committed themselves to removing the economic road-blocks that are still restricting wheat production. These include the establishment of incentive prices for wheat grain, assuring the availability of adequate stocks of the right kind of reasonably priced fertilizer at the village level and the establishment of adequate credit to assist the farmer to purchase the new inputs that are necessary to revolutionize his production. The demands for these changes now come from the “grass roots” of society —the millions of peasant farmers who have seen that their life can become better with the adoption of a new “package” of inputs and who are bringing strong political pressure on the governments forcing them to act.

Within the past two years there has been a great swell of enthusiasm among both scientists and farmers as they have observed the level of yield increases from the Mexican dwarf varieties when they are properly cultivated. In the following paragraphs the developments are indicated in some detail for a number of countries that are now in the vanguard of the wheat production revolution.
THE CATALYST
A high-yielding, disease-resistant, dwarf variety which has the ability to respond to water and fertilizer.
Whether raised with an ox-driven water wheel, or from a tube well with a motor-driven pump, or brought by a canal such as the one in the photo being built for the Mangala project in West Pakistan, the important thing is that there is enough water, evenly distributed, and on time to allow the plant to express its full yield potential.
A GOOD SEED BED
Plow deep and plow well. The power of the tractor permits more timely preparation and saves days of labor. But the end result is the important thing --- a deep well prepared seed bed where the plant can put down deep roots to use the water and nutrients of the soil.

LEVEL LAND
Adequate water distribution requires level land. Breaking up the big lumps provides a bed where seeds can be planted at a uniform optimum depth --- neither buried nor exposed. However, adequate land leveling is more than this --- it is the preparing of a completely leveled or contoured field, permitting uniform water distribution.
PROPER PLANTING
A uniform stand of plants can only come from a correct rate of seeding at the right depth. Varieties differ in tillering ability, but all will tiller more profusely when well-irrigated and heavily fertilized. The new dwarfs do best when sown not more than two inches deep as the dwarf plants have short coleoptiles which are not able to emerge from deep plantings.

FERTILIZER
After centuries of cropping and receiving little manure, the soils of traditional agriculture are depleted. Without fertilizer the new varieties remain an unexploited potential. With fertilizer ...
THE RESULT

... with fertilizer, water and good seed properly planted, yields of three and four tons per hectare are becoming commonplace. Good farmers are aiming at seven and eight tons per hectare, more than 100 bushels per acre.
Pakistan

Pakistan embarked on its Accelerated Wheat Improvement and Production Program in mid-1964. This is a cooperative program sponsored by the Government of West Pakistan, with the wholehearted support of the Central Government and with the assistance of the Ford Foundation. The Ford Foundation gives financial and technical assistance to support this program through a grant to CIMMYT. Mr. Haldore Hanson, the Ford Foundation representative in Karachi, has provided unique overall guidance. Dr. Ignacio Narváez, of Mexico, is contracted under the CIMMYT grant to serve as resident consultant and adviser to the government of West Pakistan on this program. The wheat program director of CIMMYT also serves in an advisory capacity to the program.

When the program was initiated in 1965 with the importation of 350 tons of Penjamo 62 and Lerma Rojo 64, it was believed that Pakistan could become self-sufficient in wheat production by 1970 if the “package approach” were adopted and vigorously executed. At the end of the 1966-67 season the program is two years ahead of schedule. The results during the past year were highly satisfactory, and in some cases spectacular.

Today a general enthusiasm and optimism has replaced despair. This is true of government officials, scientists and the farmers.

During the past year four ton per hectare yields were common on many farms where Mexican dwarfs were grown commercially under the package program. Five ton per hectare yields were harvested on many farms and even six, seven and eight ton yields were harvested on small areas on a few farms. Yields of less than three tons per hectare were rare, and confined to farms and farmers who looked for magic in the dwarf seed alone without applying the whole package of improved practices.

If the country is successful in bringing sufficient fertilizer, especially phosphates, through the crowded port of Karachi and having it distributed to the village level by mid-October, Pakistan has a good chance of becoming self-sufficient in wheat production during the 1968 harvest.

President Ayub Khan and his cabinet members have given their full support to the Accelerated Wheat Improvement Program. The government is regimenting its economic and technical forces to achieve this objective. It is continuing to encourage the drilling of more shallow tube wells by both the private and public sectors. It has been giving high priorities to importations of adequate quantities of fertilizers. Better methods of fertilizer distribution and more credits for fertilizer purchases are being organized.

Pakistan has recently imported from Mexico 42,000 tons of seed of the dwarf varieties Super X and Siete Cerros, both from the cross 8156,
since these two newer varieties outyield the first introductions, Lerma Rojo 64 and Penjamo 62, by approximately 20 percent. This operation represents the largest single purchase of wheat seed ever negotiated anywhere in the world. The government has already established incentive floor prices for wheat grain for the 1967-68 planting season. It is already organizing lines of credit to defend these floor prices for wheat in those areas where large increases in production are likely to glut the market. Warehousing capacity is being increased as rapidly as possible.

The Pakistan government now realizes it has a dynamic revolution in wheat production under way. This revolution is already well advanced and is beginning to spread to other crops, especially rice and maize. In all probability it will also soon spread to sorghum, millet and cotton.

The government realizes that vast capital investments are required to expand fertilizer plant production capacity if the agricultural production revolution is to be propelled forward on schedule. It is now vigorously encouraging the expansion of fertilizer production capacity by both government and private sector investments. Many of the new fertilizer plants are being financed by joint Pakistani and foreign private capital.

If Pakistan can become self-sufficient in food production within the next three years, its efforts and methods will serve as an effective model for many of the hungry nations of the world.

While Pakistan is exploiting the use of high yielding semi-dwarf varieties from Mexico, it is developing an aggressive wheat breeding program of its own. The Pakistan program has now advanced to the second phase, namely, exploiting varieties reselected in Pakistan from Mexican breeding materials. Among the most promising varieties are two high yielding varieties: Indus 66, a red grain type, and Mexipak 65, a white grain type reselected from the cross No. 8156 (Penjamo sib × Gabo 55) which was introduced from Mexico as a segregating population. These two varieties, similar to Super X and Siete Cerros from which they were reselected, are capable of outyielding by 20 percent the direct earlier introductions, Penjamo 62 and Lerma Rojo 64. They will also provide better and more diversified protection against changes in rust races.

The third phase of the breeding program has not yet reached the pay-off stage. This is the crossing program initiated in Pakistan to combine the desirable characteristics of Pakistan and Mexican varieties. In the 1967-68 season some of the earliest lines from this program will enter the yield testing phase.

During the past year it has become evident from extensive soil fertility studies conducted on farms throughout the country, that phosphate deficiencies are more widespread than was formerly thought to be the case. On the basis of these results the Pakistan government has now taken steps to import larger quantities of this plant nutrient and to encourage its widespread use.
Most of the wheat sent out from CIMMYT headquarters goes in the form of small samples. However, because of the broad range of adaptation of the Mexican dwarfs, countries determined to rapidly increase production have bought large quantities of seed in Mexico. The port of Guaymas on Mexico's west coast this year handled the largest shipment of seed wheat ever exported by any country — 41,500 tons purchased by Pakistan. Turkey also bought 22,500 tons in 1967 and India purchased 18,000 tons in 1966. These are stop-gap importations until the countries concerned can build up local seed stocks of dwarf varieties.
India

India moved aggressively forward in its accelerated wheat production scheme during the past year.

During 1965-66 crop cycle 250 tons of seed of the dwarf Mexican varieties Lerma Rojo 64 and Sonora 64 were imported from Mexico. The yields on approximately 3,000 hectares sown with this seed were highly satisfactory. The Indian government acted boldly and decisively on these data and during May 1966 sent a special commission to Mexico to purchase 18,000 tons of seed of Lerma Rojo 64 and Sonora 64. Up until the purchase made by Pakistan in 1967, this was an all-time world record for an international seed purchase.

This new seed import, together with the seed harvested from the 1966 crop in India, was sufficient to sow 350,000 hectares during November and December of 1966. All of this area was heavily fertilized (120-40-0) and irrigated.

The results on the recently harvested crop were impressive. Yields of 4,000 kilograms per hectare were common wherever the package of cultural practices was applied as recommended. As in Pakistan, the best farmers harvested yields of more than 5,000 kilos per hectare with a few harvesting yields of 6,000 and even 7,000 kilos. Only rarely were yields of less than 3,000 kilos per hectare harvested and in these cases the reason could be found in the mishandling of one or more of the cultural practices.

From the past harvest sufficient seed of Lerma Rojo 64 and Sonora 64 were harvested to plant the entire irrigated area during the forthcoming season.

In addition to the commercial plantings last season of Lerma Rojo 64 and Sonora 64, thousands of small demonstration plots (1/2 to 1/4 of an acre) were sown across the Indian wheat belt, using the improved seed and the package of improved cultural practices. Yields of 10,000 kilograms per hectare (155 bushels per acre) were harvested in one plot of Sonora 64 and from two plots of the Indian reselections from S-227 (Kalyan 227) and V-18. One reported, but unconfirmed, yield of S-227 (Kalyan 227) reached 11,600 kilos per hectare (174 bushels per acre).

The success of the past season has generated tremendous enthusiasm among farmers, scientists and government officials. It is estimated that approximately 3.2 million hectares (8 million acres) under irrigation will be sown to Mexican wheats, employing high levels of fertilization (i.e. 120-40-0) during the 1967-68 crop cycle. The remaining 10 million hectares sown to wheat will be planted to tall Indian varieties. It is estimated that about one fourth of the area sown to these varieties, 3.2 million hectares, will receive some fertilizer, probably an average of no more than 20-20-0. The combined effect of these programs should result in a considerable increase in Indian wheat production next year.
The seed imports plus the seed harvested from the dwarf varieties in India in 1966 was sufficient to sow 350,000 hectares during November and December. All of the area was heavily fertilized and irrigated. The kinds of results shown by this director of research with two cooperating farmers in Uttar Pradesh place India well on the road toward self-sufficiency in wheat production.

The enthusiasm that has been generated will propel the accelerated wheat production program ahead at an increasing rate, a rate which will largely depend on the availability of fertilizer at reasonable prices and the speed with which the so far neglected resources of sub-surface water of the Gangetic plain can be mobilized.

The success during the past year of the intensive cultivation of semi-dwarf wheats will also exert an indirect influence on the cultivation of other crops, during the forthcoming crop cycle. Considerable land in north India, which was formerly devoted to sugar cane production, will be switched to double cropping with wheat and maize. These changes, together with the success of the intensive cultivation of IR8 dwarf rice and high yielding maize varieties, will collectively exert a favorable influence on cereal grain production.

Millions of farmers who have seen the spectacular results with the intensive cultivation of wheat, rice and maize will be clamoring for more fertilizer. The Indian government is now aware of the change in temperament and attitude of the farmers and is moving aggressively to expand fertilizer plant production capacity. Action will be needed to obtain vastly greater foreign capital investments, both government and private, if the demand is to be met. Similarly, vast investments will be needed to tap the underground Gangetic "lake" for irrigation purposes.

India is now moving aggressively into the second phase of its All Indian Coordinated Wheat Breeding Program. Several new varieties are being increased and distributed. These resulted from reselections made
in segregating materials introduced from Mexico. Varieties now being multiplied and distributed include:

1) PV-18, also known as V-18. A high yielding red grain semi-dwarf reselected from the cross Penjamo sib × Gabo 55 (cross No. 8156).

2) 5-227, also known as Kalyan 227, a high yielding white grain semi-dwarf reselected from the same cross.

There will be sufficient seed available of these varieties to sow more than 200,000 acres during 1967-68.

3) 5-309. A high yielding cross reselected from the cross II 53-388 × Pitic sib. The seed of this variety will be available to sow more than 15,000 acres during 1967-68.

All of the aforementioned lines will outyield Lerma Rojo 64 and Sonora 64 by 20 percent when adequately cared for.

The Indian program is also beginning the third phase of its improvement program. More than 50 highly promising lines have been isolated from the cross Lerma 64 × Sonora 64 (No. 19008). These are in the final stages of yield testing and several will be placed in preliminary stages of multiplication during the 1967-68 crop cycle.

India is moving vigorously to multiply the aforementioned varieties so as to diversify the disease resistance of the commercial varieties of which a growing portion are represented by the Mexican varieties Lerma Rojo 64 and Sonora 64.

Turkey

Turkey’s experience with dwarf Mexican wheat varieties dates back to 1962 when small experimental samples were introduced by Turkish scientists who had trained in Mexico. Promising results with these and subsequent introductions set the stage for the introduction of 60 tons of Sonora 64 seed from Mexico during the summer of 1966 by the Turkish Ministry of Agriculture.

The seed from this introduction was grown on 100 private farms and on a government seed farm in the Adana area for testing and multiplication during 1966-67 season. Record-breaking yields were harvested, despite exceptionally heavy and prolonged rains. An average yield of 4,600 kilos per hectare (70 bushels per acre) was harvested, with yields on one farm climbing to an all-time Turkish record of 6,600 kilos per hectare (100 bushels per acre). Several hundred farmers traveled more than 200 miles to see these plantings. Enthusiasm soared and with it the demand for seed.

Spurred on by these results and enthusiasm, the Turkish Ministry of Agriculture, assisted by a 3 million dollar loan from U.S.A.I.D., sent a mission to Mexico in April of 1967 to purchase more seed. A purchase was made involving 22,000 tons of the commercial varieties Penjamo 62, Lerma Rojo 64, Super X, Siete Cerros, Mayo 64, Pitic 62 and Sonora 63.
Experimental quantities of several tons each of the newer Mexican varieties INIA 66, Tobari 66, Noroeste 66 and the dwarf durum Oviachic 65, were also included.

This large seed purchase will be sown at lower elevations in the coastal areas of Turkey. For the higher elevations, where severe frosts occur, modest quantities of the winter wheat varieties Burt, Brevor and Gaines are being imported from the State of Washington (U.S.A.).

The Turkish government is also struggling to increase its fertilizer production capacity and sees the possibilities of again becoming self-sufficient in wheat production within the next two to three years.

Afghanistan

Afghanistan has also begun to move aggressively in changing wheat production. By May of 1966, enough data were available to indicate that many of the same varieties that are performing well in neighboring Pakistan, India and other Near East countries, are also well adapted to Afghanistan. During the 1966-67 season, the Ministry of Agriculture and U.S.A.I.D. have cooperatively tested these varieties throughout the country. Despite a particularly cold, severe winter, the results were very encouraging, particularly where fertilization and water management were good. More than 500 trial-demonstrations involving Lerma Rojo 64 and the two best local lines, both with and without fertilizer, were seeded. Seed of these varieties was imported from Pakistan and Mexico and multiplied during the year. It is estimated that 10-12,000 tons of Lerma Rojo 64 will be available to farmers for seeding this fall (1967) as well as smaller quantities of Mexipak, Penjamo 62 and Sonora 64.

Argentina

A number of lines from the first cycle of crossing between Argentine varieties and Mexican varieties are now in the final stage of yield testing. Several lines from the cross Sonora 64 × Klein Rendidor, II-19975, are especially promising. These lines appear to have the possibility of responding well to the judicious use of chemical fertilizer, which is not true of current Argentine commercial varieties. There are many outstanding crosses appearing in the second cycle of crosses between Argentine and Mexican varieties that are even better than those from the first cycle.

It should be pointed out that the diversity of breeding materials emerging from the Mexican, Pakistan, Indian and Argentine breeding programs has no equal in spring wheat breeding programs anywhere in the world. Whereas only three years ago the flow of new combinations was almost exclusively from Mexico to Pakistan, India and Argentina, this is no longer the case. Currently many new crosses from India, Pakistan and Argentina are flowing back to the international center in Mexico for evaluation and potential exploitation. CIMMYT is now truly function-
ing as an international clearing house and evaluation center for many new crosses being made in these four breeding programs.

The four programs are also tied indirectly to the breeding programs of Colombia, Chile and Ecuador which have for a long time had direct links with the Mexican program and vice-versa.

**Rhodesia**

Within the past year Dr. O. J. Olsen of Southern Rhodesia has named and distributed two varieties derived from Mexican introductions. These are:

**MEXICAN No. 15.** Derived from Sonora 64 (Tezanos Pintos Precoz × Nainari 60) II 18889-13M-3Y-5M. This variety is derived from the same cross that gave rise to the Mexican variety JARAL 66.

**MEXICAN No. 47.** Derived from (Pitic × Chris sib) Sonora 64 II 19957-18M-1Y-3M-7Y. This variety is a close sister of the recently named Mexican variety CIANO 67.

**Denmark**

The same line that is being multiplied for release in Southern Rhodesia under the name of MEXICAN No. 47 is being multiplied for tentative release in Denmark under the provisional name of “Norman”.

**Guatemala**

Approximately 30 different advanced lines from Mexico are in final stages of yield evaluation in Guatemala.

**California, U. S. A.**

Based on one year of tests, several of the newer Mexican varieties —INIA 66, Tobari 66, JARAL 66, CIANO 67 and NORTEÑO 67— appear promising for direct introduction into California.

Very favorable results are now being reported from most of these countries and the area cultivated to these varieties is certain to increase markedly next year. Enthusiasm runs high, especially in Afghanistan, California and Rhodesia.

**Other countries**

Other countries currently growing large areas of CIMMYT wheats are Nepal, South Africa and Kenya.

During the next year, Cyprus, Tunisia, Morocco, Lebanon, Sudan and Iraq will be growing Mexican dwarf varieties on an exploratory commercial basis. This seed is either being imported directly from Mexico or from some area already growing these varieties commercially, such as Pakistan or California.
The research program operated jointly by the Mexican Instituto Nacional de Investigaciones Agrícolas and the CIMMYT continues to produce new higher yielding commercial varieties to meet Mexican needs. INIA has the responsibility for releasing the varieties locally and CIMMYT takes the lead in extending this material and information to other countries.

The Mexican dwarf wheat varieties, which were bred and developed to help solve Mexico's food problem, are now playing a vital role in the battle against hunger in many countries of the world. This clearly focuses on the international scope and impact of research done to solve a local problem.

RECENT WHEAT RESEARCH RESULTS IN MEXICO

Most of the wheat research in Mexico is conducted under joint projects with the Instituto Nacional de Investigaciones Agrícolas (INIA). The INIA has the responsibility for the application of research results and materials to meet Mexican needs; the CIMMYT is responsible for extending and utilizing this information for the welfare of other countries.

New Commercial Mexican Varieties

During the past year the following semi-dwarf varieties have been named and released by INIA for production in Mexico. Collectively they will probably constitute 40 percent of the acreage sown to wheat in Mexico during the 1967-68 crop season. They will rapidly replace the older varieties Pitic 62, Penjamo 62, Sonora 63, Sonora 64 and Lerma Rojo 64, which are now susceptible to one or more races of one of the three rusts.

TOBARI 66. A red grain type wheat with medium strong gluten, possessing good resistance to all three rusts, was selected from the cross: Tezanos Pintos Precoces x Sonora 64A, and has the pedigree II 19021-4M-3Y-102M-100Y-101C.
JARAL 66. A red grain bread type wheat with strong gluten, possessing good resistance to stem and stripe rust. It was selected from the cross: Sonora 64 (Tezanos Pintos Precoz × Nainari 60) and has the pedigree II 18889-4M-1Y-1M-3Y.

INIA 66. A red grain wheat with medium strong gluten, possessing good resistance to stem and leaf rust which was selected from the cross: Lerma Rojo 64 × Sonora 64 and has the pedigree II 19008-83M-100Y-100M-100Y-100C.

NOROESTE 66. A red grain wheat with medium strong gluten possessing good resistance to stem and leaf rust, from the cross: Lerma Rojo 64 × Sonora 64 and has the pedigree II 19008-52M-4Y-4M-2Y.

SIETE CERROS 66. A white grain wheat with medium strong gluten but somewhat too tenacious. It has high yield potential in the drier areas where the rusts are not limiting factors in production. This wheat was selected from the cross: Penjamo sib × Gabo 55 and has the pedigree II 8156-1M-2R-4M. Reselections of this wheat are being multiplied in Pakistan under the name of Mexipak 65, and in India under the name Kalyan 227, S-227 and V-17. In Mexico a red grain sister selection is grown commercially under the provisional name of Super X. Its red grain counterpart is being multiplied under the name of Indus 66 in Pakistan and PV-18 and V-18 in India.

NORTEÑO 67. A white grain wheat with medium strong gluten, possessing good resistance to stem and leaf rust which was selected from the cross: Lerma Rojo 64 × Sonora 64 and has the pedigree II 19008-52M-6Y-3M-2Y.

CIANO 67. A red grain wheat with medium strong gluten and excellent bread-making properties, possessing good resistance to all three rusts. This variety was selected from the cross: (Pitic 62 × Chris sib) Sonora 64 and has the pedigree II 19957-18M-1Y-3M-9Y.

AZTECA 67. A red grain variety similar in milling and baking and in disease resistance characteristics to its sister selection CIANO 67. This cross is: (Pitic 62 × Chris sib) Sonora 64 and has the pedigree II 19957-18M-5Y-1C.

BAJIO 67. This is a reselection from Tobari 66, which is significantly superior in yielding ability. Its pedigree is Tezanos Pintos Precoz × Sonora 64A and has the pedigree II 19021-4M-3Y-102M-100Y-102C-1Y.
Promising New Research Leads

During the past year two unusually promising crosses have been identified. One of these, CIANO 67 sib × (Sonora 64 × Klein Rendidor), cross II 23584, is particularly promising from the standpoint of outstanding agronomic type and yield potential. It is similar in phenotype to the high-yielding, broadly-adapted varieties Siete Cerros and Super X, but possesses both better gluten strength and disease resistance.

The second derived from the complex cross: (Tezanos Pintos Precoz × Sonora 64A) (Lerma Rojo 64 × Tezanos Pintos Precoz-Andes4), is unique from a dough-handling and baking standpoint. Two selections of this cross, II 22429-11M-1Y-1M and II 22429-16M-1Y-1M, as well as reselections from them are superior in quality to Sonora 64, INIA 66 and CIANO 67. They have elastic dough with greater overall gluten strength than the North Dakota variety Justin which is now considered the standard for spring wheat quality.

A broad range of rust resistance continues to be one of the key characteristics of the new dwarf varieties. Rust spores are collected from infected plants in the greenhouse and later injected into the material under test in the field to assure complete exposure to the pathogen and consequently an accurate evaluation of disease resistance.
All selections are studied in the field by the wheat pathologist and trainees to keep a close check on the development of different kinds of rust and different races of this pathogen. The varieties now being released have a broad range of field resistance for protection against possible new races.

Development of Dwarf Durum Varieties

The first dwarf durum wheat variety that was released was Oviachic 65. This is now grown on a considerable commercial acreage. It has good disease resistance, industrial quality and genetic yield potential. However, it is late maturing and day-length sensitive.

Currently five superior dwarf durum wheats are in the last stage of yield testing and simultaneously in preliminary multiplication. These possess higher yield potential, earlier maturity, larger grain and less sensitivity to date of sowing than Oviachic. These lines are:

1) (Pitic sib X Barrigon Yaqui) Tehuacan 60¹, D-14497A-15C-2Y.
2) (Pitic sib X LD 357) Tehuacan 60², D-14540-1C-1Y-1C.
3) (Pitic sib-Barrigon Yaqui² X Tehuacan 60) Pitic sib-Tacor 125 X Tehuacan², D-21563-2M-2R-2M.
4) (Pitic sib-Barrigon Yaqui X Tehuacan) (Pitic sib-T. gluitinosa X Tehuacan 60³), D-21564-3M-1R-1M.
5) Pitic sib-Barrigon Yaqui² X Tehuacan) (Pitic sib-T. gluitinosa X Tehuacan 60³), D-21570-2M-3R-2M.
The dwarf durum wheat varieties have the same strong straw and high yield potential as the dwarf bread wheats. They are being used commercially in Mexico as well as for crossing with rye to form dwarf triticales.

Hybrid Wheat Research

Research has been aggressively pursued by CIMMYT and INIA during the past three years to explore the feasibility of hybrid wheat. Studies during the past three years have demonstrated that heterosis is a common phenomena in crosses between wheat varieties. The magnitude of heterosis in crosses between good wheat varieties is generally between 20 to 30 percent, about the same magnitude that is being exploited commercially in hybrid maize and sorghum. Wheat, unlike maize or sorghum, produces only small quantities of pollen. Moreover, it is largely self-pollinated. These characters will make high production costs for hybrid wheat seed and may limit or even prevent the use of hybrid wheats. More research is needed to clarify these points.

Development of Sterile Lines

Currently about 125 cytoplasmic sterile varieties and lines are in various stages of development. All carry *T. timopheevi* cytoplasm. These represent a wide range of types from the spring wheat varieties of the world, as well as superior lines from the Mexican program. Several cytoplasmic sterile lines, including Sonora 64, Nadadores 63 and Lerma Rojo 64, are being increased for field scale crossing studies during the 1967-68 crop season.

Development of Restorer Lines

In the Mexican hybrid wheat program major research emphasis has been placed on fertility restoration. It has been established that the genetic control of restoration of pollen fertility to lines carrying *T. timopheevi* cytoplasm is complex. A minimum of two major genes, and more likely three, are involved. There are many modifying factors that also influence restoration, depending upon the background varieties being
employed. Therefore, the fertility restoring mechanism being used in wheat is much more complex than that currently employed in hybrid corn and sorghum. Recently, Oehler and Ingold in Switzerland have reported finding a single gene restorer in the variety PRIMEPI. This has yet to be confirmed, but if true, would greatly accelerate hybrid wheat research development.

In the Mexican program a technique has been worked out which has greatly facilitated the development of restorer lines. This involves a critical examination of anther and pollen development of highly fertile, segregating plants carrying *T. timopheevi* cytoplasm. This search is done daily during the flowering season in the field. Spikes from each plant that appears promising, based on field examination, are studied more critically in the laboratory for anther development and normality of pollen development. Only plants with normal anthers throughout the spikelets and possessing a minimum of 96 percent stainable pollen are kept for further study. All such plants are test crossed by transferring their pollen to stigmas of cytoplasmic sterile lines, to evaluate their fertility restoration capacity. Only plants which restore fertility to a high degree in progeny from these test crosses are continued to the next generation. Selection, examination and test crossing are continued each generation until lines homozygous for pollen fertility restoration are obtained.

Although the potential of hybrid wheat in relation to cost cannot yet be fully assessed, a research program is going forward to develop cytoplasmic sterile lines as well as restorer lines.
Currently two lines, both derived from Lerma Rojo 64, appear to be homozygous for pollen fertility restoration in *T. timopheevi* cytoplasmic sterile lines and are being increased for field testing in strip plantings during the 1967-68 cycle. With these restorer lines it should now be possible to begin to study problems in seed set, the width of strips of restorer and sterile lines, etc. From such studies the cost of hybrid seed production can be determined. These costs will largely determine whether hybrid wheat is economically feasible. It will take perhaps two more years of research to determine the feasibility of hybrids.

Although most of the research effort has been devoted to the development of hybrid bread wheat varieties, *Triticum aestivum*, limited work has also been done on hybrid durum wheats, *T. durum*. Preliminary indications are that pollen fertility restoration in *T. timopheevi* cytoplasm, is simpler and easier to achieve in the tetraploid *T. durum* than in the hexaploid *T. aestivum*. This may be indirect evidence that the restoration system is in some way associated with the degree of polyploidy.

**Dwarfness in Hybrids**

As Dr. Orville Vogel of Washington State University did with winter wheat, the Mexican wheat breeding program has pioneered the development of semi-dwarf and dwarf spring wheat varieties. The dwarf stature which permits the efficient utilization of heavy doses of nitrogenous fertilizers without lodging is one of the characteristics that has contributed greatly to their high yield potential. They have revolutionized our ideas on wheat yield potential.

The Norin dwarf genes that have been employed in both the Mexican program and the Washington program are all recessives.

When the dwarf Mexican varieties are crossed with tall-growing spring wheat varieties from Canada, the U.S., Argentina, India, Pakistan or Australia, the F\(_1\) hybrid is essentially as tall as the tall parent. Lodging in such hybrids becomes a critical factor limiting yields.

For the past two years many new short wheat varieties have been studied by CIMMYT in an attempt to find dominant dwarf genes which will overcome this problem in hybrids. Currently two groups of lines seem promising. These are: 1) Tom Thumb × Sonora 64 and derivatives crossed with many other varieties such as Nainari 60, Chris, Tacuari, Buck Manantiales; and 2) Olsen Dwarf × various tall wheats.

The winter wheat variety Tom Thumb was collected in Tibet during the 1930's as a curiosity. It has one or more genes exhibiting a strong dominance for dwarfness in the F\(_1\) hybrids between it and tall varieties. Although Tom Thumb has many defects under Mexican conditions, including poor yield and grain test weight, weak gluten, and winter habit, these are being corrected in the current breeding program. These dwarfness genes show definite promise for use in the hybrid program.
The impressive head size of the triticale suggests the high yield potential of this new man-made cereal. As better wheats and ryes are used to form triticales, even higher yield levels should be possible. Problems still to be resolved: considerable sterility on the late tillers and partially shrunken grain.

Two years ago seed was received of two extremely dwarfish lines from Dr. O. J. Olsen of the Ministry of Agriculture of Southern Rhodesia. These lines were derived from a complex double cross. One parent involved a Mexican dwarf — a Pitic sib — crossed into a dwarf plant of unknown origin found in a farmer’s field in Rhodesia. The other parent carries the Italian variety Mara in its pedigree. These dwarf Rhodesia lines act as dominants in crosses with tall wheats. The lines possess better yield potential, better grain test weight and gluten quality, and better disease resistance than the Tom Thumb derivatives. They definitely offer promise as a source of dwarfing for the hybrid wheat program.

RESEARCH ON TRITICALE— A MAN-MADE CEREAL

Three years ago the CIMMYT embarked on a cooperative research program with the Plant Science Department of the University of Manitoba, whose research effort with this man-made cereal — an amphidiploid between wheat and rye — goes back to 1954. During the past two years this work has been greatly expanded and accelerated in both Mexico and Canada. Results are encouraging.

In Canada several thousand acres are currently planted to one of the early, and still very imperfect, Triticale varieties. During the past year the yield of Triticales on farms in Manitoba was on the average 30 percent greater than Selkirk, a wheat grown under the same conditions.
Canadian scientists are currently evaluating five newer and potentially better Triticales at various locations in Canada and other countries.

During the past year twenty Triticale varieties developed by the cooperative project between CIMMYT and the University of Manitoba, were compared with wheat and barley under irrigation at Ciudad Obregón, Sonora, Mexico. The best five Triticales yielded 106 percent of the two highest yielding Mexican barley varieties. They yielded 97 percent of the wheat variety Penjamo 62 and 73 percent of Siete Cerros and Super X. Considering that these Triticales were formed using either primitive wild tetraploid wheats or durum wheats of low yield potential, it is surprising that they yield so well in comparison with the high yielding dwarf wheats. Triticales appear to be able to compete even better with wheat under drought or when grown on poor soil. Such comparisons are also being studied during the summer in the Mexican highlands at Toluca, Chapingo and Huamantla. As better wheats and ryes are used to form Triticales, it is felt that yield levels vastly superior to wheat are possible.

The Triticales that are currently available have conspicuous defects. Most of them possess considerable sterility, especially in the late tillers. Most also have partially shrunken grain. Progress has been made in improving both fertility and grain test weight, but more improvement is needed in both of these characteristics.

During 1966-67 six hectares of space-planted $F_2$ populations representing 188 different crosses with approximately 2,000 plants per cross were grown at INIA's Northwest Research Center (CIANO). Only 1,100 individual plant selections were made in this material and more than half of these selections were discarded on the basis of grain or endosperm shriveling.

It has become evident after studying this large number of new crosses that more variability is needed in Triticales in order to assure rapid progress in breeding. CIMMYT consequently hopes to develop several hundred new Triticales, employing superior parental dwarf wheats—both tetraploids and hexaploids—and diverse superior ryes. Since there are serious sterility barriers involved in making new Triticales, a cytologist will be added soon to the CIMMYT staff to assist with this research.

**Nutritional Aspects of Triticales**

Cereals contribute approximately 75 percent of the total intake of protein in the human diet throughout the world. Cereal proteins are especially important in human diets in the developing countries, where the high cost of the nutritionally better animal proteins place these foods outside of reach.

Unfortunately, cereal proteins are all deficient in certain of the essential amino acids, especially lysine. The discovery of the effect of the
Opaque-2 gene on the lysine content and nutritional value of maize has stimulated similar research in all of the other major cereals. Recently Dr. Evangelina Villegas, now on the CIMMYT staff, completed her doctorate at North Dakota State University where she studied the lysine variability in wheats, ryes and Triticales. Her work indicated that the variability in lysine content among hexaploid wheats was small, that it was somewhat higher at the tetraploid level and appeared highest at the diploid level. Ryes in general were much higher in lysine content than wheats, and there was much variability between different rye varieties. Triticales were higher in lysine than wheats and generally intermediate between the two parent species, wheat and rye.

These discoveries indicate that added emphasis should be directed toward developing high yielding Triticales rich in lysine. Although present Triticales varieties are rather poorly adapted for preparing leavened bread type products, they can almost certainly be used to produce unleavened products such as the chapatti. Triticales will become one of the CIMMYT's major research efforts.

To handle the vast amount of data collected each year from cooperating scientists in the international yield trials, the statistical center of the Graduate College at Chapingo provides computer facilities.
Nearly 50 young scientists from the Near East, in addition to many from Latin America, have received training in Mexico. Dr. N. E. Borlaug (left) is shown here with the 1966 group of trainees at the CIANO research station on Sonora coast of Mexico.

THE TRAINING OF YOUNG SCIENTISTS

One of the most significant activities conducted by CIMMYT is the training of young scientists. During the past six years, 48 young scientists from the developing countries of Africa and Asia have come to Mexico for practical training in different aspects of wheat improvement. This training program has been a joint undertaking with the Mexican Ministry of Agriculture, the Food and Agriculture Organization of the United Nations, the Ford Foundation and the U.S.A.I.D.

These training programs, under CIMMYT direction, have been from seven months to one year in duration. Each training group has consisted of 6 to 10 young scientists. This may be increased as the CIMMYT staff is expanded.

The training program is a practical one with emphasis placed on “learning by doing”. Each young scientist participates in all aspects of the wheat improvement program from breeding to cereal chemistry.

The emphasis is devoted to teaching the trainees about the application of research to solve production problems. Insofar as time permits, each trainee spends a short period of time on modern wheat farms to become familiar with land preparation, fertilization, planting and irrigating. All of these experiences will be valuable to the trainee when he returns to his home base. Moreover it gives him confidence.

The CIMMYT staff attempts to maintain contact with all trainees after they return to their home countries. With but few exceptions the trainees
have returned and continue to work on wheat research, extension or production. Some of those who have demonstrated outstanding ability, dedication and organizational ability, have been subsequently granted fellowships and are now studying toward PhD degrees in foreign universities. They will become the research leaders in their countries in the years ahead.

The following persons have received training during the past year:

<table>
<thead>
<tr>
<th>Name</th>
<th>Country of Origin</th>
<th>Period</th>
<th>Starting Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ali Anwar Abdi</td>
<td>Pakistan</td>
<td>One year</td>
<td>2/25/67</td>
</tr>
<tr>
<td>Pashtoon Ahad</td>
<td>Afghanistan</td>
<td>One</td>
<td>3/1/67</td>
</tr>
<tr>
<td>Abdul Ghafoor Asi</td>
<td>Pakistan</td>
<td>One</td>
<td>2/25/67</td>
</tr>
<tr>
<td>Farzand Ali Khan</td>
<td>Pakistan</td>
<td>One</td>
<td>2/25/67</td>
</tr>
<tr>
<td>Cristian Hewstone</td>
<td>Chile</td>
<td>Two years</td>
<td>8/6/67</td>
</tr>
<tr>
<td>Manzoor Hussain</td>
<td>Pakistan</td>
<td>One year</td>
<td>2/25/67</td>
</tr>
<tr>
<td>Néstor Guillermo Machado</td>
<td>Argentina</td>
<td>Nine months</td>
<td>8/15/67</td>
</tr>
<tr>
<td>Noor Mohammed Memon</td>
<td>Pakistan</td>
<td>One year</td>
<td>2/25/67</td>
</tr>
<tr>
<td>Mohammed Osmand</td>
<td>Afghanistan</td>
<td>One</td>
<td>3/1/67</td>
</tr>
<tr>
<td>Mario Lalama</td>
<td>Ecuador</td>
<td>Six months</td>
<td>4/1/66</td>
</tr>
</tbody>
</table>

In addition to sponsoring the training program for an increasing number of young scientists, CIMMYT has been host to a rapidly expanding number of senior wheat scientists, research and extension administrators and officials during the past two years. During the first eight months of 1967 more than 50 senior scientists and officials visited the CIMMYT wheat program for periods varying from three days to two weeks. This type of training also appears to be serving a worthwhile need.

**PLANS FOR THE FUTURE**

As wheat cultivation becomes more intensive, greater risks are involved. One hundred bushel yields per acre under modern methods can suddenly become 100 bushel losses when rust races change and varieties that once were resistant become susceptible. The only protection against such losses is a better knowledge of the variability of pathogenicity of the parasite and a constant searching for new and better sources of resistance. During the past year additional staff in plant pathology has been added to strengthen this phase of the program.

The research work on breeding phases of wheat and Triticale improvement is being pushed forward aggressively over a wide part of the spring wheat areas of the world. CIMMYT has become a hub and center for catalyzing both varietal improvement and the training of young scientists.

Research work is being strengthened in both the plant pathology and cereal chemistry aspects of wheat and Triticale improvement. Increased research will be initiated on soil fertility and agronomy to keep pace with varietal improvement.
In crop production the soil is the medium in which the plant develops. Progress in obtaining higher yields from improved seeds of corn and wheat depends directly on the improvement of the medium in which these seeds are grown. The goal of the CIMMYT program in soils and plant nutrition is to isolate, identify and manipulate all of the yield limiting factors.
The purpose of the soils and plant nutrition program is to promote continuous improvement in corn and wheat production by making the soil a more adequate medium for the growth of these crops. The specific objectives are as follows:

- Prepare a comprehensive methodology for fertilizer use research and promote the development of more adequate methodological procedures by conducting or cooperating in research designed specifically for this purpose.

- Help train personnel and assist scientists with planning, execution and interpretation of results of fertilizer use research in countries with which CIMMYT is cooperating in increasing the production of corn and wheat.

- Develop a similar program in soil-plant-water relationships which will include cooperation with various institutions in the development of graduate training and research in this area of crop production. Assistance may be given in providing in-service training to local technicians currently involved in crop production programs.

- Conduct and promote basic studies on the effect of levels of available soil moisture and oxygen in the growth and composition of wheat and corn.

- Conduct and promote research on plant-soil relationships to obtain a better understanding of how the quantity and quality of corn and wheat production are influenced by soil and genetic variability.

- Investigate soil conditions which limit production and do not react normally to classical soil management practices. This work will be conducted in laboratories and greenhouses of the Center or in cooperation with other research institutions.

- Sponsor national and international meetings of soils and plant nutrition specialists to exchange scientific information or teach new methodological procedures.

At present the Center has only one senior scientist to carry out the objectives outlined above. Arrangements are being made to add additional scientists who will serve as leaders in the promotion of this work. A brief description follows of the research under way and results obtained during 1966.
FERTILIZER USE PROGRAM IN 1966

The adequate use of fertilizers offers one of the principal means of achieving increased production of corn and wheat in the developing countries. To attain greater and more effective use of fertilizers the following activities received attention in 1966:

(1) Field study of the fertilization of unirrigated maize in the Bajio region of Mexico.
(2) A study of optimal treatment design for fertilizer use experimentation.
(3) Production of a film and manual on field technique for fertilizer trials.
(4) Visits to West Pakistan and Egypt to observe soil problems limiting the production of wheat and maize.
(5) Presentation of a short course to graduate students at Chapingo on "Fertilizer Use Methodology".

The maize fertilization study was conducted in cooperation with the Soils Department of the National Institute of Agricultural Research (INIA). The study of treatment design was carried out in collaboration with Dr. Foster Cady, Department of Statistics, Iowa State University, who is presently with the Graduate School at Chapingo. The film is being prepared in collaboration with the Information Specialist of CIMMYT and technicians of the Agricultural Information Department of INIA.

FERTILIZATION PRACTICES FOR UNIRRIGATED MAIZE

This study was initiated in 1962 to determine optimal fertilization rates for unirrigated maize in a region where the frequency of drought varies from very low to quite high. By the end of 1965, fertilizer experiments had been conducted at 85 locations throughout the region, and reasonably good information on fertilizer use had been generated.

However, relatively little information on maize response to fertilization at different levels of drought on the heavy clays (Grumusols) in the central portion of the area had been obtained. Consequently, it was decided to continue the study in the central region in 1966, and experimental plantings were made at 8 locations on Grumusols with average annual rainfall varying from about 675 to 825 mm.

A few modifications in experimental techniques were introduced in 1966. The plot size was changed from 4 rows 17 meters long to 6 rows 8 meters long. The "double square" treatment design was used in three experiments and the "double diamond" design at two locations (figure p. 87). Nitrogen rates were 0, 60, 120, 180, and 240 kg/ha and phosphorus
Treatment designs used in fertilizer experiments. The treatments that comprised each design are shown as circled dots. Adequate use of fertilizer offers one of the rapid means for increasing production of corn and wheat.

I. Double Square

II. Double Diamond

III. Triple Square

IV. Seventeen Point Asymmetric

(P₂O₅) rates were 0, 30, 60, 90 and 120 kg/ha. Two additional treatments, one with potassium and the other with zinc, were included.

The treatments from a “triple square” and a “seventeen point asymmetric” design (figure above) plus a treatment with potassium, were used at two locations. Nitrogen rates were 0, 60, 120, 180, 240, 300 and 360 kg/ha for the triple square and 0, 40, 80, 120, 160, 260 and 360 kg/ha for the asymmetric design. Phosphorus (P₂O₅) rates were 0, 30, 60, 90, 120, 150 and 180 kg/ha for the triple square and 0, 20, 40, 60, 80, 130 and 180 kg/ha for the asymmetric design. The treatments from the two designs were combined in the same experiment to permit a comparison of the relative efficiency of the two designs in reducing “bias error”
The eighth experimental planting was a uniformity trial for determining optimal plot size. It occupied 0.5 ha and was harvested in units of 3.4 m².

The field study was modified to generate information on optimal treatment design and plot size as these are methodological questions for which answers are being sought.

The experiments were conducted so as to eliminate insofar as possible variability due to differences in insect damage and weed competition. An insecticide was applied in the row at planting to give protection against soil insects. A pre-emergence herbicide was used in a 30 cm band over the seed and other weeds were controlled opportunistically by cultivations. An insecticide was applied in six experiments to combat infestations of the corn budworm.

Observations on plant wilting, excess soil moisture, hail damage and disease attack were recorded at each site every week or 10 days. Rainfall data were collected within one kilometer of each experiment using a standard rain gauge. Pits were dug at each site and a description of the soil profile was made. Soil samples, taken from selected horizons, were used to establish native nutrient levels and moisture retention characteristics.

Corn yields were significantly increased by the application of both nitrogen and phosphorus in all experiments. Small but significant (at the 5% probability level) increases in yield due to potassium were observed at four locations. Yields were not significantly affected by applications of zinc at any locations.

The yield data for each experiment were regressed on levels of nitrogen and phosphorus using a quadratic model. The estimated yield functions are presented in Table 1. The linear and quadratic effects of

<p>| TABLE 1. Quadratic yield functions, expressed in kilograms of grain per hectare, estimated from the data obtained in field trials conducted in El Bajio in 1966. |
|---|---|---|---|---|---|---|
| No. of | Yield | Linear | Quadratic | Linear | Quadratic | Inter- |
| Exp. | fertilizer | effect | effect | effect | effect | section |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th>of nitrogen</th>
<th>of nitrogen</th>
<th>of phosphorus</th>
<th>of phosphorus</th>
<th>N x P</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>308</td>
<td>28.14</td>
<td>-0.07141</td>
<td>45.64</td>
<td>-0.2842</td>
<td>0.1003</td>
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<tr>
<td>2</td>
<td>1739</td>
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<td>-0.1086</td>
<td>6.21</td>
<td>-0.00357</td>
<td>0.0</td>
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<tr>
<td>3</td>
<td>1098</td>
<td>23.39</td>
<td>-0.05871</td>
<td>29.21</td>
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<td>0.03160</td>
</tr>
<tr>
<td>4</td>
<td>572</td>
<td>18.82</td>
<td>-0.05823</td>
<td>35.58</td>
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<td>5</td>
<td>962</td>
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<td>0.1219</td>
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<td>7</td>
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<td>18.30</td>
<td>-0.03874</td>
<td>16.12</td>
<td>-0.1054</td>
<td>0.02443</td>
</tr>
</tbody>
</table>

* Ratio of (mean squared deviation of treatment means from regression equation) and (variance of the mean). All values are significant at the 1% probability level.
nitrogen and phosphorus, as well as a positive interaction, were large in all experiments except number 2. In the latter case, the linear and quadratic effects of phosphorus were small and the interaction effect was not significantly different from zero.

The values of the coefficients of the yield functions for the seven experiments were quite variable. The soils at all sites were Grumusols and the observed variability in soil properties among sites was small. Also, rainfall was adequate at all locations throughout the season so climatic variability was evidently small. No important effects of diseases, insects, weeds or hail were observed. In effect, the information on the productivity factors accumulated at each location was not adequate for explaining the variation among sites in yield and response to fertilization. The difficulties that are encountered in adequately accounting for variation among sites represent a major obstacle to generating accurate fertilizer use information. Research on this point is continuing.

In the last column of Table 1 are given the F values obtained by testing the means squared deviation of the treatment means from regression against the variance of a mean. Deviations from regression were highly significant in all cases and quite large in all experiments except number 2. This means that the quadratic model did not give an adequate expression of the yield equation in these experiments.

The yield equations in Table 1 were used to calculate optimal rates of fertilizations. Current fertilizer prices in Mexico were used, and it was assumed that the value of the marginal yield should be 50% greater than the cost of the marginal input. As is seen in Table 2, optimal rates of nitrogen varied from 83 to 155 kg/ha, while optimal rates of P₂O₅ ranged from 0 to 88 kg/ha. Again, this illustrates why variation among sites limits the usefulness of general fertilizer recommendations.

The rates of nitrogen and P₂O₅ necessary to produce the maximum yield in these experiments are given in Table 2. The rate of nitrogen

<table>
<thead>
<tr>
<th>No. of Exp.</th>
<th>Optimal rate *</th>
<th>Rate for maximum yield</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>P₂O₅</td>
</tr>
<tr>
<td>1</td>
<td>134</td>
<td>91</td>
</tr>
<tr>
<td>2</td>
<td>145</td>
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<td>7</td>
<td>155</td>
<td>88</td>
</tr>
<tr>
<td>8</td>
<td>123</td>
<td>55</td>
</tr>
</tbody>
</table>

* Calculations based on current fertilizer prices in Mexico and the assumption that the value of the marginal yield is 50% greater than the cost of the marginal input.

** The precision of the data do not permit the estimation of this value.
Well designed yield trials conducted on the full range of soil and rainfall in a region offer the best means to obtain adequate information on which to base fertilizer recommendations.

A soil profile reveals important information which must be related to fertilizer response in order to make adequate fertilizer recommendations. This is a deep Gru-musol near Atotonilco, Jalisco, in Mexico.

Adequate fertilizer response data can only be obtained if management variables are carefully controlled. In this case a soil insecticide is being applied to avoid possible damage by soil insects.
required for the maximum yield varied from 172 to 270 kg/ha with an average of 226 kg/ha. The required rate of P\textsubscript{2}O\textsubscript{5} varied from 86 to 120 kg/ha with an average of 106 kg/ha.

The Mexican agronomist that conducted these field experiments will use the data from the uniformity trial in preparing a thesis for the M.S. degree. The information obtained in these experiments on treatment design forms a part of a more comprehensive study of this question.

**TREATMENT DESIGN FOR FERTILIZER USE EXPERIMENTATION**

Fertilizer experiments are conducted to obtain information on plant response to applications of the essential nutrients. Experiments generally consist of several fertilizer treatments replicated two or more times. The treatments are combinations of rates of selected plant nutrients together with information on the manner of application to the experimental unit. The list of fertilizer treatments comprises the treatment design.

The scope of fertilizer experiments is generally limited to observing plant response to rates of the several nutrients that lie within discrete limits. For example, in studying maize response to fertilization, information may be desired for rates of nitrogen between the limits 0 and 300 kg/ha, rates of phosphorus from 0 to 150 kg/ha and rates of potassium from 0 to 200 kg/ha. These limits define the factor space within which observations on maize response to application of nitrogen, phosphorus and potassium are desired.

The central question in selecting a treatment design is how should a limited number of points be distributed within a given factor space. Literally an infinite number of rate combinations lie within the limits established for the different elements and may be chosen for experimentation. However, different treatment designs may vary significantly in the precision with which they permit the estimation of plant response to fertilization in different parts of the factor space. The objective of the investigator is to select that particular series of treatments which will be most efficient in obtaining the data he desires on plant reaction to fertilization.

Treatment design is presently being examined from the point of view of the investigator who is interested in making field observations on fertilizer response for the purpose of defining optimal rates for crop fertilization. Several aspects that are being considered and conclusions which have been reached are summarized below:

1. In order to compare two or more treatment designs, certain restrictions must be placed on the fertilizer levels that may be included in the study. The criterion of Box and Wilson, who suggest that different designs be brought to the same "size" by adjusting the spread of each of the variables, was found to be inapplicable. It is suggested that lower
and upper limits be assigned to the factor space on the basis of prior knowledge of crop response to fertilization, and that these limits be the minimum and maximum rates of the fertilizers for all designs under comparison.

2. The response function that is calculated from the data obtained in a fertilizer experiment is an estimate of the true response function. The precision of this estimate of the true function depends upon the magnitude of errors originating from two sources. The first of these, called the "variance error", is a measure of the deviation of the estimated function from the true function assuming that the correct model was chosen to represent the data. The second source of error, called the "bias error", arises due to the deviation of the assumed model from the true model.

3. The variance error has two distinct components. One of these, the experimental error, arises due to random variation among experimental units. The second component is a function of the distribution of the treatment combinations in the factor space and is influenced by the selection of the treatment design. It appears in the regression analysis as the elements of the inverse matrix. The size of these elements depends upon the number of treatment combinations, the distribution of these treatments within the factor space, and the number of times the set of treatments is replicated.

4. Several criteria have been employed in comparing designs from the standpoint of minimal variance. Perhaps the criterion which has been viewed most favorably for fertilizer use experimentation is the minimization of the variance of the coefficients of the response function. Box and associates consider the mean variance of the predicted yield over the immediate region of interest as the appropriate criterion to employ in comparing designs. In fertilizer use experimentation, however, the investigator is interested primarily in measuring the slope of the response function at some point corresponding to the optimum. Consequently, it seems apparent that for this type of research it is the minimization of the variance of the slope of the response function that should be considered in comparing designs.

5. The concept of bias error is quite simply visualized and understood in a qualitative way. The nature of this error is illustrated in the figure on the adjoining page. The average sorghum yields which were obtained at five levels of nitrogen fertilization are plotted together with the prediction equations estimated for the quadratic (A) and square root (B) models. Let us assume for illustrative purposes that the quadratic equation is the true expression of the relationship between yield and nitrogen fertilization, and that we choose to represent the results in the form of the square root equation. Then, the mean squared deviation of the square root curve from the quadratic curve will constitute the bias error. If, on the other hand, we had chosen to represent the data using the quadratic function, there would have been no error due to bias.
Yield functions fitted to quadratic (A) and square root (B) models for data obtained in a sorghum fertilizer experiment.

6. In comparing treatment designs it is found that a change in the distribution of treatment combinations that results in a reduction of variance error produces an increase in bias error and vice versa. Consequently, the investigator in selecting a treatment design, must decide which type of error he wishes to minimize.

7. The magnitude of the variance error depends upon the number of treatments, the distribution of these treatments within the factor space, and the number of replications of the design. The size of the bias error, on the other hand, is determined by the number and distribution of the treatments but not by the number of replications. Until some generally applicable quantitative procedure is available for selecting designs that give proper weight to the two sources of error, it seems reasonable to select a design that will minimize bias error, and control the size of the variance error through replication.

FIELD TECHNIQUE FOR FERTILIZER TRIALS

A colored 16 mm film entitled “Field Technique for Fertilizer Trials” is currently being produced. It describes the steps involved in conducting fertilizer experiments with maize on farmers’ fields and should be useful in training agronomists in proper techniques. A manual is also being prepared for use in conjunction with the film, presenting the methodology of conducting fertilizer trials in greater detail.
COMMUNICATIONS

The general objective of the work in communications is to gain adoption of more productive and profitable practices among the producers of maize and wheat. The work of the plant breeders, soil scientists, plant pathologists and entomologists begins to make its impact on agricultural production when individual farmers decide to adopt the practices which come out of this research. Every scientist is interested in this end result of his work and the Communications Department works closely with all of the scientists to reach this common goal. To gain the adoption of the practices which will bring about increased production requires a several pronged attack.

In Communications the problem is being attacked in two ways.

The first is the transfer of new knowledge from those directly involved in basic research to the large number of scientists throughout the world who can make immediate application of this knowledge. Toward this end the CIMMYT is involved in training young scientists and production specialists, as has been reported in other sections of this report. In addition, a publications program has been initiated to attain systematic distribution of information on a world-wide basis.

The second aspect of the work in communications is research to discover: a) the relative importance of the factors which have held back the adoption of more productive cropping practices and b) the most efficient ways to eliminate these barriers and bring about rapid increases in production.

TRANSFER OF KNOWLEDGE

Publications

The newsletter "CIMMYT News" has been published regularly since July 1966. Its function is to make known the program of the Center, the progress in research, activities of the technical personnel and other news of general interest related to the improvement of maize and wheat production. It includes coverage of the cooperative programs being carried out in different parts of the world. The pages of CIMMYT News are also open for informal interchange of ideas related to maize and wheat improvement. It is published in English and Spanish and reaches scientists and institutions of research, education and extension in 70 countries, including 22 on the American continent, 18 in Europe, 19 in Africa, nine in Asia, and those of Australia and New Zealand. The present list includes 1,545 names for the English edition and 1,712 for the Spanish.

Research is showing the way to notable increases in corn and wheat yields. However, it is the farmer who makes this potential a reality by learning new production methods, using better seeds and applying products of modern chemical industries.
Two series of bulletins disseminate the results of CIMMYT research. Up to now, seven bulletins have been published in the Research Bulletin series—three in both Spanish and English, one only in Spanish and three only in English. Five miscellaneous publications, issued previously in mimeograph form, were republished in a single bulletin in order to make available once again the results of earlier international comparative wheat yield trials. This information, which is principally numerical, was published only in English. The Department has also collaborated directly in the publication of six Master of Science degree theses prepared by Rockefeller Foundation scholars at the Chapingo Graduate College. All of this material is listed below.


M.S. Theses


Reacción de treinta selecciones del género Lycopersicon al ataque de Phytophtora infestans (Mont.) de Bary. 1967.

Heterosis, acción génica y correlaciones de catorce variedades de maíz en Colombia. Daniel Sarria V. 1966.

Efecto de la selección masal en dos variedades de maíz. Francisco Humberto Tapia B. 1966.


As a service to the Central American Food Crop Improvement Program, an 80 page proceedings issue of the papers presented at the 12th annual meeting was edited and published.

CIMMYT staff members are also encouraged to contribute to established journals. Reprints of the published articles are obtained for distribution through the communications department and are regularly announced in CIMMYT News.

Visual Aids

During the past year photographic help has been provided on a part-time basis by the Rockefeller Foundation. Part-time help in film developing and movie production has been obtained through cooperative arrangements with the Instituto Nacional de Investigaciones Agrícolas (INIA). This has been a satisfactory provisional arrangement.

For the future, plans are being made for a broader program to include the production of visual aids and prototype materials, and to provide training in this field for technicians from national programs where there is a need to use visual materials in promoting more efficient maize and wheat production. In this connection training has been provided in cooperation with the INIA for a visual aids specialist from Ecuador. The INIA film production team is currently producing a movie for the Instituto Colombiano Agropecuario and simultaneously training Colombian technicians in this field.

Materials for farm audiences are preferably produced in each local area. CIMMYT help with these kinds of visuals can best be limited to prototype materials and to technical assistance. However, there is an extensive need for materials to be used in training extension agents, agronomy students, technical farm advisors of commercial firms and other middle echelon development agents. The textbooks on applied research and data gathering methods tend to be outdated and inadequate.

To begin to fill this gap, CIMMYT is planning a series of films and slide sets, with accompanying manuals, on the methodology of important
Changing from traditional methods offers the farmer the possibility of higher yields and greater returns. At the same time he must make a substantial investment and absorb the risk associated with trying something new. Adequate field testing of new practices by research and extension programs can greatly reduce this risk. This man participates in the Rural Credit Program of the National Bank of Nicaragua.

The introduction of better production methods among the large number of small holders is held back by the lack of technicians and the high cost per hectare of reaching individual decision-makers. In El Salvador the Catholic priest Jose Romeo Maeda and the agronomist Jesus Merino Argueta are successfully organizing local credit societies which serve as nuclei for extending credit and teaching how to use the new inputs.
research techniques. The first of these is a 16 mm colored film on "Field Technique in Fertilizer Trials". This has the technical direction of the soil scientist and is being filmed on actual field trials on Mexican farms during the growing season. It is intended for both classroom and post-college training of agronomists and will be made available in English and Spanish.

FIELD RESEARCH IN COMMUNICATIONS

At the time the CIMMYT was founded a beginning had already been made in Mexico in research on how to gain more rapid yield increases on farm plantings. This earlier work was carried out largely with small holders and in cooperation with the Instituto Nacional de Investigaciones Agrícolas. Through this research the following points were clearly established: 1) that much more efficient methods would have to be found to reach large numbers of farmers with specific operational information about new practices, 2) that in promoting new practices greater attention had to be given to the relation of additional return to additional cost, 3) that the new inputs must be available to the farmer at the time that he needs them, 4) that credit would have to be more readily available for purchasing the new inputs, 5) that some form of production risk insurance must be available if the new practice requires substantial capital expenditure, 6) that guarantee prices or some other system for reducing market risk must be available to assure a reasonably stable price.

The field studies indicated that the lack of one or several of these usually explained the slow adoption of practices which according to cost-return calculation based on research results should have been adopted quickly.

The main focus of the communications program for the present will be field testing of this formulation of the essentials for gaining rapid adoption. Procedures must be developed for rapidly identifying the limiting factors in any region and providing blueprints or programs to rapidly correct the deficiencies and bring about adoption of yield-raising practices. It is eminently clear that adoption is not brought about by information alone no matter how well presented, or how complete or how well demonstrated. Adoption is brought about by a set of conditions such as those mentioned above of which information is only one. The goal of the communications program is to reduce the disparity between the experimentally demonstrated yield possibilities and those being obtained by farmers under similar ecological conditions.

Central American Study

At the invitation of the program committee of the XIII annual meeting of the Central American Food Crop Improvement Program, a study was conducted of extension corn production programs in Central America. This study was conducted jointly with Dr. Sebauld G. Manger Cats, Land Use Specialist of the FAO, in an attempt to extract guidelines for future programs from previous experience in the region. Corn promotion programs
A careful analysis of successes and failures in crop promotion programs can yield insights and principles of great value for establishing future programs. Farmers were interviewed in groups during the review of the Central American programs.

were reviewed in Guatemala, Honduras, El Salvador, Nicaragua and Costa Rica. The report was presented to the annual meeting at San José, Costa Rica, in early March in two sections, the first a review of production programs and the second a study of corn marketing in the area. The report was well received and it is felt that this type of analysis followed by recommendations for specific programs may be a useful function of the CIMMYT. Both reports are available from the CIMMYT in mimeograph form.

Closer Ties Between Plant Scientists and Extension Workers

In the flow of information one of the serious problems is the organizational separation between research and extension programs. One illustration of this is the fact that in more than 20 years of existence of the Latin American Plant Science Association, numerous sections have been added to cover all aspects of theoretical and applied research on plant production, with the exception of research on how to bring about adoption of the practices by farmers. There has usually been a single panel or presentation on relations between research and extension but no serious approach to incorporating the agronomists working on adoption research. For this reason CIMMYT staff took the initiative in communicating with other researchers in this field throughout Latin America with the result that a section covering this research was incorporated in the Venezuela meeting in September 1967. It is hoped that this may eventually help to establish a more intimate relationship between research and extension programs throughout Latin America.
Where ecological conditions are favorable, yields can often be increased rapidly by making readily available the new inputs—improved seeds, fertilizers, insecticides, herbicides. In Central America private industry has undertaken a program to establish a distribution network and to train local sales and service personnel who cooperate closely with government programs.

DOCUMENTATION SERVICES

The need for documentation services and library facilities is being resolved in the following manner. The Agricultural Library developed by the Rockefeller Foundation in Mexico, has been donated to the National Agricultural Library at Chapingo where it is available to students and staff of the various agencies involved in the National Center for Agricultural Education, Research and Extension. It will also be available to CIMMYT staff and students. Plans are also being made to develop small collections of frequently consulted books and journals in each department of the CIMMYT.

It is hoped to develop the major maize and wheat library in cooperation with Chapingo and simultaneously develop the necessary documentation services in maize and wheat. The first step toward this goal is a grant from the Rockefeller Foundation for the training of two professionals in documentation. The project includes the training of eight science librarians from various parts of the world at the National Agricultural Library in Washington. These eight students, including the two from Mexico, are carrying out M.S. degree programs at the Catholic University and will prepare the maize and wheat bibliography for the 1958-1968 period as a thesis project. These persons should then work closely with CIMMYT and the National Agricultural Library at Chapingo to provide maize and wheat documentation services for CIMMYT staff and for other scientists around the world.
SOURCES OF SUPPORT FOR 1967

I. CASH RECEIPTS

A. General Support

1) The Ford Foundation 107,900
2) The Rockefeller Foundation 323,700
3) Corn sales and miscellaneous 9,245

Sub-Total A 440,845

B. Restricted Grants and/or Contracts

1) The Rockefeller Foundation
   a) Central America and Caribbean Corn Project 15,000
   b) Puebla Pilot Program 42,200
   c) Equipment and vehicles 60,000

2) The Ford Foundation
   a) Pakistan Wheat Project 230,000

3) Other
   a) Fertilizer for Puebla program (American Potash Institute) 2,000

Sub-Total B 349,200

Grand Total 790,045

II. OTHER

A. Number of scientists commissioned to the Center:

   The Ford Foundation 2½
   The Rockefeller Foundation 9

B. Consultants or Temporary Staff (man months):

   The Ford Foundation 2
   The Rockefeller Foundation 14