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Edited by:

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DEAN BORK

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Introduction

The impact of CIMMYT's outreach programs is largely dependent upon the quality of information, materials, training and coordination emanating from its core program in Mexico and from the highly effective cooperative network of national programs in countries with which it collaborates.

The quality of this vast cooperative effort is mainly dependent upon the effectiveness of specific scientists, either nationals of a country or expatriate scientists employed by CIMMYT or by other organizations interested in increasing food production, especially in developing countries.

CIMMYT believes that the effectiveness of these scientists can be further enhanced by bringing them together periodically to get better acquainted with each other, with the various programs and, above all, with the major problems that can best be solved locally, regionally or globally. Also, CIMMYT believes there is much to be gained from seeing the research and training activities underway in the core program.

So, CIMMYT invited key maize and wheat scientists, working toward a greater efficiency in maize and wheat production in several areas of the world, to Mexico to participate in a workshop with the specific purposes of:

1. Reviewing the present research and training activities underway in the core program;
2. Promoting a better understanding among participants of work in progress and the common problems and limitations to maize and wheat production in the areas or regions in which they are working;
3. Discussing CIMMYT's role and how can this role be made more useful;
4. Planning ahead, regionally and globally; and
5. Discussing plans for a detailed symposium on each crop.

The papers presented at the Maize workshop by participants from around the world are presented here. All the papers were edited for consistency of style, most were condensed, and some were revised and restructured. During the translation and editing, efforts were made to maintain the authors' emphases and philosophies.

Maize Improvement and Production in Perú

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Perú has about two million hectares of cultivated land representing 1.6% of its area. About 362,000 hectares are planted annually and more area is planted to corn than any other crop. The average annual production reaches nearly 600,000 metric tons.

Ecologically, the country can be divided into three regions. The Coast extends along the Pacific Ocean. This area receives 30 to 40 millimeters of rain annually. Being an arid zone, agriculture is not possible without irrigation. The zone extends up to 1,600 meters elevation. The climate is mild, soils are productive, and with the established irrigation facilities, excellent yields are possible.

The Sierra includes valleys of the Andes Mountains ranging in altitude from 1,600 to more than 3,500 meters. Maize is grown under irrigation and under rainfed conditions in this region.

The third area is the Jungle on the eastern slopes of the Andes. This tropical, humid area extends through the Amazon River into Brazil.

Maize is grown in all 23 departments. Thirty percent of the corn area is in the Coast, 60% in the Sierra, and 10% in the Jungle.

There was a sharp increase in production from 362,000 metric tons in 1963 to 590,575 metric tons in 1967. The Coast produced half of this, the Sierra 40% and the Jungle 10%.

An increase in corn area in the Coast may account for part of this production increase. This increase in area can be attributed to the release of high-yielding hybrids developed by the Corn Program. The new seed allowed maize to compete with more productive crops like cotton and sugar cane in terms of net income.

There is a tremendous diversity of maize types and a great variety of uses for the crop. Thirty-eight percent of the total production is used directly for human consumption, generally prepared by boiling or roasting the kernels. The types most used by humans have floury textures and varied colors. However, hard endosperm types are ground and cooked for many dishes.

In the Coast, the predominant types are semiflints and flints, even when some floury types are grown in the northern coastal section. These floury types are used mostly to make an alcoholic beverage. Most of the production from the Coast is used for animal feeding, mainly for mixed poultry feeds.

Two percent of the total production is absorbed by the starch industry and some other industrial by-products. Another two percent represents seed for planting.

LAND DISTRIBUTION

Peru's land distribution in 1967 showed a very peculiar characteristic. Eighty percent of the cultivated land was in the hands of one percent of the farmers. Eighty-three percent of the agricultural units are less than five hectares and it is estimated that 95% of the 850,000 agricultural units are subsistence units.

The government is carrying out a drastic program of land reform which will probably change these figures radically. The cooperative organization of big sugar cane plantations and large land holdings in the Sierra will probably change the agrarian structure, also.

LIMITATIONS TO MAIZE PRODUCTION

Due to the many ecological conditions, it is difficult to generalize about production limitations. Nevertheless, there are problems and limiting factors. These can be grouped as follows.

1. For research, there is a lack of land for experiment stations, limited laboratories and equipment, insufficient funding of research

institutions and, very importantly, there is a definite shortage of properly trained personnel.

2. In promotion and extension, there are inefficiencies in the release of improved seeds and in the allocation of credit to maize growers. Operational funds are limited and there is a need for more properly trained technicians.

3. Marketing, storage and distribution are far from adequate. There is a definite need for organizing trade centers, for allocating credit for construction of storage facilities at the farm level and at the regional level, for establishing a price policy, for organizing a national information system of marketing, for establishing marketing standards for crop insurance, and for import and export regulations.

NATIONAL MAIZE PROGRAM

With the initial support of the Rockefeller Foundation and the Peruvian government, the National Agrarian University started a nationwide maize program in 1954. The program focused on varieties and agronomic practices. So, the country was divided into several ecological areas.

Four years later, two topcrosses and a double cross were released for the Coast. The introduction of a semiflint corn was successful, considering that the farmers traditionally planted less productive flint types.

The maize program includes five major projects. Breeding involves developing hybrids for the Coast and for the Jungle. This project also includes developing synthetics, improved varieties and composites for the Sierra.

The agronomy project involves: fertility trials in all regions; population-fertility-hybrid trials; use of chemical weed control; biological and chemical insect control; date-of-planting trials; rotation experiments; and residual effects of fertilizer determinations.

The third major project is seed production, including foundation seed, seed certification, seed processing, establishment of a policy on seed production and distribution, and a nationwide varietal yield test in 25 locations.

The fourth project involves the maintenance and classification of 1,700 collections of maize from Perú and about 300 from other countries.

The fifth project involves special comparison studies of methods for maize improvement in local varieties, selecting short plants in the tropics, developing high quality protein maize, developing high-oil and high-protein synthetics, developing waxy corn and conducting International Maize Adaptation Nurseries (IMAN) and International Opaque Maize Trials (IOMT) sent by CIMMYT.

The maize program annually conducts about 150 breeding trials, 40 agronomic trials and 20 special studies trials. Also, the maize program supervises production of all certified seed in the country.

Data collecting and analysis have been computerized in order to have the experimental results in time for the next planting season.

The program has been self-supporting since 1963. This has been possible through an agreement with the seed growers by which they pay a royalty equivalent to 10% of the selling price. With these funds and income from foundation seed sales, the program is able to meet its operational budget. The salaries for the 12 professional people in the program are paid by the University.

Due to the program, Perú no longer imports maize. If the proper steps are taken by government officials, Perú will be able to meet the increased demand of the future. Otherwise, it might have to recur to imports to meet the demand.

STRENGTHENING THE NATIONAL PROGRAM

CIMMYT should help the national program by:

1. Supporting development of an organization to coordinate and centralize all activities in maize research and production. Local technicians think this is a viable solution to many problems which render their efforts little less than useless in many instances.

2. Financing short-term visits of national scientists for exchange of information and supporting the assistance of qualified scientists to international meetings.

3. Supporting the publication of abstracts of papers on maize from all over the world.

Maize Production in Brazil

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IMPORTANCE, TYPE AND USE OF MAIZE

Brazil, with an annual corn production of 12 million metric tons, ranks second among all nations. Almost 30% of all agricultural land in Brazil is devoted to corn growing, ranking it first among all crops. Maize accounts for about 14% of the total agricultural production value, ranking second to coffee.

Four south-central states, Río Grande do Sul, Paraná, Sao Paulo and Minas Gerais, account for 70% of the production. Including Santa Catarina and Goiás accounts for 80%. Thus, the northern and northeastern states account for only 20% of Brazil's maize production.

Eighty percent of the maize produced is used for animal feeding. About 12% is exported and about 5% is used directly for human consumption. Starch and other industrial uses account for only 3% of the production. Use of maize directly as human food is more common in the northern and northeastern states than in the central and southern states.

Yellow varieties account for most maize acreage in Brazil. Semident varieties predominate in the central states. This is generally due to the hybrid vigor easily obtained from crosses between dent and flint inbred lines, but it is also because farmers in this region did not have a tradition of maintainance or cultivation for a specific type. The semident types were easily accepted.

In the southernmost states of Río Grande do Sul and Santa Catarina, yellow dent corn accounts for most maize acreage, but in the northern and northeastern states, the local orange flint and yellow dents account for most maize acreage.

The yellow dents are of the Tuxpeño type, improved in Sao Paulo and then introduced in the northern area with excellent results. Tuxpeño germ plasm has also been involved in the development of several improved varieties for the central states. White flints, popcorns, opaque-2 maize and some other types are grown for specific purposes.

LIMITATIONS TO MAIZE PRODUCTION

The national average maize yield is 1,300 kg/ha. Corresponding figures for the North and Northeast, Minas Gerais and Río Grande do Sul, and Paraná and Sao Paulo, are, respectively, 820, 1,300 and 1,800 kg/ha.

While the cooperative farmers of Sao Paulo to get 4,000 kg/ha, experimental trials include yields of 8,000 kg/ha and the winners of the national yield contest produced an average of 14,000 kg/ha.

These data show that production efficiency must be increased to take full advantage of present varieties' yield potential. Increasing the present yield level must also be considered.

In Sao Paulo, about 80% of the maize area is planted to improved varieties or hybrids. The genetic yield potential of these seeds has been proven consistently. Low yields are mostly due to poor agricultural practices. Soil management, seedbed preparation and poor husbandry result in rather low plant densities and low yields. Also, fertilizer is used on only 10% of the maize acreage.

In southern Brazil, about only 20% of the maize acreage is planted to hybrid or improved seed. Here, seed quality and poor cultural practices are mostly responsible for low yields. The need to expand use of improved seeds is a pressing one in Brazil.

Brazilian farmers, in general, know how to grow maize properly. Still, some improvements could be introduced in cultural practices. Perhaps the most important factor limiting production is the limited attention the farmers give to their maize fields. This, in turn, is often due to the low net income they get from their maize crop since the market prices vary markedly.

WHAT CAN BE DONE?

In the central and southern states, the main problem is economic. Also, extension work is needed to convince farmers to improve management of their maize fields, especially soil management to insure proper plant density. Many of the recommended practices will not increase the cost of production. Fertilizer use should be increased.

In northern and northeastern Brazil, there is a pressing need for maize improvement and production programs. All varieties used have been obtained from the South and it is unlikely that these are well-adapted to northern conditions.

Even though good hybrids and varieties are available in central and southern Brazil, much improvement still needs to be done. Improvement of plant type is much needed. Most Brazilian maize plants are too tall. Better high yielding hybrids and open-pollinated varieties can be obtained.

There is much germ plasm diversity that can be explored with promising results. Tuxpeño germ plasm has been utilized with excellent results. Several outstanding, open-pollinated varieties of Tuxpeño germ plasm have been obtained and have achieved great popularity. These include Azteca, Piramex, Maya and Centralmex. Elite inbred lines obtained from these varieties are already being used in the synthesis of some good commercial hybrids.

Tropical flint germ plasm, mainly from Cuba, Central America and Colombia, has also been important to Brazil. However, its study and utilization have not been very intense.

For greater progress in maize improvement in Brazil, the following items should be considered.

1. Obtain more information about tropical germ plasm that could be potentially useful to local programs.
2. Intensify programs of population improvement, including formation of composites and intensive use of efficient methods of population improvement.
3. Study the performance of intervarietal crosses.

For the northern and northeastern regions where there are practically no local breeding programs and where corn is usually planted in small fields, emphasis should be on obtaining improved, open-pollinated varieties. Extensive tests of the more promising germ plasms should be carried out. Then, simpler selection techniques should be used to develop better varieties.

Attention should also be given to research on cultural practices such as time of planting and population density.

What is the National Program Doing?

In central and southern Brazil, several programs for maize improvement are underway. Both official and private institutions have made great progress in genetic improvement in maize. Two private organizations are devoting much effort to develop better hybrids. Most of the official institutions are emphasizing population improvement. In recent years, much more progress has been made with population improvement than with hybrid corn breeding.

Opaque-2 corn is already established, mainly in the state of Paraná. Agroceres, a pioneer private organization in hybrid corn, started selling opaque-2 hybrid seed to swine farmers in 1969. The experience was so good that this year about 800 metric tons of opaque-2 hybrid seed is being sold to farmers.

In the northern and northeastern states almost all national programs are operating very inefficiently. Here there is more need for technical assistance than for anything else.

CIMMYT's ROLE IN BRAZIL

Consider these suggestions:

1. CIMMYT should be acquainted with the existing corn programs in Brazil and help them get better results more efficiently.
2. Providing periodical information to breeders that reports promising germ plasm and other achievements from CIMMYT would be very helpful.
3. CIMMYT should develop basic germ plasms adapted to tropical climates. Specific characteristics such as high nutritional value, short plants and better plant architecture could be incorporated in such stocks with great benefit to tropical programs all over the world.
4. Periodic meetings among breeders from various countries would be of great value. This would provide opportunities for better acquaintance among corn breeders and exchange of materials, experiences and information. These meetings have already proven useful in several areas.

Maize Production in the Philippines

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Corn ranks second to rice as a staple food in the Philippines. Approximately 20.8% of the population eats corn grits instead of rice.

Corn ranks next to rice in the use of agricultural resources, also. The area planted to corn more than doubled since the early 1950's and exceeds the combined areas devoted to four important commercial crops: coconuts, sugar cane, abaca and tobacco.

PRODUCTION STATISTICS

Corn area in 1960 was 1,845,540 hectares compared to 2,392,200 in 1970, an increase of 29.5%. Production in 1960 was 1,165,274 tons and for 1971, 2,004,975 tons, an increase of 72% (Table 1). The average yield increased from 0.63 to 0.86 tons/ha, a 35% increase.

TABLE 1. Area planted, production and average yield in the Philippines for 1960-71.

Crop Year	Total Area Planted (hectares)	Production (tons)	Average yield (tons/ha)
1960	1,845,540	1,165,273.8	0.63
1961	2,045,460	1,209,557.1	0.59
1962	2,016,270	1,266,299.5	0.63
1963	1,949,510	1,272,849.9	0.65
1964	1,897,570	1,292,708.7	0.68
1965	1,922,750	1,312,681.5	0.68
1966	2,106,070	1,379,827.5	0.65
1967	2,166,840	1,434,969.3	0.66
1968	2,247,860	1,616,873.4	0.72
1969	2,256,140	1,732,834.2	0.77
1970	2,419,600	2,008,212.6	0.83
1971	2,392,200	2,004,975.0	0.86

The yield per unit is still very low. However, since 1966 the average yield has increased each year. This is mainly attributed to the increased emphasis on production by the Philippine government, starting in 1966. The average yield increased steadily from 0.65 tons per hectare in 1966 to 0.86 in 1971, a 32% increase. Rice production for the same period increased 30%, from 1.32 to 1.72 tons/ha.

Shelled corn production by region is shown in Table 2. About half the total area is grown in Mindanao. The Southern and Western Mindanao regions account for 38% while the two Visayas regions account for 27%. The yield per hectare is higher in the Cagayan Valley, Southern Tagalog and Southern and Western Mindanao than in the other regions.

TABLE 2. Shelled corn production, area and average yield per hectare by region in the Philippines for the 1971 crop year.

Region	Production (tons)	Area (hectares)	Average Yield (tons/ha)
Ilocos	10,716	21,600	0.50
Cagayan Valley	224,010	238,500	0.94
Central Luzon	48,621	82,300	0.59
Southern Tagalog	161,937	164,500	0.98
Bicol	70,680	99,400	0.71
Eastern Visayas	179,550	324,600	0.55
Western Visayas	209,703	301,700	0.70
Northern and Eastern Mindanao	159,714	262,700	0.61
Southern and Western Mindanao	940,044	896,900	1.05
TOTAL	2,004,975	2,392,200	0.84

TYPES AND USES OF CORN

White and yellow corn are grown commercially in the Philippines. White corn is grown for human consumption, for manufacturing corn starch and for many other by-products such as corn oil, syrup, dextrins, glucose and gluten.

About 60% of the total corn requirement is eaten as corn grits. Corn grits supplement rice when the rice supply runs short. When milling corn grits, the by-products are bran and corn germ. Bran and corn germ are fed directly to livestock while some big corn mills extract oil from the corn germ. About 10% of the total production is used to make starch.

About 10% of the corn area is devoted to yellow corn. But, yellow corn production does not meet the feed requirement, requiring feed manufacturers to use white corn, too.

Five percent of the total production is consumed as green corn. The commercial green corn is the regular white and yellow corn, yellow sweet corn and white glutinous corn. Sweet and glutinous corn are most popular.

Popcorn is grown commercially in the Philippines to a very limited extent.

LIMITATIONS TO PRODUCTION AND THE NATIONAL PROGRAM

Slow Acceptance of High-Yielding Varieties

The average yield of 0.86 ton/ha in the Philippines is still one of the lowest in Asia. Although several high-yielding varieties developed by the University of Philippines College of Agriculture and the Bureau of Plant Industry have an average yield of 3.5 tons/ha, farmers still hesitate to use them because: they stick to the native varieties and traditional farming methods; there are not enough trained extension workers to promote corn production; the recommended varieties are susceptible to downy mildew (However, these are resistant to rust, the second major disease.); quality seeds are inadequate; some regions prefer early maturing varieties; and there is a lack of credit to buy inputs, especially fertilizer and insecticides.

The government has recently emphasized corn, unlike the past when rice was the major concern. The objective of the national corn program is to increase production by planting high-yielding varieties and practicing good cultural management.

Strategies to accomplish our objective are:

1. Intensify research on varietal improvement, cultural management, processing and marketing. The U. P. College of Agriculture, the Bureau of Plant Industry and agricultural schools are given these responsibilities.

2. Continue training extension workers in priority provinces.

3. Intensify campaigns in the use of high-yielding varieties and recommended cultural practices through brochures, mass media, farmers' classes, etc.

4. Employ an additional 224 extension workers for the Mindanao and Visayas regions.

5. Increase seed production of recommended varieties, including newly-released, downy mildew-resistant varieties.

6. Conduct more applied research on varieties and fertilizers in farmers' fields in priority provinces.

7. Conduct more production trials (400 square meters) using a corn kit—seeds, fertilizers, insecticides and instructions.

8. Extend production loans to farmers using high-yielding varieties and recommended cultural practices, especially in areas with a potentially high concentration of corn production.

Low Price of Corn at Harvest Time

Corn marketing is controlled by wholesalers and millers in strategic locations. At harvest time, big wholesalers and millers buy cob corn rather than shelled corn from farmers. Marketing facilities such as transportation containers and facilities for shelling are provided by the buyer.

Farmers are at a disadvantage, especially at harvest time when prices are low. Usually there is a great difference between prices at the farm and at market centers. However, this year corn prices at the farm are attractive to farmers. Total production is low because of several typhoons.

The Rice and Corn Administration (RCA) stabilizes corn prices and provides incentives through farm price supports. RCA allows prices in the free market to be based on supply and demand. The government intervenes only when prices are below the support price and if the consumer price is above the ceiling price set by the government.

Lack of Credit Facilities

Most farmers learn of the yield potential of newly developed varieties through local demonstration trials. However, most corn farmers cannot afford some agricultural inputs, particularly fertilizer and insecticides. Farmers often borrow money from middlemen and pay their loan with corn at harvest—valued at prices dictated by the middlemen.

The Agricultural Credit Administration (ACA) and the Rural Bank extend production loans to corn growers who plant recommended, high-yielding varieties, use efficient and improved farming pesticides, and who are under the guidance of trained corn technicians. ACA extends its assistance only to members of the Farmers' Cooperative Marketing Association while the Rural Banks assist selected corn farmers.

For the 1971-72 fiscal year, credit assistance to only 10% of the total programmed area, totaling $1,250,000, is forseen.

Corn Borer Infestation

The corn borer *(Ostrinia furnacalis,* Guenee), which is especially severe during the rainy season, is the most destructive corn pest in the Philippines. Losses reach 20% to 80%. Corn borer insecticides available in local markets are Sevin, Gesarol, Resitox, Thiodan and Basudin.

Chemical control is more expensive during the wet season because frequent spraying is required for effective control. Also, with the unpredictable weather conditions, farmers cannot spray when it is necessary.

Entomologists are now evaluating systemic and granular insecticides while breeders screen varieties for corn borer resistance. Since 80% of the corn farmers cannot afford to buy equipment and chemicals, this will be the best practical approach.

Downy Mildew Infection

One of the limiting factors to corn production is downy mildew, a disease cause by *Sclerospora philippinensis,* Weston. The disease attacks plants at all stages of growth, although plants are most susceptible from emergence until they are one-month-old. Losses reach 100% with the newly recommended, high-yielding varieties and 80% with the native varieties.

The disease is widespread in Mindanao and the Cagayan Valley where 60% of the total corn area is located.

Research institutions have concentrated on developing varieties resistant to this disease and effective chemical controls. The U. P. College of Agriculture and the Mindanao Institute of Technology this year released two new varieties resistant to downy mildew—Philippine DMR-2 and MIT Var. 2. However, yields of these varieties are lower than the UPCA VAR varieties. UPCA has found several promising approaches to chemical control. However, more studies are needed to make it economical for farmers' use.

This year the government approved and funded a downy mildew program of research, training and production. Research will concentrate on varietal improvement, cultural management, chemical control and adaptive research in farmers' fields. Most work will be done at Central Mindanao University and Mindanao Institute of Technology. Training consists of a four-week course on conducting downy mildew adaptive research by selected production technicians.

Cooperative research on this disease is now established among countries in the region through the Inter-Asian Corn Program. There is an exchange of breeding materials and an Inter-Asian Downy Mildew Yield Trial is being conducted.

CIMMYT's ROLE

Introducing new germ plasm will be CIMMYT's most important contribution to national programs. Evaluation of elite materials such as the International Maize Adaptation Nurseries (IMAN) and opaque-2 yield trials is a good approach. CIMMYT should make promising entries from these trials available for further evaluation in several locations. Other germ plasm of particular interest should be evaluated, not by each country, but by regional centers like the Inter-Asian Corn Program and the elite entries should be sent to national programs within the region.

CIMMYT could further help the Philippines program by training corn specialists in the national program and staff members of the U.P. College of Agriculture and the Bureau of Plant Industry.

Lastly, CIMMYT should sponsor symposiums or workshops on specialized topics of particular interest around the world such as a follow-up symposium on high-lysine corn and breeding for insect resistance. Likewise, a symposium on regional topics such as downy mildew disease of corn may also be sponsored.

Maize in Bolivia

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Maize has been one of the main crops in Bolivia since pre-Incaic times. The Incas developed varieties with hard, semihard and soft endosperm of various colors for different uses. At present, corn is one of the basic food crops and is very important to Bolivia's economy.

Maize is grown mostly by small farmers under a great diversity of climates and soils from the tropics to 3,500 meters above sea level. It occupies 217,400 to 280,120 hectares, or 27% of Bolivia's cultivated area.

Total production is 390,000 metric tons of which 256,700 tons are consumed by humans —an annual per capita consumption of 5.3 kilograms. Fifty-eight thousand five hundred tons are used as fodder and the total loss due to factors such as insect damage of stored grain is about five percent, or 19,500 tons.

The growing cycle varies from 150 to 270 days. There are many varieties and the highest yielders are varieties of the Cusqueño *(paltawaltacu)* type.

IMPORTANCE, USE AND TYPES OF MAIZE

Maize and potatoes have long been of vital importance in the diet of the Bolivian peasants. Maize has been used for food, beverage, fodder, fuel, ornaments, dye, wrapping, medicine, sorcery and for the building of shelters.

Some of these uses still persist, particularly those concerning human consumption, such as corn-on-the-cob, roasted corn, boiled corn, corn flour, ground fresh corn with cheese and *chicha*. In the inter-Andean valleys, *chicha* is fermented but in the tropical zones it is prepared as a fresh drink.

Different varieties are used for different purposes. *Huillcaparu* is the most widely used for human consumption and it is also the most commonly cultivated variety. *Checchi* is used to prepare *tojori* (roasted ground corn mixed with sugar), *Chuspillo* is used for roasting and *Culli* (purple maize) is used for *api* or *mazamorra* and also to prepare *chicha*. In addition to these varieties, there are many soft-endosperm corns which are used for *chicha*. *Cusqueño* types of the variety *paltawaltacu*, which has large, soft kernels, are preferred for consumption as fresh corn.

The Bolivian corns attracted attention for their genetic variability and wide distributions, and were studied to distinguish the existing races. The Rockefeller Foundation and the Bolivian government with the collaboration of the U.S. National Academy of Sciences, the U.S. Agency for International Development and the Botany Department of the Faculty of Agronomy of the Universidad de San Simón, headed by Dr. Martín Cárdenas, sponsored collections of corn throughout Bolivia.

Eight hundred eighty-four collections were obtained, studied and classified for their external and internal botanical traits, physiological and genetic aspects, and fitted into 32 races. Later, 143 additional collections were obtained and studied.

The recognized races of maize in Bolivia are: *Confite Puneño; Altiplano; Platillo; Kcello; Kulli; Huilcaparu; Chake-Sara; Aysuma; Platillo-Grande; Checchi; Cuzco-Huilcapuru, Paru; Chuspillu; Cusco Boliviano; Pisankalla; Uchuquilla; Karapampa; Argentino; Niñuelo; Camba; Morado; Perola; Yunqueño; Pojoso Chico; Cholito; Cubano Dentado; Cateto; Pororo; Coroico Blanco; Coroico;* and *Enano.*

With the advent of the agrarian reform and the corresponding social changes in rural areas, many varieties which had been cultivated since ancient time have been lost. Consequently, the collections preserved in germ plasm banks are invaluable and their study is useful in breeding better maize for Bolivia and Latin America.

LIMITATIONS TO MAIZE PRODUCTION

The limitations to maize production are genetic, agronomic and economic, all affecting the well-being of the farmers. It is necessary to develop high-yielding, early-maturing varieties to replace the poor-yielding types grown in the transandean valleys and in the Tropics.

Uchuquilla is one of the earliest varieties with a growing cycle of 150 days but it yields poorly. The highest yields are obtained with *paltawaltacu* types which require 270 days to mature.

The great diversity of varieties negates standardization of plant densities, weed control, fertilizer use or disease control, particularly stunt caused by a virus transmitted by *Dalbulus maidis*. Floury types grown in the valleys of Cochabamba and the tropical areas of Santa Cruz are susceptible to this virus-caused stunt.

It is necessary to control the ear-worms *(Heliothis zeae* and *H. virescens)* the borers *(Diatraea saccharalis* and *Elasmopalpus lignocellus)* and other insects like *Diabrotica speciosa, Aphis maidis* and the Fall Armyworm *(Spodoptera frugiperda).* Insects that attack stored grains, such as *Sitophilus granarius, Rhyzoperta dominica, Sitotroga cerealella* and *Plodia interpunctella,* should also receive attention.

Average yields for unimproved varieties vary from 1,392 to 1,670 kg/ha, while improved varieties yield 3,000 kg/ha.

Production costs vary from US$69.10 to US $77.50 per hectare and the net income per hectare varies from US$8.50 to US$26.40.

The price received by the producer is US $0.05 per kilogram and the price paid by the consumer is US$0.10 per kilogram.

The low prices paid to the farmers and fluctuations in supply and demand create situations where production costs are barely covered. Price fluctuations caused by unstable markets and lack of storage facilities are about 30%. Despite increasing maize use for fodder and possibilities of exporting surplusses, Bolivia lacks good storage and marketing systems and this hurts the small producer.

Also, the small size of farmers' plots in the valleys of Cochabamba helps make maize production a low-profit undertaking. Finally, add the vagaries of the weather, particularly drought, which causes a partial loss of the crop each year.

SOLUTIONS TO THE LIMITING FACTORS

Overcoming the limiting factors demands:

1. Start a practical breeding program, including mass-selection schemes to use the additive genetic variance present in the local varieties. Using weight per plant as a criterion for selection, the yield of the variety *paltawaltacu* was increased 19% over the original population.
2. Select for resistance to virus stunt in varieties used for fresh corn and grain.
3. Select for adaptation to rainfall, altitude, temperature and so forth. Develop early-maturing, high-yielding varieties with broad adaptation using populations available in the national and international germ plasm banks.
4. Develop a sound extension program to promote use of the improved seed, fertilizers, weed, insect and disease control to lower production costs and increase yields.
5. Establish a grain storage program to avoid losses caused by insects and adopt price stabilization and marketing policies.
6. Establish regional cooperative programs with the participation of educational and research centers, and international institutions, to exchange experiences, information and materials, and to train technicians for various production projects.
7. Promote cooperatives among small farmers to increase the size of the plots planted to maize and increase their efficiency. It is assumed that the operational system would be a type of Puebla Project. In Cochabamba there are 155,000 hectares of arable land and 209,400 farmers, a ratio of 1.3 farmers per hectare.
8. New technology must be used to increase production and to improve rural welfare.

NATIONAL AND REGIONAL PROGRAMS

There is no national maize program sponsored by the Ministry of Agriculture and at present, emphasis is on wheat production. National development plans call for growing soft-endosperm maize and other types in irrigated areas and for the industrial use of maize.

The Research Division of the Ministry of Agriculture has one technician at the Saavedra Experiment Station working on mass selection, variety testing, intervarietal crosses and seed productoin of the *Amarillo Cubano* variety.

In the valley of Cochabamba, the faculty of Agronomic Sciences has organized a Department of Plant Breeding. Efforts include:

1. Mass selection programs for local varieties. Hybrid maize programs were abandoned

because farmers prefer to produce their own seed. Considering their precarious economy and ignorance of the merits of hybrid seed, a good, open-pollinated variety from mass selection will be better suited to these conditions.

2. Work is being done to improve maize protein through the incorporation of the opaque-2 gene into local varieties.

3. Theses on fertilizers, genetics and socioeconomics have been done by students.

4. Under the direction of Ing. M. Romero, an experimental program has been initiated to increase maize production in plots of 1,400 square meters belonging to five farmers using three improved varieties, fertilizers and insect control. It follows the guidelines of the Puebla Project.

CIMMYT's ACTION IN BOLIVIA

Considering that the main objective of CIMMYT is "to obtain fast and continuous increments in production" through research in genetics, agronomy and socioeconomics plus the training of technical personnel at its center in Mexico, the establishment of a cooperative program in Bolivia would contribute to the training of teams of local technicians capable of promoting the improvement of maize production.

This would raise the living standard of Bolivian peasants and small farmers, who comprise 62% of the total population.

Maize Production in Thailand

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Maize is one of the most important field crops in Thailand, second only to rice. Maize is grown mainly for export. Its export value exceeded US$90 million in 1970. Less than 10% of the corn has been used locally for poultry and livestock feed.

With increasing demand for maize, the area and total production in Thailand has increased tremendously each year. Under present circumstances, production of 3.5 mililon metric tons could be achieved by the end of 1976.

PRODUCTION STATISTICS

Maize production in Thailand increased from 543,000 metric tons in 1960 to more than 1.5 million metric tons in 1970. The area has increased almost threefold. However, yield per hectare has been relatively low and static.

Total area, production, average yield per hectare, market value and export value are shown in Table 1.

Except for the export values, data after 1968 are not available and have been estimated in some cases. The average price of maize during 1960-70 was about US$58 per metric ton. Due to the high market demand in the 1970 season, the price of maize was up to US$67 per metric ton, the highest in the history of maize export. It is estimated that the export value in 1971 will reach US$110 mililon despite considerable damage to the second crop from downy mildew diseases.

PRESENT PRODUCTION CONDITIONS

Maize is grown throughout Thailand. However, the main growing areas are in the upland, central region where the soils have been relatively fertile and the transportation links to Bangkok, the only deep-water harbor, are good.

At present, a deep orange flint type originating from a few Central American maize

TABLE 1. Area planted, production, average yield, market value and export value (Thailand, 1960-1970).

Year	Total Area Planted (hectares)	Production (tons)	Yield (kg/ha)	Market Value (1,000 Baht)[1]	Export Value (1,000 Baht)[1]
1960	285,000	543,900	1600	549,300	551,000
1961	306,600	598,300	1913	670,100	597,000
1962	328,000	665,400	2069	672,100	502,000
1963	417,900	857,700	2206	909,200	828,000
1964	551,800	935,100	1725	1,009,900	1,346,000
1965	576,800	1,021,000	1819	1,246,000	968,000
1966	653,300	1,122,400	1900	1,257,100	1,520,000
1967	744,000	1,212,300	1798	1,494,800	1,355,000
1968	780,000[2]	1,331,000	1925	NA	1,556,000
1969	800,000[2]	1,500,000[2]	NA	NA	1,674,000
1970	NA	NA	NA	NA	1,853,000

[1] Approximate exchange rate is 20 baht for US$1.00.

[2] Estimated.

NA: Figures not available.

varieties occupies almost 95% of the growing area. A few varieties of white, yellow-waxy and yellow-sweet maize are also grown commercially around the large cities as vegetable maize for human consumption. Young ear maize picked at the silking stage has established itself recently as a vegetable.

Most maize growing areas in Thailand depend mainly on rainfall which is distributed over more than six months annually. Farmers usually grow one or two crops a year. The dates of planting vary from late March to early August, and cropping patterns differ each year and at each location. The amount and distribution of precipitation are critical factors in determining maize production.

Generally, the soils of the maize growing region were recently cleared and are relatively high in fertility. Maize planted in these soils is productive. Therefore, Thai farmers have not found it necessary or economical to use chemical fertilizers.

However, continuous maize depletes soil nourishment to an unprofitable level. Also, the virgin lands for expansion are limited. Farmers need to consider soil improvement. Extensive economic fertilizer trials and demonstration plots are needed to supply information, too.

Most maize farmers are former rice growers who have migrated from lowland rice areas with little knowledge of upland crop cultivation. Cultural practices are primitive and supervision provided by corn technicians has been inadequate. With the exception of tractors, disk plows and shellers, no other modern farm tools have been used.

Seed quality is another problem. With humid conditions all year, seed stored at normal room conditions deteriorates and is often destroyed by insects within a few months. Farmers have to depend mainly on seed selected locally. Generally such seed is poor quality and produces relatively low yields. No private seed producers are available. The Department of Agriculture and a few other government agencies are the only organizations dealing with seed production and distribution.

The seed quantity is limited and cannot reach the demand which increases each year. Distribution of new promising varieties has to be made through regional farm testing, farm demonstrations and seed increase programs which are carried out in many locations throughout the maize areas.

Diseases and insects are limitations and will continued to be problems that deserve much attention. About 25 diseases are known to occur in Thailand. Downy mildew (*Sclerospora* spp.), is probably the most serious disease facing corn producers in Thailand today. The disease, first observed in Thailand's Corn Belt three years ago, has expanded into the main growing areas at an alarming rate. It is estimated that more than 10,000 hectares have been damaged in the 1971 growing season.

Curvularia leaf spot *(Curvularia lunata)* three *Helminthosporium* leaf blights *(H. turcicum, H. maydis* and *H. carbonum)* and rust *(Puccinia polysora)* are common.

Among insect pests, thrips *(Frankleniella* spp.) corn borers *(Ostrinia salentialis* and *Sesamia* spp.) the armyworm *(Pseudaletia unipuncta)* and the corn earworm *(Heliothis* spp.) are frequently found throughout the growing areas. Outbreaks of locust *(Patanga succineta* L.) still cause great economic loss each year. These limitations require several years of intensive research to overcome.

THE NATIONAL MAIZE PROGRAM

The future of the Thai maize trade is still bright, but the production problems continue to increase. The government is aware of the situation. In the Second and Third National Economic Development Plans for 1967-76, maize development has been recognized as one of the most significant programs and all agencies involved in maize research and production have been supported financially. The production target for the end of 1976 is 3.5 million metric tons.

To cope with the important maize limitations, a more intensified program of research and extension was established with the National Corn and Sorghum Research and Training Program in 1966. The program, a coordinated effort of the Rockefeller Foundation, aims to increase corn and sorghum production through development of improved varieties and a sustained flow of new technology. Today, all aspects of maize research are carried out by the three agencies at the national research center and at several regional experiment stations.

Despite major emphasis during the initial five-year period directed toward the development of facilities and personnel, many new research findings have been achieved and a number of promising maize varieties have been developed. The program has made a successful beginning and will contribute benefits, not only to the farmers, but to the nation as a whole.

CIMMYT's ROLE

Lack of qualified people to carry on research and production programs seems to be one of the serious problems. Education and training of all staff who can be immediately effective in strengthening the national program is necessary. Scholarships and grants for training abroad rely on outside funds.

CIMMYT support by visiting staff in various disciplines would be beneficial and would greatly contribute to the success of the program. Assistance in providing improved sources of germ plasm for Thailand's environment as well as new and improved technology for lowland tropical conditions is welcomed.

The Corn Breeding Program of The National Institute of Agricultural Research (INIA) in Mexico and its Relation With CIMMYT

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Agriculturally, economically and socially, corn is the most important crop in Mexico. The area planted to corn annually fluctuates from 7 to 8 million hectares. This is 45% to 55% of the total agricultural area.

The crop value is close to US$640 million, topping all agricultural crops. The social importance of corn is based on its use for direct human consumpion as the most important food in the diet of the Mexican people and because it still has a religious meaning in the Indian cultural inheritance. For these reasons, fluctuations of corn production in Mexico carry important sociopolitical connotations.

For the last six years, Mexico has been self-sufficient in corn production. During 1970, 8 million hectares of corn where planted with a total production of 9.6 million tons and an average yield of 1,200 kg/ha. In 1940, the average yield was 491 kg/ha.

This production increase is of great significance considering that of the 8 million hectares planted, 7.2 million hectares are dryland corn and of this area, close to 4 million hectares have only irregular or very poor rain. These lands are marginal for corn production.

The yield increase is due mainly, although not exclusively, to the results of two branches of agricultural research: (1) use of the better cultural practices, mainly fertilization, pest and weeds control, and (2) even more importantly, genetic improvement.

Before 1940, corn breeding was done by the Institute of Agricultural Research, later by a cooperative program of the Agriculture Secretary and the Rockefeller Foundation, and at present by the National Institute of Agricultural Research (INIA) that evolved from the merging of the two previously mentioned institutions.

These programs produced several high yielding, improved varieties and hybrids. The use of these by farmers and their beneficial influence upon the native varieties through natural crossing have been decisive factors in increasing corn yields. The beneficial influence of the improved varieties upon the native ones through crossing has not been appropriately estimated yet.

In México, 85% to 90% of the cultivated corn is white and only 10% to 15% is yellow. Eighty-five percent of the corn production is used for human food and 15% for livestock feeding (mainly yellow corn).

Consequently, the largest area is planted with white dent varieties of types such as Tuxpeño, Vandeño, Celaya, Chalqueño, and Cónico, which are widely used to make tortillas and numerous dishes.

Soft, floury varieties are planted in smaller areas. Types such as Cacahuacintle, Elotes Occidentales, Tabloncillo, and Pepitilla, are used to make crackers, flours, pozoles, or to be eaten as boiled or roasted corn-on-the-cob, or in soups.

Also planted in minor areas are hard, corneous, or flint varieties of the types Palomero Toluqueño, Arrocillo Amarillo, Chapalote, Reventador, Olotón, Tabloncillo Perla and others. They are used to make *pinoles* (sweet powder), for popcorn and for livestock feeding.

LIMITATIONS TO CORN PRODUCTION

Corn is grown over most of México under varied ecological, economic and human conditions. Corn is cultivated from beaches to snowy volcanos, in semidesert lands and in very humid regions.

Corn is planted under excellent culture conditions in the irrigation districts of the North and in some regions of the Bajío and the Central Plateau. If is also cultivated under very favorable conditions of rain, fertilization and culture in the humid tropics in the state of Jalisco and in a few other regions.

However, corn is grown under irregular or very poor conditions of rain and culture on more than four million hectares of semidesert lands in the northern, central and southern regions.

Altitude, latitude and temperature are factors that, under the conditions of wide genetic diversity, seem not to limit corn productivity (within the limits established by the genetic variability of the varieties adapted to each combination of these factors).

Factors most limiting corn productivity are ecologic, agronomic, genetic, agricultural extension service, seed for planting and socioeconomic.

Ecological Limitations

Drought is the most important ecological limitation since a deficiency or poor distribution of insufficient rain affects almost four million hectares planted with corn under regular or poor dryland conditions. This is 50% of the total area planted to corn annually.

Frost is also another important factor. Drought and frost force planting of early varieties that yield poorly.

It is clear that much corn is planted in a large, marginal area where production generally is not profitable. Theoretically, corn growing should be eliminated from the regions just mentioned and replaced by other more profitable crops.

But, any reduction in area will take many years and will depend on having available other satisfactory crops. Also, farmers will have to be assured of corn at a reasonable cost to feed their families.

Now, breeders and other specialists must intensify their activities in these regions to increase the present low yields of corn. Meanwhile, other more profitable crops may be found to replace corn.

Corn breeders must direct their efforts towards the formation of early varieties (preferably open-pollinated) with good yielding capacity and with a reasonable degree of resistance to drought, frost, pests and diseases.

In these regions, agronomic research must be directed towards the best use of the rain, fertilization, cultural practices, weed and pest control and storage.

Other factors that limit corn production are the pests and diseases that probably reduce yields 20%. Entomological and phytopathological research with the introduction of genetic resistance is needed.

Agronomic Limitations

Very good native, improved varieties and hybrids are not being used at their maximum yielding ability because of improper cultural practices such as fertilization, population density, row spacing and irrigation. Undoubtedly, more research on these problems will permit an important increase in corn yields.

Genetic Improvement

Corn breeding in Mexico is a difficult task complicated by diverse ecological and socioeconomic conditions. For this reason, the breeding program tends to form varieties with a wide area of adaptation and with general characteristics that are not always the best for specific areas.

This situation, naturally, constitutes a limitation to the increase of corn production. The general objectives of improving the quality and yielding ability through introduction of desirable agronomic traits could logically be better reached by regional breeding in ecologically and economically specific areas. However, this would require more financial and human resources.

It is necessary, too, that breeding joins the physiological and agronomic disciplines to form specific varieties for environmental conditions such as high planting densities and high rates of fertilization.

The Extension Service

Corn growers have not had much support from extension workers. This group should make available to farmers, in a dynamic and effective way, the results of agricultural research concerning improved varieties, hybrids, recommendations for fertilization, irrigation, planting dates, control of pests, weeds and diseases, and so forth.

Extension is a factor that has considerably limited the increase in corn productivity. This has to be corrected since many farmers either do not know the improved varieties or they are not prepared to cultivate them properly.

Seed Production and Distribution

Improved varieties and hybrids have been available in Mexico for many years, but the area planted to them has never exceed 15%. This is partly due to a deficient extension service, but it is mainly because the official institution in charge of seed production has not been able to offer seed of the improved varieties and hybrids in sufficient amounts and with adequate genetic purity. The poor quality seed delivered to the farmers for many years has made them reluctant to buy seed of the improved varieties. This has caused the proliferation of private companies, mainly backed by foreign funds.

The seed production situation has been aggravated because the obsolete Seed Law does not permit these companies to work with the improved varieties obtained by official research, even though these companies are willing to pay a royalty for use of the improved seed.

The critical situation with respect to production of improved seeds is limiting corn production in Mexico and has to be corrected. We hope this will change since a new director and team is working at the National Seed Producing Agency to improve the situation.

Socioeconomic Limitations

Another factor limiting corn production in Mexico is the lack of an organized, efficient and integrated structure, preferably regional, that would provide to farmers all necessary supplies and facilities such as seed, fertilizers, pesticides, credit, extension and marketing at a convenient time. As illustrated by the Puebla Project, the benefits of such organization will be reflected in the gradual increase of corn production.

THE CORN BREEDING PROGRAM

Genetic improvement of corn by INIA is done at 20 experiment stations in 4 main ecological areas—the hot regions, humid and dry regions, the Bajío and other regions of intermediate altitude, and the highlands. These areas contain the eight regional centers of agricultural research that integrate INIA.

The more important objectives of the program are the formation of high-yielding, improved varieties and hybrids with desirable agronomic traits such as resistance to pests, diseases, drought, frost, and lodging, and better protein quality. Although the regional programs work mainly on corn of normal height and white dent endosperm, most of the programs also include popcorns, dwarfs, yellows, prolifics and others.

Until 1970, the national breeding program produced about 50 improved varieties and hybrids with agronomic traits, in most cases, highly superior to the native varieties. The use of these improved varieties and their natural crossing with the native varieties is unquestionably accountable for 40% to 50% of the average yield increase in México during the last 30 years.

Among these improved varieties and hybrids, some outstanding ones are: for the high valleys, H-125, and H-129 with irrigation, and H-24 and H-28 for dryland for the Bajío, H-309 and H-366 for moisture and irrigation conditions, and H-220 and VS-201 for dryland; for the humid tropics, H-503, H-507 and VS-450; and for the dry tropics, H-412 and V-410.

Breeding methods more frequently used are the classic systems for hybrids and synthetic varieties, recurrent and reciprocal recurrent selection, backcrossing, modern mass selection, convergent improvement, and modified or specific methods to obtain basic information on drought resistance, genetic variances, etc.

As a source of genetic variability, INIA has a germ plasm bank preserving more than 5,000 native varieties and more than 1,500 foreign varieties. These varieties are being regionally evaluated for desirable agronomic traits with the objective of forming composites including one or more of those desirable traits while preserving the varietal identity in the bank.

The corn program of CIMMYT is another source of genetic variability for INIA's breeding program.

Because of their great importance, the breeding programs for dryland corn are getting more attention. Other important programs of INIA are drought resistance and protein quality improvement.

Drought Resistance

This research is of great complexity, involving ecological conditions and plant properties. Indirect methods for identifying this trait have not been defined yet. However, selection by moisture stress treatments under greenhouse conditions seems promising.

With respect to direct methods of identifying drought resistance, topcrosses and inbred lines are being studied to detect those which show the least reduction in yield when comparing their performance under irrigation with that under drought. The behavior of selections resistant to moisture stress in the greenhouse are being studied under drought conditions in the field during the rainy season by protecting the plants against the rain with bleached cotton. Under the same conditions the stomatal behavior of diverse varieties of corn is being studied.

Protein Quality

All the commercial improved varieties and hybrids of INIA and some outstanding experimental ones are being converted to varieties rich in protein by introducing opaque-2 and floury-2 genes. Several varieties rich in protein being integrated show yields almost similar to their normal counterpart.

Already this year, the current breeding programs have delivered to the National Seed Agency for commercial production the following new, improved varieties and hybrids.

H-131: Hybrid for irrigated conditions in the states of Mexico and Puebla, superior in yielding ability to H-129.

H-133: Hybrid for irrigated conditions and specific for regions between the intermediate altitudes of the Bajío and the highlands of the Central Plateau. Superior to the native improved variety previously recommended.

H-30: Hybrid for dryland conditions in the states of México, Puebla and Tlaxcala, or to be planted under irrigation or moist conditions in the Toluca Valley. Yields more than H-28 and it is similar in cycle.

H-32: Early hybrid for dryland plantings in the Valley of Toluca.

H-367 P: First Mexican popcorn hybrid for the intermediate region of the Bajío. Hopefully, this hybrid will eliminate imports of popcorn which total US$2.4 million annually.

H-508 E and **H-509 E:** Dwarf hybrids for the hot regions. Very similar genetically to H-503 and H-507, but superior to these under conditions of high population density and fertilization.

VS-521: Synthetic variety for the tropical regions, mainly for the state of Guerrero. Yields slightly less than H-507.

CIMMYT AND NATIONAL PROGRAMS

I have modified this suggested topic slightly to give some consideration not only to what should CIMMYT do and what should CIMMYT's role be in relation to the above four topics already discussed, but I am also going to present some personal opinions of what CIMMYT should not do in its relationship with the national corn programs. This is on behalf of better relations between these organizations and so that their work may be more effective.

I consider that CIMMYT benefits México, like other countries, not only through the direct contributions that the members may receive, but also through international interchange of material and ideas brought by numerous world scientists.

Nevertheless, I think that this benefit may be even greater if CIMMYT helps these countries by supplying materials, counseling the official programs, and advising the programs of extension service and seed production. CIMMYT should aid national programs but CIMMYT should not attempt to displace or to duplicate them by going into the formation, production, recommendation or distribution of improved varieties since these duties are the responsibility of national programs.

CIMMYT research projects should be mainly of basic nature and international scope, such as the determination of more adequate breeding systems, the architecture of more efficient phenotypes, photoperiod insensibility and the formation of germ plasm composites with desirable traits.

CIMMYT should do basic research on quality, precocity, resistance to drought, frost, pest and diseases, basic studies on population genetics, and in general, on the physiology and biochemistry of corn.

The information and materials should then be passed on to the national breeding programs for use in their applied breeding programs.

It is my feeling that CIMMYT should not deliver improved materials directly to private companies. This procedure may be unfavorable for the national programs because they may receive contributions like royalties if the companies receive the varieties from them and not directly from CIMMYT.

CIMMYT should continue to honor countries' regulations in relation to introducing and exchanging materials. In case of conflict between CIMMYT and the national regulations, an agreement with the proper authorities should be sought.

Faced with the possibility that CIMMYT's exchanges of worldwide corn materials may introduce new species or races of diverse pests, it would be appropriate to discuss this possibility with the authorities in the country concerned.

Finally, I would like to acknowledge and to thank CIMMYT for valuable aid to INIA's Department of Corn and Sorghum in retaining its more experienced people. This assistance has undoubtedly permitted this department of INIA to reach this results presented before and several more not mentioned.

International Training Program of the Inter-Asian Corn Program

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One phase of the Inter-Asian Corn Program (IACP) is the International Training Program conducted at the National Corn and Sorghum Research Center in Thailand. This is a cooperative effort between IACP, Thailand's National Corn and Sorghum Program and the national corn programs of other Asian countries.

The principal objective of the International Training Program is to upgrade research and extension workers involved with maize development programs in Asia. Through expansion of the capabilities of these contributors, progress in corn production at the farm level should be accelerated.

The principal focus is on increasing field competence in production and research technology. The basic requirements for the production of the corn crop are emphasized and the role of management in the utilization of resources in meeting these requirements is presented.

Program structure is determine by three major factors: (1) the needs of the participating trainees; (2) the qualifications and availability of personnel to contribute to the training programs; and (3) facilities available, particularly field laboratories.

A strong effort is made by the IACP staff to visit countries of southern and southeastern Asia and to become familiar with corn production problems. National programs, including staff development plans, are reviewed. From this background the role to be filled by personnel nominated for training can be visualized and the preparation necessary for fulfilling this role can be assessed.

The IACP staff and the National Corn and Sorghum Program of Thailand include agronomists, plant breeders, soil scientists, plant pathologists, entomologists and farm management specialists. In-depth guidance can be provided in these fields.

The National Corn and Sorghum Research Center is at Farm Suwan, an experiment station and student training farm of Kasetsart University. It is 155 kilometers northeast of Bangkok at a latitude of 14.5° North and at an elevation of about 300 meters. The average annual rainfall is 1,000 to 1,200 millimeters. The mean temperature is 27° C with a range from 14° C to 33° C.

There are three seasons. The monsoon season begins in late July with heavy rains continuing through October. The dry season, which is also the cool season, extends from November into March. During the hot season from late March through June, there is moderate, erratic, rainfall. There is usually a relatively dry period from late June until the monsoon begins. Water in limited quantity is available from wells for supplemental irrigation so experimental crops can be grown throughout the year.

In the breeding programs, typically three generations are grown each year. This presents a rather ideal situation for providing training in plant breeding. During one year, complete cycles of procedures used in various selection schemes can be completed. In six months, starting either on January 1 or July 1, experience can be obtained involving a crop grown during a rainy season plus experience with irrigation systems either at the start or end of a dry season.

There are 100 hectares of land developed for research and training purposes at the Center. Mechanization is rather highly developed in land management and crop processing operations.

There is a hostel that can accommodate 24 persons. Each trainee is assigned to a separate room with its own private bath and patio. A growing library of technical literature is available.

In the operation of the program, no set structure is followed. Lectures are given encompassing "Agronomy 1" for Asian conditions. As far as possible, the participants learn by doing. Confrontation of real situations and guiding of reactions into constructive activity would seem to offer a reasonable approach to preparing people to meet future problems and to contribute to their solution. The work experience is supported by more formal lectures and by reading assignments.

Each participant conducts one or more field projects. These projects are designed to familiarize the trainee with basic principles of crop production and to explore some new technology of production or research. Considerable effort is devoted to identification of the important issues.

If the project involves the response of corn to levels of an environmental variable, various models are considered. Provision is made for collecting data from which conclusions may be reached about the validity of the various models. The trainee is encouraged to think analytically.

Skill in application of proper techniques is essential to the collection of reliable information. Well-conceived experiments carefully executed with results rigorously evaluated and interpreted constitute the ultimate goal in research. The future developments of agriculture will come from research. The future of emerging countries depends on a developing agriculture.

Thus, a strong agricultural research base is essential for national development. The IACP training program is conducted with this in mind. The extension worker also needs to understand the research process which generates new technology. He must be able to evaluate research results and determine their applicability in the solution of problems limiting agricultural progress in the area which he serves.

Maize Culture In Venezuela

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Socioeconomics

Exportation is minimum, principally as flours. During the past few years, maize has been imported in varying amounts.

National production has increased, mainly due to increased area rather than increased productivity. Up to 1961, most maize production was accounted for by small production units in areas of dense rural population.

Presently, the trend is towards establishment of maize in areas of good natural conditions. Much of the rural population depends on maize.

Research

Certified seed of five varieties and four double crosses is being produced. All of them are for altitudes up to 800 meters above sea level.

There is not enough information on planting systems, plant densities per hectare, fall armyworm control, chemical weed control and mechanical harvesting.

Extension

From 1962 to 1967, the National Project of Extension in Maize was in operation. Now. maize extension work is done through the extension agencies of the Ministry of Agriculture and Livestock.

Technical Assistance

There was a very positive experience with the publication of farmer's guides for the Maize Production Plan in 1962.

Another positive experience was the Program of Maize Productivity of 1970, sponsored by "Foremaiz" and the Ministry of Agriculture. This plan included 4,000 hectares within the small-farm sector of the state of Portuguesa. Average yields were 95% above the state's average.

Importance and Uses of Maize

There has been a sustained tendency towards increased use of maize by the animal feeds industry and by the industry of precooked meals for humans. The dry processing industry requirements for maize have decreased since 1964 when precooked meal appeared in the market.

LIMITATIONS TO MAIZE PRODUCTION

Production Systems and Socioeconomics

Predominance of small units and the low socioeconomic level of farmers have made difficult the use of modern technology to increase maize productivity.

The Agrarian Reform Law of 1960 attempts to change peasants into small farmers, making them owners of their land and providing them with holdings more suitable for cropping together with technical, sanitary, educational and economical assistance.

The Fourth Agricultural Census in 1971 should show a positive change in the maize producing units with respect to increases in size and the concentration of farming in areas more suitable to maize production.

Soil Fertility

There is very limited information on maize fertilization. Even when some recommendations exist for rates and types of fertilizers for some soils, these are seldom used.

The first map of the largest soil groups has been completed. Also, there has been a considerable increase in the national network of fertilizer trials and studies on mineral nutrition in maize.

Climate

Maize is produced up to 800 meters above sea level, totally under rainfed conditions. The amount and distribution of rains constitute the most important climatic factors.

Knowledge has been accumulated on plant densities according to moisture levels, chemical weed control, ridge-planting and superficial drainage for areas of high rainfall.

An early variety (Minita) has been developed for areas of scarce rainfall. There has been little research on use of irrigation in maize.

High-Yielding Varieties

There are several improved varieties and hybrids, both white and yellow, and early, intermediate and late maturing. All are adapted to altitudes up to 800 meters above sea level. There are opaque-2 versions of all of them.

Seed production and certification is well organized.

To determine which materials perform better in each zone, the network of regional trials has been increased.

Four maize improvement programs will be started in 1972. They will cover the most important maize growing areas.

NATIONAL PROGRAM

The goal is to increase maize production through extension, technical assistance, agronomic improvement and genetic improvement.

Objectives

The objectives of the national program are:

1. Extension work using demonstration days, maximum yield trials and field trials.
2. Technical assistance, especially in training personnel.
3. Agronomic improvement through the use of farm equipment, and studies on fertilizers, plant densities, mineral nutrition, irrigation and drainage.
4. Breeding for improvement of local varieties, new high yielding varieties, protein improvement, especially for flint types; forming populations with specific characteristics like earliness and short-plant types.
5. Studies on disease and pest resistance.

Target Areas

The *Programa Integral de Desarrollo Agropecuario* contemplates the start of four regional projects for maize investigations in 1972. The eastern, south-central, west-central and western regions will each be covered by a center.

The overall program will be coordinated by the Center of Agronomic Investigations in Maracay.

WHAT CIMMYT COULD DO

Considering the problems presented, CIMMYT's possible role and things CIMMYT could do include the following.

1. Provide advice for establishing regional programs of technical assistance for the improvement of maize production.
2. Provide training of personnel in the areas of technical assistance and research.
3. Provide populations of tropical maize with desirable characteristics like short plants, prolifics, high nutritional value, and resistance to drought, insects and diseases.
4. Provide some help in statistical analyses and chemical determinations.
5. Continue to sponsor international or regional meetings, or both.

The Maize Situation in Nicaragua

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Nicaragua

IMPORTANCE, TYPE AND USE OF MAIZE

Maize has been and continues to be the basic food of the people of Nicaragua. Maize is grown by small and large farmers, at low and high elevations, and under varying conditions of rainfall. It is used fresh as corn-on-the-cob, and in local dishes and refreshments.

The economic importance of maize in Nicaragua can be summarized by the 1969 statistics of national production—213,372 metric tons worth US$11.5 million. Although the maize area is larger than that of any other crop, 343,511 kilograms costing US$54,753 were imported to cover the production deficit. This is 0.9% of all imports.

Credit granted by banks for corn growing was US$4.44 million, corresponding to eight percent of the agricultural credit and ranking behind cotton and rice. Fifty-nine thousand hectares were covered by this credit.

Due to the absence of minimum prices, the market value of maize varied from a maximum of US$8.30 to a minimum of US$2.85 per 45.5 kilograms.

The total area harvested was 242,000 hectares and the average yield was 876 kg/ha.

The area harvested varied among states but the most important producers are Matagalpa, Chontales, Jinotega and Boaco. The highest yields are obtained in Rivas and Chinandega on the Pacific coastal plains. Maize is produced here using the most modern technology on vast areas where farm equipment can be used profitably.

The National Bank of Nicaragua considers credit for maize production one of its more important activities. In 1970, rural credit was granted for planting 14,500 hectares and banking credit financed 6,200 hectares more. Fifty-three percent of the area covered by the rural credit was planted to unimproved varieties. The goal for 1971 is to provide financial backing for planting 28,000 hectares.

A 1969 survey indicated that farmers working under the rural credit line obtained yields of 1,358 kg/ha, while those under banking credit obtained 1,160 kg/ha. The average yield obtained by both types of farmers was 1,290 kg/ha. Results in 1970 were essentially the same.

White dents are planted more frequently but there is a pronounced preference for white flints. Due to the insufficient supply of maize in the rural area, texture is not important as long as the endosperm color is white.

The local varieties commonly used on the Pacific coast are early-maturing types (80 days). In the north-central region, the advanced generations of double cross hybrids distributed to farmers in the past are used for planting and are known as *Criollos* or *Maices de Montaña.*

Maize is used mainly for human consumption. A relatively small area is planted to yellow endosperm types for animal feeding. Industrial uses of maize are restricted to the manufacture of powdered mixtures for refreshments and animal feeds.

Estimates for 1972, 1973, 1974 and 1975, indicate that Nicaragua will face a shortage of 4,000, 35,000, 79,000 and 92,000 metric tons of maize for human consumption, respectively.

FACTORS LIMITING MAIZE PRODUCTION

The main factors limiting maize production are susceptibility to *Helminthosporium,* stunt virus, streak virus and *Fusarium.* The commercial varieties used at present have been selected for high yield under moisture conditions different from those under which they are grown. Their performance is satisfactory in certain regions but in others they are highly susceptible to all or some of these diseases. Losses due to these diseases in 1970 were estimated at US$11.84 million.

Our program has tested local and exotic materials in areas representing conditions of the main maize areas of Nicaragua but the results are insufficient to draw definite conclusions.

Poor coordination among the breeding program, the extension service and rural assistance, and the credit institutions has negated the best use of improved varieties. Production and distribution of improved seed has been insufficient and erratic, and is a factor in the low production.

The lack of minimum prices is another factor determining low production.

ELIMINATING THE LIMITING FACTORS

The maize improvement program is developing new materials and testing introductions to determine tolerance to the prevailing diseases. Extensive testing involving commercial and experimental varieties has allowed a better evaluation of their performance under different environmental conditions.

Drying and storing was a problem. At present, there are 100 storage centers with capacities from 3,270 to 14,170 metric tons. Eighty-two percent of the storage capacity is used for maize, which can be stored up to six months. Also, the National Bank of Nicaragua is promoting corn growing by expanding its rural and banking credit lines.

The maize growers of Nicaragua associated in 1971 for a greater coordination of the aid provided by the credit and technical assistance institutions. Maize program personnel took part in extension activities for a week to help the corn grower associations of Masaya and León.

ACTIVITIES OF THE NATIONAL PROGRAM

The national corn improvement program works in breeding, genetics, improved cultural practices and plant protection. All these activities are not done every year. Sometimes the major effort is testing experimental varieties or improving cultural practices.

The program staff consists of three technicians and two field assistants. Two of the technicians hold bachelor of science degrees and the third one is a *Perito agrónomo.* The two assistants have 15 years experience.

The trials are planted in fields provided by cooperating agencies such as the agricultural schools, National School of Agriculture and Livestock, Experimental Agricultural Center La Calera, Regional Center for Agricultural Diversification Campos Azules, the Irrigation Project of the National Bank of Nicaragua, the Agrarian Institute of Nicaragua and members of the Corn Growers Association of Masaya.

The cooperators provide land, labor and funds for supplies and expenses not covered in the budget of the Agriculture and Livestock Ministry. The greatest and most opportune help comes from CIMMYT.

Results obtained during the year complement recommendations given to corn growers. An annual report covering all activities of the program is published and distributed to all cooperators and technicians of collaborating commercial concerns dealing with agricultural products. Up to 1971, the maize program has developed seven maize varieties. Six are open-pollinated and one is a hybrid.

POSSIBLE ROLE OF CIMMYT

CIMMYT should reach a formal agreement with the Ministry of Agriculture and Livestock of Nicaragua to meet the personnel, supplies and equipment requirement needed to achieved the objectives of the maize improvement program. Otherwise, the program personnel will lack continuity and the activities will be limited by insufficient funds.

Maize Research and Prospects in India

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IMPORTANCE OF MAIZE IN INDIA

India, with 5.7 mililon hectares, ranks next to the United States, Brazil and Mexico in total maize area (Tables 1 and 2). But in total production, India ranks sixth in the world behind the United States, Brazil, Mexico, Romania and Yugoslavia.

TABLE 1. Area, production and yield for some important maize growing regions of the world.

	World	Latin America	Africa	Asia	India
Area (million ha)	106.0	25.9	17.0	15.8	5.7
Production (million tons)	251.1	34.0	18.3	17.3	5.7
Yield (kg/ha)*	2,370	1,320	1,080	1,100	1,000

* Based on F.A.O. Production Yearbook (1969).

Maize is an important cereal in India. In total acreage, it ranks fifth behind rice, sorghum, wheat and *pennisetum,* and in total production it ranks fourth. Both maize area and quantity produced have increased steadily during the past two decades, with an annual increase of 3.8% and 8.4%, respectively (Table 3).

MAIZE TYPES

Maize in India is cultivated from 15° to 35° North latitude. The states of Uttar Pradesh, Bihar, Rajasthan, Madhya Pradesh and Punjab account for most production and maize acreage. More than 80% of the cultivated maize area is rainfed. The rainfall is erratic and highly unpredictable.

The Indo-Gangetic plains, where most maize is grown, receives 20 to 40 inches of rainfall.

TABLE 2. Area, production and yield for some important maize growing countries.

	United States	Brazil	México	Romania	Yugoslavia	India
Area (Million ha)*	22.61	9.58	7.80	3.34	2.46	5.72
Production (Million tons)	111.59	12.81	9.36	7.10	6.81	5.67
Yield (kg/ha)	4,930	1,340	1,200	2,120	2,770	970

* Based on F.A.O. Production Yearbook 1969.

TABLE 3. Area, production and mean yield of maize in India, 1948-69.

	1948-52	1952-56	1956-60	1960-64	1964	1965	1966	1967	1968	1969
Area (Million ha)*	3.349	3.735	4.107	4.507	4.618	4.765	5.074	5.583	5.716	5.862
Production (Million tons)	2.165	2.913	3.382	4.281	4.658	4.760	4.894	6.269	5.701	5.674
Yield (kg/ha)	650	780	840	990	1,010	1,000	960	1,120	1,000	907

* Based on Department of Economics and Statistics of the Government of India.

However, most of it falls during July and August. Traditionally, maize is grown during summer months but in more recent years winter maize area under irrigation in Peninsular India and the state of Bihar is increasing.

Yellow flint to semiflint varieties account for most maize acreage. In small pockets, white flints are grown, also. A white dent variety (Malan) is grown in the Kungalgarh region of Rajasthan. Flints are generally preferred because of the varied uses to which maize is put.

MAIZE USES

More than 90% of the maize produced in India is used directly as human food. Starch and other industrial uses, and cattle feed account for only five to six percent of total production.

Depending on the use, whole maize grains are milled into fine flour or coarse meal. Flour is used for making chapaties, which are thicker than tortillas. Coarse meal is used in making various porridges.

Maize in early dough stage is used as roasted or boiled ears. Grains are also used as popcorn; popping is done in hot sand.

PRODUCTION LIMITATIONS

In India, it is becoming increasingly apparent that the cost of maize production should be reduced. This calls for improving the efficiency of production and increasing the present yield level. Prices of maize in India are considerably higher than in the United States or on the international market (Table 4).

TABLE 4. Comparison of the price of maize in the United States and India, 1955-68 (U.S. cents/kg).*

Year	United States	India
1955	5.3	4.5
1956	5.1	6.5
1957	4.4	7.6
1958	4.4	7.5
1959	4.1	7.5
1960	3.9	6.4
1961	4.3	7.1
1962	4.4	6.5
1963	4.4	6.5
1964	4.6	10.3
1965	4.6	13.5
1966	4.9	10.3
1967	4.6	13.8
1968	4.2	8.1

* Based on F.A.O. Production Yearbook 1969.

Some of the important limiting factors are diseases, insect pests, lack of early-maturing hybrids and composites, and lack of improved opaque-2 populations.

Diseases

Locally grown maize varieties are susceptible to several diseases. Most of the improved composites and hybrids have considerable resistance to *Trichometasphaeria turcica (Helminthosporium turcicum)* and *Cochliobolus heterostrophus (H. maydis)* and downy mildews, particularly *Sclerophthora rayssiae* var. *zeae, Sclerospora sacchari* and *S. sorghi.*

Not much has been done on ear and stalk rots. The important stalk rots in India are *Pythium aphanidermatum, Erwania carotovora* var. *zeae* and *Cephalosporium maydis.* Marked variability for resistance in some maize populations to the various stalk rots and downy mildews have been recorded. Stalk rots cause considerable damage, especially under high population density and waterlogged conditions which frequently occur when the fields are not well drained.

Inoculation techniques have been developed and it is now possible to screen materials for their relative resistance. One or two cycles of selection have been carried out for resistance to downy mildews and stalk rots in several composites with a limited degree of success. Much more needs to be done.

Insect Pests

The most important maize insect pests in India are the stem borer *(Chilo zonellus)* and Pink Ragi borer *(Sesamia inferens).* Techniques for mass rearing of both species of the the borer have been perfected. A method of scoring for resistance has been developed, also.

Antigua Gr. I (of race Olotón) has shown marked resistance. Other promising sources of resistance are Barbados Gr. I and Caribbean Flint Composite. Genetic studies suggest that resistance to the borer is polygenic. Elite inbred lines resistant to the European corn borer *(Ostrenia nubilalis)* were observed to be susceptible to *Chilo zonellus.*

With the increase in maize acreage in more recent years, some insect pests known to be of minor importance are causing greater concern. Pests like shoot fly *(Atherigona* spp.) and leaf hopper *(Pyrilla* spp.) have caused severe damage. Relatively little or no information on the sources of resistance or nature of inheritance or nature of inheritance is available.

Early-Maturing Hybrids and Composites

The states of Uttar Pradesh and Bihar account for nearly half of India's production, but they suffer from inadequate soil moisture during September. Most of the maize varieties maturing beyond 85 days under rainfed conditions suffer towards the grain-filling stage. There is an urgent need for developing early-maturing materials for this region.

A strong negative association between yield potential and relative maturity has been recorded. Chase recorded a yield increase of 25.5 kilograms for one day delay in maturity from planting to flowering. Relatively little has been done with regard to the development of early-maturing (80 to 85 days) maize hybrids.

Improvement of Protein Quality

Both the opaque-2 and floury-2 genes have been incorporated into several elite maize composites and parental inbred lines of promising maize hybrids. Three opaque-2 composites, with yields about 90% those of normal maize hybrids, have recently been released.

There is an urgent need for improving the opaque-2 populations by increasing the total protein level, improving the test weight, and if possible, altering the grain appearance without adversely affecting the nutritive quality. This should improve the acceptability of these nutritionally superior maize populations.

OVERCOMING THE LIMITATIONS

Generally, improvement of maize and development of suitable cultural practices will have to be done for two distinct environments.

A) *Intensive farming:* regions with a more or less assured rainfall or farmers have adequate facilities for irrigation, or ability to finance necessary inputs.

B) *Subsistence farming:* farmers are dependent on natural rainfall. Irrigation, other facilities and inputs are minimal or lacking.

While the possibility of extending irrigation and credit facilities exists, it will take time before most farmers in the "B" category can gain the status of "A". Moreover, with the availability of better resources the cropping pattern may also change in favor of a more remunerative crop.

The primary aim of "A" farmers is to maximize their profits and they will readily accept new hybrids or cultural practices. Farmers in the "B" category are likely to be more conservative. Farmers in this category will accept new hybrids/composites (preferably the latter) and cultural practices provided stability of performance is assured. Stability of performance for the "B" category is more important because the capacity to absorb risk is non-existent.

Intensive farming assures continuous improvement of yield levels. In the lowland tropics, despite intensive improvement work, a yield plateau of 4 to 5 tons/ha has been reached. How plant types may be modified to deliver a major boost in yields is often discussed. There may be several views on the ideal plant type but probably one of the approaches is to identify populations able to withstand high plant population stresses.

Most of the varieties and hybrids presently used do not respond to a high population level (100,000 plants or more/ha) because of the agronomic history under which they were selected and cultivated. Characteristics like erect leaves, smaller tassels, high nitrate reductase activity, fewer husk leaves and prolificacy have been reported to be closely associated with ability to withstand population stresses.

Most Indian farmers are in the "B" category. Improving corn production for these farmers deserves more attention though it is more difficult. With the rapid population increase, not only food but the employment problem will have to be solved. In the next decade, India's agriculture may have to provide employment for more than 80% of the population, most of which is in the "B" category.

Due to the lack of desired levels of inputs under subsistence farming, optimum yield potentials cannot be realized. So, it is desirable to maximize responsiveness to fertilizer and other inputs at a lower level (a supersigmoid distribution) even though optimum response may be comparable to the usual high-yielding hybrids/composites.

Diseases and pests take a heavy toll irrespective of the level of farming. Resistant varieties not only provide an effective means of control but also insure production stability.

Bottlenecks

There is an urgent need to identify additional and better sources of resistance, both for major diseases and insect pests. Polygenic sources of resistance are known for several important diseases and pests. Identification of oligogenic sources of resistance would greatly expedite the transfer of resistance to agronomically more desirable sources.

Information on the relative distribution pattern of races of important pathogens is lacking. Such information is particularly vital for stalk rots and downy mildews, irrespective of whether horizontal or vertical resistance is involved.

Combining disease and pest resistance is the desired goal. In fact, simultaneous selection for both major diseases and pests can be carried out effectively when inoculation techniques are perfected and populations of adequate size are used.

Intrapopulation improvement, involving the active collaboration of pathologists, entomologists and breeders, for resistance to stalk rots *(Pythium, Erwania* and *Cephalosporium)* and stalk borers *(Chilo zonellus* and *Sesamia inferens)* is being carried out in several elite populations.

Maturity

A negative association between maturity and yield has been recorded by several workers.

The maturity period is a sum of the following distinct stages: sowing to germination; germination to floral initiation; floral initiation to tassel emergence; tassel emergence to silk emergence; silk emergence to physiological maturity; and physiological maturity to harvest. Variability in various genotypes have been recorded for the stages of growth even though total growing period is identical.

Brawn observed a close association between the grain-filling period (flowering to physiological maturity) and yield level. It is apparently possible to select genotypes comparable in one or more stages of maturity but drastically different in other stages even though the total period of maturity may be similar.

Also, it is apparently possible to develop hybrids with similar moisture contents at harvest but different in grain-filling period and rate of drying. Early-maturing selections with prolonged grain-filling periods (with marked decreases in other stages of growth) are likely to yield higher than selections of similar maturity.

So, there is a great need for studying the variability in populations in regard to the various stages of plant growth to sort out earlier maturing genotypes with the yield potential of late-maturing types.

Close association between leaf number and relative maturity have been reported by Chase and Nanda. Leaf foliage also determines the grain/stover ratio. Studies on altering the leaf number while achieving the desired maturity and yield level deserve a detailed analysis.

THE NATIONAL PROGRAM

Since 1957, maize improvement work in India has been done under the All-India Coordinated Maize Improvement Scheme. It has 16 research stations representing the four major maize growing zones in India—the Himalayan Zone, Northeastern Zone, Northwestern Zone and Peninsular India.

Each zone has a main station and several substations. Most of the stations are equipped to handle breeding, agronomic, pathological and entomological investigations.

Breeding

Since the start of the project, 9 hybrids and 6 composites have been released. Five hybrids and two composites are grown extensively. This year another white hybrid and three opaque-2 composites have also been released.

Most of the hybrids under production possess a reasonable degre of resistance to foliar diseases. These hybrids have yielded 30% to 35% more than the local varieties under recommended cultural practices (120-60-40 NPK under irrigation).

Breeders are currently engaged in: (1) development of early-maturing hybrids and composites (80 to 85 days or less) for rainfed regions; (2) evaluation of F_1 varietal hybrids; (3) intrapopulation improvement; (4) incorporation of resistance to major stalk rots and stalk borers (in collaboration with pathologists and entomologists); (5) improvement of protein quality; and (6) screening of new populations under high plant population densities.

Pathology

The important diseases that attack maize are leaf blights, brown stripe, downy mildew, and stalk rots caused by *Pythium, Erwania* and *Cephalosporium.* Pathologists and breeders are screening inbred lines, composites and hybrids for important diseases. An intensive interpopulation and intrapopulation screening program is underway for *Pythium* and *Erwania* stalk rots. CM 600, a white flint Indian variety has shown marked resistance to *Erwania.* Two white inbred lines, CM 400 and CM 300, are resistant to *Pythium.*

Entomology

Though several insect species attack maize, stalk borers *(Chilo zonellus* and *Sesamia inferens)* are most important. With the availability of mass-rearing techniques on semisynthetic culture media, it has been possible to do large scale screening of maize populations.

Antigua Gr. I has shown considerable resistance. Other sources of resistance are Barbados Gr. I and Caribbean Flint Composite. Breeders and entomologists are screening elite inbred lines, composites and hybrids under manual infestations. Intrapopulation improvement for borer resistance in several populations is in progress.

Regional and International Programs

The Indian maize program is cooperating with several regional and international programs by contributing materials.

Key programs are: IACP regional testing program; IACP downy mildew nursery; CIMMYT testing program; and FAO testing program.

ROLE OF CIMMYT

CIMMYT, because of its unique international position, can play a pivotal role in maize improvement around the world. CIMMYT headquarters are located at the center of maize's origin. In addition to the enormous genetic collection, vividly representing the extensive variability stored and classified in the germ plasm bank, additional variability may be added through new collections. This rich treasure still remains unexplored by several countries.

Germ Plasm Evaluation

The enormous intraracial variability is apparent to any one who has seen maize collections from the germ plasm bank grown in the field. It is strongly recommended that these maize collection be individually evaluated and high-yielders/combiners be identified through multilocation tests and made available to national programs. However, racial composites tend to mask the elites already available.

Disease Pest Nursery

With the increased productivity emphasis, several diseases and pests have assumed greater importance. Many of these diseases are common in the Afro-Asian countries. National resources, both financial and manpower, are limited to handle this problem effectively.

There is an urgent need for wide-scale, cooperative, regional testing/screening of promising stocks. This would not only aid in the identification of resistant sources but would also help identify races of the pests, if any.

Central Inoculum Laboratory

As stated before, several important maize pests and diseases are common to many Afro-Asian countries. Large-scale screening programs call for mass-rearing of egg/masses/cultures or inoculums. Techniques for mass-rearing borer eggs for several species, even though different in their culture media, basically require similar temperature and humidity control equipment.

A centrally located regional laboratory producing egg masses/culture media can effectively meet the needs of several national programs. Several basic questions shall have to be answered before these proposals are practical.

Regional collaboration to exchange more virulent isolates for the screening of resistant genotypes will prove very useful.

Catalog of CIMMYT Germ Plasm

Detailed information on much of the germ plasm collection stored and maintained at CIMMYT is not available to the national programs. With the availability of such information, national programs can more effectively call for the desired materials to meet their specific needs.

There is an urgent need to publish the information presently available and to substantiate it with annual additions.

Strengthening National Programs

CIMMYT should help the national programs by helping provide special equipment to meet local needs, financing short-term visits of regional scientists for exchange of information, and financing short-term, specialized training.

Maize in the Asian Region

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Maize is a relatively new crop in Asia compared to other important cereals. The species was introduced in the 16th century by European traders. Grown as an ornamental and garden plant for many years, it probably did not become agriculturally important until 200 or 300 years later.

Today the crop is a stable food for millions of people and is becoming important as a livestock feed. Even in areas where the crop is of minor importance, its potential is being explored through multiple cropping and crop diversification programs.

The future of maize in Asia, an importer of the crop, appears bright and the cereal should play an important role in agricultural growth in the years ahead.

IMPORTANCE, TYPE AND USE OF MAIZE

Asia currently plants about 16 million hectares of maize and produces more than 17 million metric tons of grain (Table 1). These figures represent about 15% and 7% of the world area and production, respectively, according to 1968 FAO statistics.

During the last 20 years, the area planted to maize has increased about 75% and production has increased 120% but grain yield per unit area has increased about only 25%. In terms of area, the crop has become relatively more important in world statistics but has remained static in production and lagged in yield per hectare.

In 1968, South and Southeast Asia planted almost 90% of the maize in the region and produced about 84% of the grain. India, Indonesia and the Philippines accounted for more than 70% of the total area planted (Figure 1). Statistics on area and yield for individual countries are given in Table 2.

TABLE 1. Some Asian maize statistics.

Year	Area		Production		Yield	
	Millions of hectares	% of world total	Millions of metric tons	% of world total	100 kg/ha	% of world average
1948-52	9.1	10.4	7.8	5.6	8.6	54.7
1952-56	10.2	11.2	9.4	6.1	9.2	54.1
1962	13.8	14.0	15.3	7.3	11.1	52.1
1963	13.0	12.9	14.5	6.5	11.1	50.7
1964	14.4	14.3	16.2	7.5	11.3	52.8
1965	13.7	13.8	14.9	6.6	10.9	47.8
1966	14.7	14.2	15.9	6.6	10.8	46.6
1967	14.9	14.0	17.3	6.5	11.6	46.6
1968	15.8	14.9	17.3	6.9	11.0	46.4
Mainland China						
1948-52	9.6		14.1		14.7	
1952-56	9.7		18.8		19.5	

Source: F.A.O. Production Yearbook, Vol. 23, 1969.

FIGURE 1. Distribution of maize area in Asia (1968).

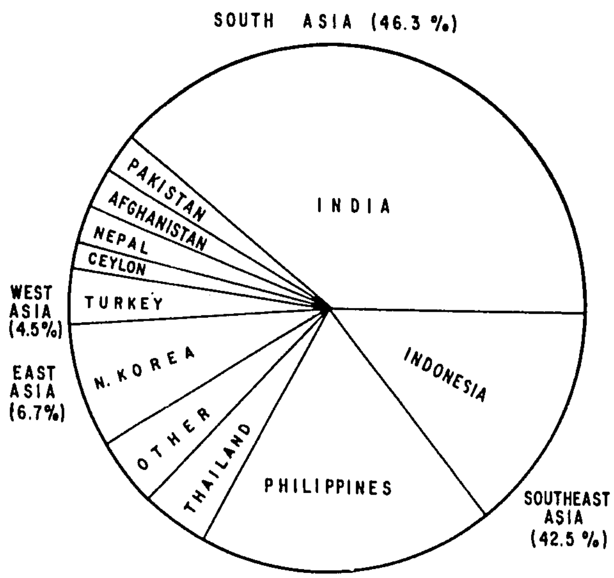


TABLE 2. Asian regional and national maize statistics for 1968 and general trends for 1962-68.

Region and country	Area (1,000 ha)	Yield (tons/ha)	Trends (% yearly change[1]) 1962-68 Area	Trends (% yearly change[1]) 1962-68 Yield
East Asia				
Japan	18	2.83	−13	3
Korea, North	1,000	1.71	Static	− 3
Korea, Rep.	43	1.47	10	15
Total/Ave	1,061	1.71		
Southeast Asia				
China, Taiwan	21	2.40	3	4
Philippines	2,181	0.67	2	Static
Malaysia, Sabah	4	0.64	7	Static
Malaysia, West	4	1.71	Static	3
Vietnam, North	210	1.10	Static	Static
Vietnam, Rep.	29	1.10	− 3	Static
Laos	42	0.55	6	Static
Burma	150	0.43	3	Static
Thailand	670	2.01	14	Static
Cambodia	113	1.36	Static	Static
Indonesia	3,269	0.95	5	Static
Port Timor	18	0.94	Static	Static
Total/Ave	6,711	0.97		
South Asia				
Afghanistan	510	1.43	Static	Static
Pakistan	620	1.01	5	Static
Nepal	440	1.97	Static	Static
India	5,716	1.01	4	Static
Ceylon	17	0.73	4	Static
West Asia				
Iraq	4	1.13	6	10
Iran	25	1.40	8	8
Turkey	655	1.53	Static	4
Syria	5	1.51	− 6	11
Lebanon	3	1.23	−12	− 8
Israel	1	4.10	− 8	2
Yemen	16	1.38	4[2]	2[2]
Total/Ave	709	1.50		

[1] Sum of individual yearly changes divided by 6 (% change not compounded).

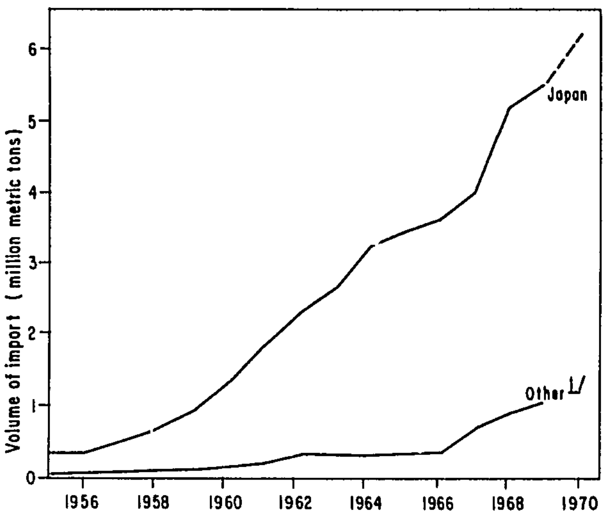
[2] 1964-68.

Source: F.A.O. Production Yearbook, Vol. 23, 1969.

Although maize type varies within the region, the characteristic local types are short, early maturing and produce relatively small ears with white or yellow-orange flint kernels. The white flint types are often found where rice is the major food and serve as a mixture with, or substitute for, rice. A very small area is planted to vegetable types (both sweet and glutinous). Recently, other field types have been introduced. Their acceptance has been best where maize is grown for feed rather than for food. Today, hybrids probably constitute no more than five percent of the maize planted.

Maize in Asia is traditionally a food crop. Within the past two decades, a significant quantity has been utilized for animal feed. The major user of maize for feed is Japan. It imported an amount equal to one-third the Asian production in 1969 (Figure 2). Large quantities are imported from Thailand, South Africa, the United States and Argentina. A small amount of maize is processed for industrial uses. Virtually all maize produced in Asia is utilized within the region, usually in the country where grown.

FIGURE 2. Corn imports for Japan and other selected countries (1956-70).



1/ Singapore, West Malaysia, Hong Kong, Taiwan and S. Korea

LIMITATIONS TO MAIZE PRODUCTION

In much of Asia, increases in production have resulted from increased acreage rather than higher yields per unit area. This stagnation in production efficiency reflects a lack of emphasis on research and industrial development. Only in recent years have local programs received attention from government administrators. While a few of these established improvement programs are adequately staffed and supported, many are skeleton in structure and operation. Therefore, the total impact of research in Asia has been only minimal to date.

The varieties presently used in Asia, although well-adapted to local conditions, impose limitations due to their low ceiling of productivity. Successful attempts have been made to introduce new and superior germ plasm to the region. In the tropical areas, varieties and collections from the tropical Americas have helped raise the yield ceiling while introductions from the Corn Belt and southern states of the United States have been useful in the more temperate climates. Numerous examples of improved varieties from exotic germ plasm can be cited for Asia.

However, the impact of these varieties has been limited since they are usually grown on a small scale. The reasons for their slow movement into commercial channels are not always understood but it is generally accepted that varieties suffer from an absence of mechanisms for providing farmers with good seed and information. Follow-up extension is often lacking in national programs. At the same time, new varieties may have faults as breeders are not always sensitive to the basic varietal requirements such as disease resistance, maturity and grain type.

Disease and insect pests are common hazards. Adequate crop protection is not always available or, if available, not always utilized. In the humid tropics and subtropics, downy mildew diseases cause devastating yield losses annually, particularly in the Philippines and Indonesia. The disease causes some crop loss in Taiwan, India and Thailand, too. The *Helminthosporium* leaf blights and the rusts are common in most humid areas. Losses due to stalk rots are becoming more prevalent, particularly in South Asia.

Two corn borers cause economic losses in the Asian region. *Chilo partellus* is often serious in South Asia. This corn borer not only causes direct loss but tends to delay planting dates in some areas. This leads to lower yields. *Ostrinia salentialis* is found in Southeast Asia and causes sporadic crop losses.

A minor insect in distribution but important in a few localized areas is the shootfly (*Artherigona* spp.). This pest, which destroys the plant in the seedling stage, is found in Indonesia, the Philippines and India during certain seasons.

The need for better crop management and improved production and agronomic practices exists in most maize areas. Good research has been conducted at several institutions. Some of the results have limited practical application. Those that can be beneficial may never be extended to the farm. Agronomic research in some institutions has become stagnated on studies of optimum plant density, dates of plantings, and effects and control of weeds.

In general, this research information is adequate for the current varieties and yield levels. Efforts are needed to apply this knowledge. The performance and acceptance of an improved variety often depend upon the agronomic practices used and the way this package is promoted.

Major limitations to higher production of maize are economic. Unstable markets in most developing countries is not conducive to higher production. In all countries, it has been clearly demonstrated that commercial fertilizers increased yields significantly. However, little fertilizer is used in maize production because of problems of fertilizer availability, cost in comparison with the price of grain, purchasing and price instability. Adequate and effective farm credit systems are lacking in most areas.

OVERCOMING LIMITATIONS

Most current biological problems limiting increased maize production can be overcome with strong, crop-oriented national programs. These improvement programs must extend from the development of new and improved technology to the successful adoption at the farm. Breeders must become conscious of farmers needs for varieties. Resistance to the prevalent production hazards must be developed. Agronomists must be problem oriented and extension personnel must not only be familiar with the technologies available but active and farm-oriented.

Economic problems are more difficult to solve because the behavior of people is often more difficult to control than that of plants. Leaders must be kept aware of agricultural problems as policy and development plans are formed.

The economics of maize is so complex and integrated with other related and nonrelated fields that every change in government policy eventually affects the crop. Development of roads and dams, signing of trade agreements and national attitudes toward outside industry are examples of events that have and will continue to affect maize production.

ACTIVITIES OF THE REGIONAL PROGRAM

The Inter-Asian Corn Program (IACP) has active participation from 13 countries which plant 85% of the maize in Asia. This program was formally organized in 1964 following three years of informal cooperation between a few countries.

IACP's goal is to help eliminate barriers to higher production and, particularly, to increase production efficiency. Some of its activities since its inception are summarized.

Seven annual workshops have been held since 1964. These meetings have opened channels of communications between workers of all participating countries.

Germ plasm has been exchanged rather freely between programs during the past few years, adding more diversity to local programs.

Uniform regional testing has been carried out during the past three years. More than 50 yield trials are grown in the 13 countries and 15 to 20 downy mildew nurseries are observed in the 6 countries where the disease is present. From the yield trials, information on germ plasm adaptability and adaptive or ecological zones has been obtained. The nurseries have produced information on the reaction of downy mildew on resistant sources of germ plasm and on variability of the causal organism.

IACP provided assistance in the development of research and extension capabilities of staff through in-service training at the IACP headquarters.

It has coordinated special regional research activities such as the development of host resistance to downy mildew.

Staff at IACP headquarters have been engaged in research in pathology, entomology, crop production and breeding to provide technology and genetic materials that complement national programs.

Headquarters staff have visited local programs to keep abreast of problems and accomplishments, and to offer assistance. Some assistance has been provided in planning and implementing new country programs.

CIMMYT's ROLE IN ASIA

The role of CIMMYT in Asia should be catalytic in nature and service in function. Some CIMMYT activities that would benefit maize improvement programs in Asia are summarized below.

1. Make available the core interdisciplinary staff for consultation, evaluation and advisory missions upon request. Also, make temporary staff assignments to provide leadership and technical assistance in problem areas.

2. Active participation of CIMMYT staff in workshops and other organized regional activities. Regular and frequent visitations so that communication and up-to-date awareness of problems and activities are maximized.

3. Provide access to the maize germ plasm bank for Asians at all times. Distribute a complete, up-to-date inventory of seed stocks along with supplementary information for collections and composites.

4. Provide a continuous flow of elite germ plasm from the world bank and CIMMYT breeding programs to the breeders. Develop and make available source populations with special characters that may be of interest and use to local programs.

5. Provide uniform international trials and nurseries planned for mutual benefit to CIMMYT and local programs. These should have specific objectives and complement rather than duplicate or replace existing regional testing programs. Routine follow-up observations by CIMMYT staff are desirable and necessary for maximum benefit.

6. Provide recommendations for uniform systems of operation, for example, designation of germ plasm (new and selected populations) and methods of note taking, data recording and reporting.

7. Provide training to Asians in areas that cannot be adequately serviced within the region. Make available postdoctoral (or equivalent) positions and some degree programs to service countries where other educational funds are not readily available.

8. Provide educational material such as training manuals, technical bulletins, periodicals, monographes, reprints of important publications, film strips and slides.

9. Sponsor workshops, symposia and other meetings on relevent subjects. Rotate such meetings to different sites throughout the world and select sites to best fit the program theme.

10. Hold regular meetings with regional staff to review, evaluate, plan and coordinate activities of the regional and international maize programs.

SUMMARY

Fifteen percent of the world's maize is planted in Asia. South and Southeast Asia grow 90% of the Asian total with India, Indonesia and the Philippines contributing the largest share. While area devoted to maize is increasing, yield per hectare has become relatively static. Lack of adequate research and development programs in past years has probably contributed the most to this condition. Varieties as well as agronomic and management practices presently used are inadequate for high production.

Well-supported, crop-oriented country programs complete in scope are necessary for the development and extension of new and improved technology. Efforts through IACP are being expanded to release some of the present production barriers. CIMMYT can and should play an active role in this movement for higher production and efficiency in Asia.

Maize Culture in French-Speaking West Africa

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Maize area is very variable among the French-speaking countries of Africa.

The number of hectares for the countries are: Dahomey, 360,000 (total of 2 seasons); Ivory Coast, 270,000; Togo, 200,000 (total of 2 seasons); Cameroon, 200,000; Upper Volta, 160,000; Madagascar, 100,000; Senegal, 86,000; Mali, 70,000; and Niger, 4,000.

This total, 1.45 million hectares, is slightly less than France's maize area (1.6 million hectares in 1970). Most of this area is in the equatorial regions which have two rainy seasons. Rainfall varies between 1,200 and 1,500 millimeters in West Africa.

In the tropical regions with only one rainy season, the areas devoted to maize are less important. In these regions, sorghum and millet *(Pennisetum thyphoides)* predominate. Rainfall varies between 300 and 1,200 millimeters.

Maize is not grown in the Saharan region. It receives less than 700 millimeters of rainfall annually.

MAIZE TYPES

Types grown in the tropical areas with one fairly long rainy season are yellow flints. Their growing cycle is variable, depending on the variety and the region, but in general it is four to five months (planted in late May and harvested in late September).

Further north, the vegetative cycle becomes shorter as the rainy season shortens.

The sanitary conditions of this tropical maize is good and storage in rustic granaries (frequently in the ground) as husked ears does not present any problems, even when no special precautions are taken.

The types cultivated in the equatorial regions with two rainy seasons are generally white with floury endosperm. Due to the two rainy seasons, generally one is very short, the vegetative cycles are shorter than in the tropical areas and seldom exceed 100 days in southern Dahomey.

Weather conditions in this area favor diseases (notably rust) and insects (stem borers and ear worms), including weevils in the stored grains. The damage caused by weevils is heavy because the cultivated types are floury.

Maizes of the highlands whether tropical or equatorial deserve special mention since their vegetative cycle is four to five months.

MAIZE USES

As a rule, maize is used for human food in Africa as roasted ears or as mush. But, there are other ways of preparing maize, too.

In southern Dahomey, *Akassa* is obtained from semiflint or semifloury maize. It is prepared from a fermented mush obtained from a filtered starch suspension. The residues are fed to animals. In certain areas, maize is used to make alcohol.

LIMITING FACTORS

In Black Africa, maize production is limited by climatic, pedologic, economic and varietal factors.

Climate

Rainfall distribution is bad and drought spells from 15 to 21 days after planting are common. This is more serious in the relatively wet tropics where the rainy season lasts up to five months than in the dry tropics where a shorter rainy shows a better distribution.

In the equatorial region, with two rainy seasons, the total rainfall may be insufficient as in the lower Dahomey where 1,100 millimeters of rain is distributed over the two seasons.

Insufficient insolation is also a limiting factor in the coastal regions of the equatorial zone.

Soils

African soils are frequently defficient in nitrogen due to lack of restitution that causes a decrease in the organic content of the soil. High temperatures also contribute to a lack of humus.

Sometimes phosphorous, not nitrogen, is also a limiting factor, especially in some fenolitic soils of southern Volta. Potassium may be deficient, as in some clay soils of Dahomey and Madagascar.

Economics

The main economic limiting factor is the high price of fertilizers due to transportation costs. The low maize price at harvest time and the cost of fertilizer mean that even when good results are obtained, fertilizer use is not profitable.

Varieties

African maizes are very heterogeneous populations which many times show defective morphologies like ears inserted too high on the stalk, causing susceptibility to lodging. On the other hand, most of these populations show susceptibility to disease, especially *P. polysora* in the tropical areas.

The floury texture of the kernels makes them susceptible to insect attack during storage (*S. orizae).*

MEASURES TO INCREASE YIELD

It is practically impossible to depend on climatic factors like amount of rainfall. Theoretically, irregular distribution could be overcome by using supplemental irrigation. But the low price of the crop and other economic considerations do not allow for experimentation.

The policy on yield improvement has been based on rational efforts on use of fertilizers and varietal improvement.

Fertilization Policy

Use of mineral fertilizer results in spectacular yield increases in almost every case. But as mentioned before, this increase may not be profitable. The use of more concentrated fertilizer and the introduction of an industrial crop in rotation with maize could be the solution to this problem.

A more concentrated fertilizer could provide a sizeable saving in transportation costs, lowering the price. The substitution of urea, ammonium sulfate and superphosphates could lead to sulphur deficiencies. But, sulphur could be added to the fertilizer formulation if deficiency symptoms appeared.

Fertilizer seems to be more profitable in a rotation plan. Cotton is recognized as a suitable component in rotation with maize. Fertilizer could be applied only to cotton. Maize could follow and make use of the residual effects of phosphorous and potassium. Also, a direct application of nitrogen would provide additional mineral fertilizer.

Policy on Varietal Improvement

The problem of varietal improvement in West Africa has become very important since 1951 due to the susceptibility of most of the varieties to *P. polysora.* It is one of the major limitations to maize production in all areas, especially Dahomey and the Ivory Coast.

The improvement programs in Dahomey and the Ivory Coast have produced several improved varieties like Scar III, Niaouli 6, Niaouli 7, Agbo 5, Agbo 6, MTS, CJB and CBB. Different schemes like S_1 selection, intervarietal crosses, selection within composite populations and ear-to-row selection have been followed with success in the formation of these varieties which show resistance or tolerance to rust and high-yield potential.

The national programs in Dahomey, Ivory Coast, Senegal, Upper Volta, Cameroon and Madagascar, are based primarily on the utilization of hybrid vigor in complex hybrid formulae, rather than single or double crosses. This is because the local infrastructures are not sufficient to handle a more elaborate seed production scheme. The more complex hybrid forms would allow for the use of F_2 seed for general distribution.

Several materials introduced from CIMMYT, Central America, the United States, Israel and South Africa have been and are still being used by the several programs in a search for characteristics like short plant, low ear placement, resistance to rust, early maturity and high yield.

Mutants like opaque-2, brachytic-2 and others have been incorporated in several of the improved populations.

COLLECTIONS AND THE ROLE OF CIMMYT

Several experiment stations in Madagascar, Dahomey, and other countries maintain several hundred populations from East Africa, Central America and other regions.

CIMMYT's germ plasm bank has played an important role during the last years by enriching germ plasm availabilities for the national programs. We hope these activities will increase in the future for mutual benefit through the interchange of materials and experiences.

It is highly desirable that CIMMYT's publications be sent to all IRAT experiment stations, especially CIMMYT's research bulletins and annual report. They constitute valuable sources of information, especially on breeding methodology.

Finally, we would like to point out that some breeding methods used by CIMMYT, like S_1 selection and recurrent selection, have been used in West Africa, especially in Dahomey, since 1950.

Maize Production in the Andean Zone

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Maize is the most important ingredient in the diet of Latin Americans and residents of the Andean Zone. This is perhaps unique among the other regions represented at this workshop. Less unique for countries in the tropics is the concentration of the crop among many small farmers compared to more commercial production in many temperate areas.

Human consumption of maize throughout the Zone and the generally high price of the grain limit its use as animal feed. Feed grains cannot compete favorably with either human consumption or export of the crop. First priority use in animals is for poultry and swine, the more efficient converters of grain to meat.

It is appropriate to preface these observations with two comments. First, the information is based on my limited experience of one year in the Andean Zone and brief visits to Bolivia, Peru and Venezuela. More time has been spent in Colombia and Ecuador.

More specific emphasis on the production in each country in the Zone will be presented by each national director or his representative. Hopefully, their detailed discussions plus this more general review will adequately describe the current situation in the Andean Zone.

IMPORTANCE, TYPE AND USE OF MAIZE

Maize provides about 30% of the total calories in the diet of Colombians. In Central America, maize accounts for more than 60% of the calories and half of the protein consumed.

These are national or zonal averages. In rural areas with limited types of carbohydrate available, maize levels in diets are much higher. When maize is supplemented by cassava, potato or platano and limited amounts of legumes, meat, or fish, the contribution of maize to the total protein the diet is high. Maize is fed to poultry and swine, but in most parts of the zone this use is very limited compared to human consumption.

There is only limited international trade in maize, except for a large import into Venezuela. Potential export is limited in Colombia, for example, by a domestic price which is two to three times the world price.

The type of maize consumed varies among countries and among zones in each country. In general, flint or semiflint maize predominates in the lowlands, while floury types prevail in the Sierra. These are traditional patterns, based on local types and varieties of maize plus the local preparations or recipes which are characteristic of each zone.

In Colombia, a book lists more than 150 recipes for maize preparation. The soft floury maize has been characteristic of the culture and consumption of this crop in the highlands for centuries.

Settlement and crop culture in the lowlands was more recent and maize here is crystalline —improved materials in the zone are generally Cuban flints and Tuxpeños, among others. These hard endosperm types have better germination under prevailing high soil moisture levels, and resist insects and ear rots in the field and in storage.

It is essential to study and understand the types of maize—endosperm, color or special characteristics—before embarking on an improvement program. It is possible to interconvert diferent maize types, but if variability exists in the desired type, it is more rapid and efficient to improve within the preferred grain types.

The opaque-2 maize hybrid experience in Colombia provides an example. As in other countries, conversion of flint-type tropical maize to opaque-2 was done through an intensive backcrossing program.

The commercial product, although high in lysine and tryptophan, did not receive the immediate acceptance which was intended to alleviate protein deficiency problems in the rural population. This limited acceptability was directly related to the floury endosperm of the new grain. It was different in appearance and could not be prepared in traditional ways.

The urgent lesson from this experience—for both national or regional improvement programs—is that utmost importance must be placed on knowledge of the crop, the types of maize grown and consumed, and the potential flexibility in each zone with respect to acceptance of a new product.

MAIZE PRODUCTION LIMITATIONS

Factors which limit maize production in the Andean Zone are as diverse as the types of maize cultural systems in the countries and the many climatic regions. These problems are generally complex and involve a series of interrelated factors. Any treatment of limitations is speculative and in no case have the factors to be discussed been quantified.

Yields in experiment station trials, regional trials, and even those attained by more progressive farmers, range from 5 to 10 tons/ha using improved varieties and hybrids available in each country. This may be compared with average yields of about 1.2 tons in Colombia and about 2 tons throughout Latin America.

This suggests that varieties or hybrids are *not* limiting in many areas, at least not up to a certain level of production and under similar conditions. This observation would lead to the shallow and erroneous conclusion that the limited time and funds available should best be invested in agronomy, fertility and extension work. There is the need for improved cultural practices and for greater emphasis on applied extension efforts, but this does not imply that varietal improvement has been finished.

The relatively low yields in the Andean Zone reflect two extremes in farming situations plus every possible intermediate stage. The Cauca Valley of Colombia, the central coast of Perú and the western Llanos of Portuguesa in Venezuela are characterized by relatively advanced cultural practices, acceptance of commercial hybrid maize and average yields of 3 to 6 tons/ha. In these areas, production may be limited by size, long growth cycle or inefficiency of current hybrids. The most rapid increases in total maize production can be made by improving the hybrids or synthetics which can be grown under these relatively intense cultural situations. Maize culture in the higher altitude areas of the Andean Zone is typically restricted to small subsistence farms. Most varietal improvement programs have failed to reach many of these farmers.

Their regional maize varieties are somewhat tolerant of insects and diseases, tall and late maturing, and have consistent but low yields. Introduction of earlier, more potentially productive, and more widely adapted varieties or synthetics in these diverse climatic and geographic zones could substantially improve maize yields and standards of living.

Inadequate cultural practices and other factors certainly limit yields of maize in the Andean Zone. Opaque-2 hybrids showed a 60% to 70% yield increase when fertilizer, weed control and insect control were provided.

Fertilizer response in many areas is still limited, probably due in part to the short cropping history in these fields. Drainage problems are the principal difference between actual yields of 2 tons and potential yields of 5 tons in western Venezuela, and are fundamental in the Sinú Valley of Colombia.

Excess rain or drought not only reduces yields but results in complete crop losses on many farms each year. Insect problems—cutworms, stalk borers and ear worms—limit production in the Cauca Valley and many other parts of Colombia.

Inadequate weed control has reduced yields by 50% to 100% in replicated trials, but no quantitative data is available for the entire Zone.

Although *Helminthosporium, Puccinia* and other pathogens appear each season throughout the Zone, there is no estimate of their influence on yield. There is certainly no disease which limits maize production like *Sclerospora* does in Asia.

Several of these limiting factors can be combined into one general "effect" on production—*low* or *inadequate plant population.* There is a complex combination of factors such as poor land preparation, low planting rates, poor germination, insect damage to seedlings, and drought or excess moisture, which may contribute to poor stands. Poor management is one of the most widely observed characteristics of maize culture throughout the Zone.

Lack of necessary inputs—seed, fertilizer, herbicide, insecticide or credit—is frequently mentioned by farmers and extension people throughout the Zone as a serious limit to maize production. Sometimes, credit is the most serious of these factors.

There are areas where commercial supplies of fertilizer, seed and chemicals are not limiting, but lack of financing restricts use of these inputs. Also, lack of credit is frequently used as an excuse for not accepting new practices when farmers are not completely convinced of the value of a change.

A preliminary study of factors limiting maize production has been completed in three departments of Colombia. The data are currently being analyzed. Using this study as a model, economists and maize specialists in CIAT and several national programs hope to extend this project to the entire Andean Zone. This more comprehensive study will attempt to quantify these factors and define a more objective base on which priorities may be established and research programs organized.

OVERCOMING THESE LIMITATIONS

Solutions to many of the breeding and production problems are obvious. Solutions to other problems are more complex and will require an integrated effort by breeders, production extension experts and credit agencies.

Genetic manipulation of maize type is the first and possibly the most direct procedure which will lead to solutions for the problems listed. Genetic variability exists for maturity, plant height, efficiency, grain type, disease and insect resistance, protein quality, photoperiod and temperature sensitivity, and general adaptation.

The logical procedure is to fix priorities. Decide on characteristics most important for a new variety or hybrid and then combine these into a single genotype.

Most breeding objectives for development of new maize synthetics or hybrids are scale neutral with respect to farm size in their potential application. A shorter, less leafy plant with a higher proportion of grain is desirable for more efficient energy conversion to useful yield.

Disease and insect tolerance are part of an integrated control package which should emphasize more biological factors as our experience in this field becomes more useful. A shorter growth cycle, when combined with more efficient plant type, increases yield per hectare per day and often increases yield per harvest.

Increased plant population could significantly improve maize yields throughout the Zone. By increasing planting rates from the recommended 16 to 20 kg/ha to about 25 kg/ha, many stand stablishment problems could be avoided.

This includes poor germination, early insect and disease loss, and moisture or other soil problems associated with poor seedbed preparation or unfavorable rainfall patterns. It is certainly less expensive to plant extra seed and later thin if necessary than to sustain losses due to a 50% stand.

More direct solutions to these problems rest with an extension of improved technology to more farmers—better land preparation, seed treatment or soil-applied insecticides, and adequate drainage or supplemental irrigation when needed.

Increased acceptance of an improved package—seed, fertilizer, insect and weed control—is a goal of the extension program. Implementing extension programs in the Andean Zone could greatly increase yields on many farms.

It is important that these extension programs and people be closely associated with the research and development effort. Only if these groups are completely integrated or in constant communication can new materials or cultural practices move directly and rapidly through practical tests into use by farmers. Also, continuous feedback to breeders and researchers helps keep the research and development effort up to date and oriented to the most urgent practical limitations faced by the man in the field.

The active interest and participation of government or private agencies in promoting and extending credit to farmers is essential for greater use of an improved production package. Even the most enthusiastic effort in research and extension can be frustrated by a lack of credit or limited availability of any factor in the production package. Most of these organizational problems must be solved by the Ministry of Agriculture and the research-extension organizations in each country.

CIAT's MAIZE PROGRAM

Each CIAT core program operates as a multidisciplinary commodity group. Success in the International Rice Research Institute was partly due to a concentrated group effort which cut across traditional specializations. The International Maize Program in CIMMYT likewise is developing strength in several supporting disciplines in addition to the traditional emphasis on breeding.

And most importantly, we are all encouraging the development of integrated research, development, and extension teams in each national program in our region. It is essential that we in CIAT develop a working model as an example for national programs. If this can be promoted and implemented in an international research institute, it is then possible to promote a similar effort in national programs in the Zone.

Our Maize Production Systems Program concentrates on varietal improvement and development of individual components of an improved production package. Since CIAT is working with several crops, it is not possible to concentrate full-time efforts of a senior scientist in each supporting area. A senior pathologist, with responsibilty in maize and rice, for example, will have at least one research associate (M.S.) or research assistant (B.S.) with full-time maize responsibility.

CIAT has been assigned a research and training role in the lowland tropics, and our efforts in the maize program will concentrate in this climatic zone. We are not completely restricted to the lowlands, however, if there are ways in which we can collaborate with national programs in their overall planning across all zones.

We also appreciate the in-depth research and development in progress or planned at CIMMYT. Our goal is to supplement this fine effort with projects which are more limited in nature and specific to the Andean Zone and the lowland tropics.

With this as background, I will list the areas in which we intend to work and the specific plans we have for first-priority research. Keep in mind the concentration of our work in the lowlands, the limited staff time and funds available, and the more comprehensive research role of CIMMYT in each of these fields.

Maize breeding is the core effort in our program and three initial objectives are to: (1) develop composites or populations with shorter plant height and ear height which are earlier and more resistant to lodging; (2) select crystalline grain types which preserve the protein quality of opaque-2; and (3) develop populations which are both widely adapted and more efficient in the production of grain per day.

Agronomic research will concentrate on factors to increase plant population under farmers conditions, on response to improved soil fertility under different conditions, and on integrating practices into a relevant cultural "production package" for the lowland tropics.

Research in crop physiology emphasizes factors involved in wider adaptation—photoperiod, temperature, moisture effects, among others—and the importance of plant type in determining dry matter production per hectare, per day, per unit leaf area, per unit light intercepted, etc.

Initial work in both pathology and entomology will concentrate on identifying and understanding the distribution of major pests and studying seasonal incidence. Breeding, agronomy and screening programs are in progress for resistance to major insects and pathogens.

The weed control project will concentrate on weed identification, integrated control, and understanding competition between weeds and the crop.

Agricultural economics has been an active effort, with a major study just completed on the acceptability of opaque-2 maize in Colombia. Another study on factors limiting maize production is now being analyzed. This project on limiting factors will be extended to the entire Zone. Future economic work will study price relationships in Latin America and inputs used in maize production on farms of different sizes.

A major problem faced by small farmers in the Zone is lack of improved and low-cost equipment for land preparation, planting, cultivating and insecticide application our agricultural engineer will work to fill this gap in the production package.

Additional support in biometrics and the library will supplement these major thrusts.

Communications and training are implicit in all efforts of the technical sections. Training young scientists from countries in the Zone will receive high priority in each aspect of the core research program. A one-month, intensive training course for breeders was completed in July and will probably be repeated at six-month intervals.

This describes the general approach and current emphasis in our program of Maize Production Systems. It is a flexible program which is under continuous evaluation. As more information is gathered in the Zone, our priorities will change accordingly.

It is an integrated effort which will supplement the already excellent work of national programs in the Zone. Also, it will extend results from CIMMYT research into the Andean Zone.

CIMMYT's ROLE

To supplement regional and national efforts in maize improvement and production, CIMMYT must continue to develop a first-rate staff in breeding and in all the supporting disciplines. Three general areas in which these experts should concentrate their efforts are research, training, and coordination and planning.

Research efforts of the maize program should concentrate on the most important problems in production on a global scale. This meeting should help to focus on these limiting factors, and give some basis for setting research priorities at the Center. Topical problems being studied adequately by regional or national programs need not be included in CIMMYT's research effort.

CIMMYT's staff should develop a comprehensive core program using facilities in Mexico, but promising new materials or practices should be tested immediately in other areas in collaboration with regional centers, and through them, with national programs. All CIMMYT specialists should travel to become familiar with research in the several zones and to bring the latest results and practices to these other programs in the field.

Training new personnel is essential to successful continuity and rapid progress in national programs. To supplement the formal course which leads to a bachelor's degree, the national maize teams normally provide on-the-job experience for new people in an apprenticeship-type situation. More specific training for a particular job should be offered by CIMMYT and by the regional centers. Degree work for the M.S. and Ph.D. is essential for selected people in each national program.

The current system of study in temperate-country universities lacks orientation toward tropical and field-type practical problems. It would be desirable if CIMMYT, CIAT and other centers could provide funds and facilities to allow maize scientists to finish course work in a major university and return to the center for a practical thesis problem and orientation to the current problems of the tropics. Several universities now have experience and precedents in this type of international program.

Coordination and planning of research within national programs, within regions and on a world-wide scale is necesary to avoid duplication and assure rapid spreading of ideas and acceptance of improved seed or practices. The review team from CIMMYT which visited the national programs in Colombia and Ecuador produced a report which contained many valuable suggestions for the continued progress of these programs.

Even more important than the report was the chance for many researchers in the field to meet members of the CIMMYT staff and learn about up-to-date techniques for field research. These visits should always be coordinated through each regional center. I propose that most seed exchange and correspondence to maize people in national programs be coordinated through regional centers, or at least that copies of letters be sent to these centers. This keeps people in the regional centers current on all activity in the zone, helps promote collaboration between national programs and regional centers, and assures better follow-through on planning and use of new information.

Another suggestion on wide-scale coordination involves regular publication of topical information for maize researchers. An informal publication similar to the Maize Genetics Newsletter could keep people current on who is where, recent publications on maize, regional and international meetings of interest to the group, and preliminary results of current research. This would provide a regular forum for exchange of information and supplement meetings like this conference.

In summary, CIMMYT should continue to promote and support an integrated program in each regional center and in each country. This support should include core research, international trials, germ plasm bank, travel by Center specialists, training and thesis research support, and coordination and evaluation on a regular basis of programs throughout the world.

The job of increasing maize production is too large for any single group. Only through pooling efforts and regular exchange of germ plasm and information can we hope to meet this challenge. We should compliment CIMMYT for the idea of an international maize workshop, and hope that the success of this first experience will help promote closer collaboration among programs and justify another similar workshop 2 or 3 years.

The West Pakistan Maize Improvement Programs

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West Pakistan

West Pakistan is not among the major maize producing nations. However, the agricultural census indicates that nearly 600,000 hectares are sown to maize, ranking it third nationally among cereal grains. Also, at least 62,000 hectares are grown in the tribal areas and the recently merged princely states. The annual maize production in the areas covered by the agricultural census has varied between 500,000 tons and the record 778,000 tons produced in 1967.

West Pakistan has about 14 million hectares of cultivated land, of which 12 million receive some irrigation. Cropping intensity overall is 110%. The two crop seasons are called *rabi,* which corresponds to a late fall, winter and spring season, and *kharif,* which covers the period from June through October.

With about 60 million people subsisting on the 16 million hectares of crops sown, the land-to-man ratio is a fairly favorable 0.26 hectares per capita. Eighty percent of the population is rural.

The average farm size is 4 to 5 hectares and the median farm size is less than 1.5 hectares, indicating a high proportion of subsistence farmers.

Crop yields are extremely low. Maize and wheat average 1 ton/ha. Part of the blame for such low yields can be placed on low fertilizer applications. The average cropped hectare receives 14 kilograms of nutrients, with a N: P_2O_5 ratio of 5:1. Use of potash is negligible, except for the tobacco crop.

Two provinces of West Pakistan account for nearly all of the production with a third possessing some potential. In the Northwest Frontier Province (NWFP), maize covers 50% of the cropped area during the *kharif* season and accounts for 40% of total food grain production. Above 35° North latitude, maize covers 80% of the planted area up to 2,500 meters elevation.

In the Punjab province, maize occupies less than 10% of the *kharif* crop area and accounts for a mere 5% of total food grain production. Because the Punjab is a much larger province in terms of cultivated area, maize production and area for both provinces are approximately the same.

While the area planted to maize in the Sind is still very small, interest is growing rapidly, both as a *kharif* and *rabi* crop.

The provincial governments in the NWFP and the Punjab began working on maize nearly 20 years ago, but yield improvement was slow. It was not until the 1967 season, which was the one good monsoon in the last six years, that everything combined to give maize yields a 50% boost over the previous five-year average.

Significantly, that was the year when seed supplies of the J-1 composite first became plentiful enough to have an impact. Synthetic 66, first developed in 1962 by crossing K55 x K64 with short term inbreds from a local white flint (Swabi white) had been in demonstration plots in the NWFP for three years and seed had been passed from farmer to farmer.

During 1968-70, characterized by relatively poor monsoons, production was 620,000 to 650,000 tons. However, this was 25% above the average of the period preceding the good year. Through use of fertilizer and high-yielding varieties, a new base level had been reached.

Yields 4 to 5 times the national average are commonplace. To narrow the gap between potential and realized yields, the government of West Pakistan sanctioned an Accelerated Maize and Millets Improvement Project in 1968. A change of government caused the breakup of the project on an all-West Pakistan basis and drastic personnel changes occurred before progress could be made.

This year both the NWFP and the Punjab governments decided to upgrade their maize research stations into semiautonomus institutes with a doubling of budgets. Land for research is plentiful in both provinces because the institutes fell heir to the large hybrid maize seed production farms.

All of the large farms available for maize seed production and research are located in the hot, arid plains up to 300 meters elevation between 31° and 34° North latitude. A substation at 1,400 meters elevation on just one-half hectare has proven very useful for growing and crossing less well-adapted material. Two testing sites have been established on rental property at 35° and 36° North latitude at 1,000 meters elevation. Both are surrounded by fairly wide, fertile plains in the hilly areas.

Since maize predominates up to 2,500 meters elevation, the lack of a testing site at elevations higher than 1,400 meters is unfortunate. However, a start can be made with the established substations to serve the mountain tracts in the Himalayan foothills. Funds will be available to conduct trials further up into the hills.

We regularly grow two crops per year at Yousafwala in the Punjab and at Pirsabak in the NWFP, sites of proposed maize research institutes. We have grown two generations of most of our materials each year on the same land. Thus far we have not produced a third generation of the same material in the same year, even with the winter nursery operating in the Sind for two years.

In the variety development work prior to J-1 and CIMMYT-Ford involvement, crosses were made among U.S. Corn Belt inbred lines and with inbreds from local varieties. These local varieties were early maturing with small, flinty grain, narrow and upright leaves, and they generally yielded very poorly. Since most of the maize was, and still is, broadcast, it has been subjected to extremely high plant populations and suffered intense competition from weeds.

Since 1966, when the first shipments of germ plasm were made from Mexico and Thailand, the program has included a wider germ plasm base which incorporated the results of the work done in India and México.

The first result of these introductions is the recently approved composite called Neelam. It has Usatigua, Tuxpeño, CBC x Eto Blanco, Guatemala, USA 342, CBC x Colorado Manfredi and the inbred lines Wf9, B7, B10, B14, 38-11, Pb7, Cl 187-2, Hy, M14 and A619 in its parentage with U.S. Corn Belt material comprising 80% of the gene pool.

Full-scale seed production was decided upon when this composite consistently surpassed J-1 by 15% with slightly earlier maturity and equalled or surpassed the best conventional hybrids at the research station and in farmers' fields. It is now grown on 400 of the 500 hectares devoted to maize seed production at the Punjab government seed farms and on an estimated 1,500 hectares on private farms.

Another composite, recently constituted from the same material plus varietal introductions from the United States and the inbred lines Oh45, B37, B57, H51, C103 and A632 not included in Neelam, is being tested preparatory to submission for approval. This has been called Akbar and matures in 110 days when planted in mid-July.

To develop a yellow variety which would mature by November 15 when planted as late as August 15, Akbar was crossed with a wide range of material, including some early U.S. hybrids and early local flints. They are under test this season.

Also, to develop a white variety to supersede Synthetic 66 and a local variety (Northern Double, derived from a mixture of indigenous types and Pride of Saline and Oklahoma Silvermine), a composite of 28 U.S. varieties ranging in maturity from Silver King of Wisconsin to Texas Surecropper was put together.

This composite, named Khalil, exceeded Synthetic 66 by 20% in yield with equal maturity in the 1970 trials. It was quickly approved for increase and is now being grown on 12 hectares at the Pirsabak station and on more than 50 hectares on private farms. It matures in 100 days when planted in mid-July on the plains and in 120 days when planted in late May at 1,000 meters elevation.

To develop an earlier white variety for the areas where cropping intensity is higher, where a delay in the start of the rainy season is likely, or where maturity is delayed by cooler temperatures, we have crossed early white flint varieties such as PI 21k201, 214277 and 222-305, with Synthetic 66, Khalil, Ganga safed, Swabi white and others.

The first International Maize Adaptation Nurseries (IMAN) trial planted this spring at Pirsabak, served as an eye-opener. Synthetic 66, used as the local check, was among the earlier entries but was beaten by 20% by another white variety of equal maturity, Nab-el Gamal from Egypt. The Argentine entry, H. Pergamino Guazu, also was equal in maturity and 20% higher in yield. Another Argentine variety, H. Abati 2 (INTA), provided a 60% higher yield and was only a few days later.

Comp. L (ME) C2 from Mexico and QK 37 from Australia were also 60% higher in yield, but they were two weeks later.

We have grown materials such as J-1 (Comiteco x Jala) which yielded considerably more than the checks at Yousafwala and placed first, with J-1 (HRC-Tuxpeño x SSS), second. Far down the list were straight U.S. Corn Belt materials which, however, were more attractive in plant type and maturity.

At the same time, yields of 7 to 9 tons/ha have been produced, (at populations of 80,000 plants per hectare with 220 kilograms of N and 110 kilograms of P_2O_5) from single cross hybrids like M14 x A619 and P67 x A619. This indicates that a wide variety of germ plasm can be used in West Pakistan to develop top-yielding varieties if cultural practices can be improved and if fertilizers, pesticides, and irrigation water can be supplied in adequate quantities.

Maize Improvement Programs in the Middle East

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Geopolitically, the Middle East comprises lands bordered by the Fertile Crescent. We will also include areas along the Mediteranean coast of North Africa because of similar climatic factors.

This vast area is mostly arid with relatively mild temperatures, precipitation during the winter and hot, dry, rainless summers. Thus, maize can only be grown where there is assured irrigation or rainfall during the summer growing season.

IMPORTANCE, TYPE AND USE OF CORN

Maize makes a significant contribution to the diet of the rural population of the United Arab Republic (UAR), Turkey and Morocco. In relation to the acreage of other cereal crops, maize occupies an important position in these countries (Table 1).

TABLE 1. Area, production and yield of wheat, maize, and sorghum and millets for selected Middle East and North African countries, 1968.

	Iran	Afghan-istan	Turkey	Morocco	Sudan	UAR
Area in Crop (1,000 hectares)						
Wheat	4,800	2,500	8,352	1,977	89	594
Maize	25	510	655	630	27	653
Sorghum & Millet	30	—	40	98	1,805	224
Production (1,000 tons)						
Wheat	4,977	2,250	9,603	2,556	88	1,518
Maize	35	730	1,000	382	15	2,297
Sorghum & Millet	21	—	53	85	988	906
Yield (tons/ha)						
Sorghum &						
Wheat	1.04	.90	1.15	1.29	.98	2.56
Maize	1.40	1.43	1.53	.61	.54	3.52
Millet	1.00	—	1.33	.88	.55	4.05

Source: F.A.O. Production Yearbook.

It is in the UAR that maize plays a major role as a cereal crop and has a dual purpose. It provides both grain and green fodder for domestic animals. As the plants develop, farmers strip the lower leaves for animal feed, reducing grain yield. More recently, use of grain as poultry and animals feeds has increased rapidly, particularly in Turkey, Syria, UAR, Iraq and Lebanon.

In the UAR, white dent types are grown exclusively and in the other countries yellow dent to semident types predominate.

Except for the UAR, most countries in the region are not self-sufficient in maize and the region imports significant quantities. With the increase in population and the poultry industry, demand for maize will increase rapidly. This is recognized and repeatedly emphasized by the various governments. For example, Iran has signed a five-year contract with a Yugoslavian scientific team for the production and distribution of Yugoslavian hybrids.

Current maize yields, except for the UAR, are relatively low (Table 1). It is sometimes stated that the Middle East, once the granary of the ancient world, has exhausted its soils and, as in the UAR, reached its natural limits.

Several scientific teams that have evaluated the agricultural potential of the region report that this is not true. It is their opinion that with appropriate modern technology, practices, management and freedom from inhibitions and rigidities, the resources of the Middle East can permit production on a much higher level.

In 20 to 30 years, for example, agricultural output can be doubled in the UAR and multiplied ten-fold in Iraq. Programs in other developing countries, particularly Mexico, Pakistan and India, have strikingly demonstrated that a dramatic breakthrough in yield levels can be obtained. Data from two specific experiments will be quoted to show that similar results can be obtained in the UAR and Lebanon.

NATURAL AND HUMAN RESOURCES

Consider the obvious natural and human resources in the maize areas of the region. These assets are particularly favorable in the UAR and can catalyze changes to increase maize productivity.

Sunshine

With very little cloud canopy, the sun shines on the ground more than 90% of the possible time.

Soils

The silt soils of the Nile Valley and the Delta are naturally fertile and productive. When properly provided with drains and not overwatered, these soils are among the most productive in the world.

Water

The Nile River accounts for at least half of the water supply from all sources in the Middle East. So, assured irrigation is available for maize cultivation in the UAR.

Diseases and Pests

Because of arid conditions, disease and pest problems in maize are relatively few compared to more humid maize growing areas of the world.

Technical Expertise

Of all the countries in the region, the UAR possesses a wealth of latent scientific talent in the agricultural sciences. Also, the country has several organized and functioning agricultural experiment stations.

To rapidly mobilize these resources for increasing maize yields, hard work, sound planning and competent execution of plans is required.

LIMITING FACTORS

Consider some factors limiting corn production and prerequisites for achievement.

Improved Maize Varieties

Crop breeding is the *sine qua non* of crop improvement. Research in the UAR led to the development of double cross hybrids and in Turkey, certain U.S. hybrids were tested and released for cultivation.

But, about only 18% of the UAR's total maize area is planted to hybrids even though hybrids were released more than 15 years ago. The introduction of U.S. 13 hybrid in Turkey resulted in only modest yield increases.

In the UAR, the spectacular jump in per hectare yield since 1965 has been largely due to shifting the planting date from late July-August to May-June, combined with greater use of nitrogen fertilizer and better plant protection measures. It is difficult to estimate the contribution made by the hybrids *per se*.

Drainage

Proper surface and subsoil drainage is basic for irrigated lands. Also, land improvement by levelling and grading facilitates drainage and allows uniform water application. These are urgent needs in the irrigated lands of the Middle East. Also, these improvement should reduce saline and alkaline conditions and lower the high water table. These factors are fast becoming major limiting factors in maize production.

Irrigation

Irrigation, particularly in the UAR, leaves standing water on fields. Gradients in plant growth and development can be seen, with poor growth in areas of water pockets. With proper levelling and grading, control can be exercised over the quantity of water applied and its uniform distribution.

Fertilizer

If maize yields are to be increased, fertilizer application has to be increased greatly. The new maize varieties being developed will have genetic potential to yield more than the older ones. Consequently, higher levels of chemical fertilization become a necessity if yields are to be increased.

Management of Agricultural Land

The present land preparation and seeding system needs to be improved considerably. The soils of the Nile Valley and the Delta have a high clay content. This makes them very sticky when wet, and hard and dificult to crush when dry.

Thus, they are not amenable to good cultivation with the agricultural implements used by farmers. Farmers use a high seed rate and yet often have poor and uneven plant stands. Agronomic research must be directed to the type of farming involved. Also, development and use of small-scale, animal-drawn machinery must be undertaken.

It is axiomatic that a multipronged approach in research and development is needed if maize yields are to be increased rapidly Teamwork and comradeship between scientists in related disciplines of agriculture need to be created in the experimental fields and on the farmers' lands.

NATIONAL PROGRAMS

In the UAR and Turkey, some limited research has led to the development of maize hybrids and improved production techniques. In other countries, national maize programs have been very small or absent. Results from these programs have been briefly presented.

In 1961, maize improvement projects were implemented in collaboration with the UAR and Lebanon. The immediate objective was to develop high-yielding varieties, soil and water management practices, and fertilizer use to maximize production from the new varieties. The aim was a breakthrough in maize yields by applying the latest research and production techniques.

Breeding

A composite approach to varietal improvement was undertaken since recent research at CIMMYT and in countries such as India and Pakistan had demonstrated that this breeding methodology and the resultant varieties had several advantages over the hybrid approach.

In Lebanon, on the basis of past performance of closed pedigree double cross hybrids, a series of first generation synthetics (DC x DC) were developed and tested in the Bekaa Valley. Mean grain yield reached 15 tons/ha. This yield was double that of the local variety and 25% more than the best double cross hybrid parent.

Second generation seed of the synthetic is being increased and will be tested in replicated trials. Data for the outstanding synthetics are presented in Table 2.

In the UAR, a different approach towards varietal improvement was undertaken. All possible combinations between groups of 10 selected varieties were developed and tested at two locations in the F_1 and F_2 generations. Some of the base varieties had been screened earlier for resistance to the major disease in the country known as late wilt (caused by *Cephalosporium maydis).*

The data obtained are presented in Tables 3 and 4. Certain F_1 varietal crosses gave very high yields and heterotic response.

For example, Synthetic La Posta-American Early gave a mean grain yield of 13.7 tons/ha, 51% more yield than the better parent (American Early) and 54% more yield than the Giza hybrid 186. Remember that AE and G 186 are two of the major varieties recommended for cultivation.

TABLE 2. Grain yield at 15% moisture for first generation synthetics in Lebanon, 1970.

Pedigree (P_1 x P_2)	Grain Yield (tons/ha) P_1	P_2	Multiple cross	% increase over better parent
A202 x U600	12.2	11.2	15.3	24.5
A204 x U600	11.5	11.2	14.2	22.9
A202 x U32A	12.2	12.2	14.6	19.0
A204 x U32A	11.5	12.2	15.0	23.0
A204 x U642	11.5	11.5	14.2	22.9
A204 x KT623A	11.5	10.3	13.8	19.2

TABLE 3. Mean grain yield at 15% moisture for outstanding F_1 variety crosses at two locations in the UAR, 1970.

Pedigree	Yield (tons/ha)	F_1 as % of better parent	F_1 as % of Giza Hybrid 186
Syn. La Posta x AE	13.7	151	154
Tep 5 x AE	12.0	131	134
Mex. June x AE	10.7	117	120
Syn. La Posta x (Ant 2D x AE F_2)	10.1	128	113
AE	9.1	—	103
Giza 186	8.9	—	100

TABLE 4. Mean grain yield at 15% moisture of outstanding F_1 variety crosses and their F_2 progeny at two locations in the UAR, 1970.

Pedigree	$\frac{F_1}{F_2}$ (tons/ha)	F_2 as % of F_1	$\frac{F_1}{F_2}$ as % of Giza 186
Syn. La Posta x AE	13.7 10.7	78	154 120
Tep 5 x AE	12.0 10.0	83	134 112
Mex. June x AE	10.7 9.3	87	120 104
Syn. La Posta x (Ant 2D x AE F_2)	10.1 8.9	93	113 100
Kitale Syn. x (Ant 2D x AE F_2)	9.6 9.8	102	107 110
AE	9.1		
Giza 186	8.9		

The F_2 performance was very interesting. There appeared to be residual heterosis in some F_2 populations and some still yielded more than Giza 186 (Table 4).

The better populations are undergoing a second year of testing and are screened simultaneously for resistance to the late wilt diseases. The data has been used to develop better varietal population along the following lines:

1. The outstanding varietal cross will be recommended for commercial cultivation. Simultaneously, a reciprocal recurrent selection program will be implemented for further improvement of the varietal cross.

2. The outstanding F_2's will be advanced to F_3 and then subjected to recurrent selection by incorporating S_1 testing.

3. The information on general combining ability of the parent varieties has been utilized for the development of elite composite populations and will be improved by Method 2 above.

In two years, data has accumulated on base varieties representing a wide spectrum of genetic variability with regard to plant type, prolificacy, disease reaction, maturity, combining ability, etc.

A second series of elite populations is being formulated, based on the above information. Prolificacy, compact plant type, disease resistance and yielding ability are being emphasized. A project for protein quality improvement is underway, too.

Moreover, in the existing double cross hybrid program, certain hybrids (such as Giza 355) possessing some resistance to late wilt have been developed and are under test.

With significant increases in per hectare yield from the new varieties and from better cultural methods, the practice of stripping lower leaves as green fodder should end. The farmer can plant part of the field for green fodder with the rest of the field for grain production.

Another method is to develop tillering types possessing high levels of grain production and then remove only the tillers for fodder. The second approach will also be given consideration as a breeding possibility.

Winter Nursery

A very successful winter nursery was grown for the first time in November 1968 and is now a regular feature of the maize program. Thus, five generations have been advanced and the sixth is in the field. The winter nursery has considerably accelerated the breeding program.

Seed Stores

Storage facilities for valuable maize germ plasm were virtually absent. Consequently, insect-proof, rat-proof, air-conditioned seed stores have been constructed.

Seed increase of different germ plasms are now indexed, cataloged and stored for further use in breeding and other projects. Also, a walk-in cold room for long-term storage of a world collection of base varieties has been installed and put into operation.

MAIZE EXPERIMENT STATIONS

About 50 acres of experimental land at each of the stations Sids and Gemiza in the UAR have been allocated for the collaborative maize project. These stations now constitute the main centers for research on maize.

To successfully implement the experiments, the system of land management and irrigation had to be improved and mechanized to have more precision over the agronomic steps. Agricultural machinery, such as tractors, plows, harrows, a land leveller, a ditcher and a ridger were brought in. Levelling and incorporation of surface drainage and siphon irrigation systems were completed.

In past years, the C. V. value of individual experiments ranged from 25% to 35% but last year, under the new management system, it was 8% to 15.7%. Also, plant stands in experiments improved 95% to 98%, from as low as 33%.

Similar improvements in experiment station facilities have also been developed in Lebanon.

CIMMYT's ROLE

What role can CIMMYT play in aiding national maize projects so they become self-perpetuating under local scientific leadership? Consider this role under different categories.

Training

The countries need technicians with practical field experience in breeding, agronomy, management of the farm land, setting up irrigation and drainage systems, and so forth. A higher level of training should help develop local scientists' ability to pinpoint bottlenecks to increased production in farms fields and then mount problem-solving and production-oriented research projects.

Scientific Sharpshooters

For several years to come, many countries will not have the required trained scientists and technicians. CIMMYT, with its scientific talent and expertise, should be able to help initiate and implement national programs, and within a relatively short period, demonstrate that existing yield plateaus can be raised, thus convincing national governments that the problem needs immediate consideration.

Coordination of Regional Activity

It is imperative that maize growing areas of the world be classified into agroclimatic zones. In each region, CIMMYT should set up an operating base from which scientific information can be fed into headquarters and from which advice and guidance can be given to national governments.

The importance of CIMMYT in the future will most likely depend on the contribution it can make towards increasing maize production on a world basis.

Additionally, certain specific problems, for example, downy mildew disease in South and Southeast Asia, can be more effectively tackled by a regional effort cutting across national boundaries. CIMMYT can make a valuable contribution by coordinating research activity.

Gene Pools for Specific Objectives

The development of a world composite, currently being carried out at CIMMYT, is one such approach but with a broad spectrum of objectives. Can gene pools for resistance to stalk rot (caused by *Cephalosporium)* be developed from different sources available in the germ plasm banks at CIMMYT and in South America? Can this be done for the major diseases and pests, for plant type (compact) and so forth?

Such gene pools, if available, can be distributed to national programs where there is a need for them.

Sharing Information

In national maize programs, considerable scientific information of practical value has accumulated. This may pertain to modification of field equipment to meet local needs, construction of a seed drying bin from local materials, germ plasm sources conferring resistance to certain disease, varietal populations possessing high general combining ability and so forth.

This type of information should be compiled, printed and distributed to maize programs in other countries.

Analysis of Adaptability of Cultivated Crops

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Genetic-environmental interaction plays an important role in the selection process during stages of the genetic improvement.

The ineffectiveness of selection schemes used in such improvement is frequently attributed to this interaction. However, in this presentation, we shall refer exclusively to the evaluation of the improved material under different environmental conditions. Simply, we shall refer to its adaptability.

For this reason, it is necessary to have a clear understanding of the general phenomenon of genotype-environment interaction to understand the problem and to be able to interpret the data obtained.

The traditional analysis of variance which tests the hypothesis of no difference among varietal, environmental and interaction effects is not sufficient since it only indicates in a gross manner the presence of interactions. It does not explain how each of the varieties interacts with the environments.

Figure 1 shows a phenotype model with no interaction. When varieties interact with the environment, this model has an additional term, *ge*, which we symbolize with the greek letter *gamma*.

The graphic interpretation we have given to this model is shown in Figure 2.

We have been able to demonstrate that in a variety which does not interact with environments, the slope of its regression line (B_i) equals unit and that the mean square of its deviations from regression equals zero (unpublished data).

FIGURE 1. Phenotypic model without interaction. The phenotypic values are a linear function with slope equal to the unit of environmental effects.

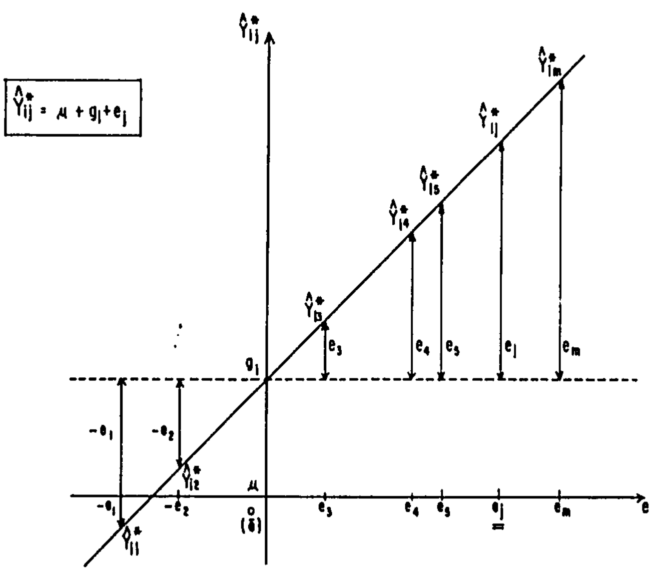
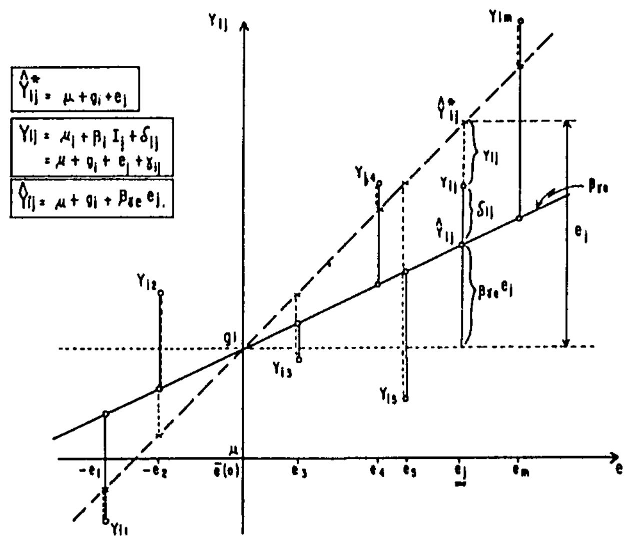


FIGURE 2. Phenotypic models with interaction. There is an additional component γ_{ij}. The adjusted phenotypic values are a function of the environmental effects with regression coefficient different from one.



These conditions are in agreement with those qualities which a stable variety should have, according to Eberhart and Russell's model—shown below—in which they have based the estimation of parameters for stability.

$$Y_{ij} = \mu_i + \beta_i I_j + \delta_{ij}$$

Where according to our nomenclature:

$$\mu_i = \mu + g_i$$

$$B_i = \beta_{g \cdot e}$$

$$I_j = e_g$$

δ_{ij} = deviations from regression line.

According to this, a desirable variety is one with a high mean value, $B_i = 1$ and $S^2_{di} = 0$.

On the other hand, Carballo and Márquez have defined the following categories which may be presented, according to the parameters of stability.

Category	B_i	S^2_{di}	Description
a	1	0	Stable.
b	1	> 0	Good response in general; inconsistent.
c	< 1	0	Responds better under unfavorable environments; consistent.
d	< 1	> 0	Ibidem; inconsistent.
e	> 1	0	Good response under favorable environments; consistent.
f	> 1	> 0	Ibidem; inconsistent.

According to these descriptions, a good response implies that the variety reacts to the influence of environment in the same direction and proportion whether the former be favorable and the inconsistency indicates the presence of fluctuations of the real values about the expected ones.

Nevertheless, the type of variety which we would call desirable will depend largely on the system of production to which it would be submitted. If, for instance, in this system we could always be sure of having the better cultural conditions, the indicated variety would be one from category *e*, because, if one variety, with a regression coefficient less than one were used, it would not take full advantage of the superior environmental conditions.

AN EXAMPLE IN MAIZE

Carballo and Márquez estimated the stability parameters in eight groups including hybrids and improved varieties from El Bajío, 1,840 to 1,800 meters above sea level, and the Mesa Central, more than 1,800 meters above sea level. The testing places were El Bajío and transition areas between there and the Mesa Central.

At present, the hybrid H-366 is recommended for El Bajío (Figure 3). Its average yield was the greatest among all varieties (8.25 tons/ha) even though it was lower in other areas. With respect to its stability parameters, the regression coefficient was significantly greater than one and the deviation from regression, greater than zero.

That is to say, this is a variety belonging to category *b* which takes full advantage of the superior environmental conditions.

For the transition area (Figure 4), hybrid H-128 R (from Mesa Central) was the highest yielding variety, approaching the behavior of a stable variety for those conditions ($Y = 8{,}56$ tons/ha, $B_i = 1.11$ and $S^2_{di} = 0.22$).

FIGURE 3. Average yield of hybrid H-366 under irrigation in environments at El Bajío, El Bajío-transition zones and transition zones.

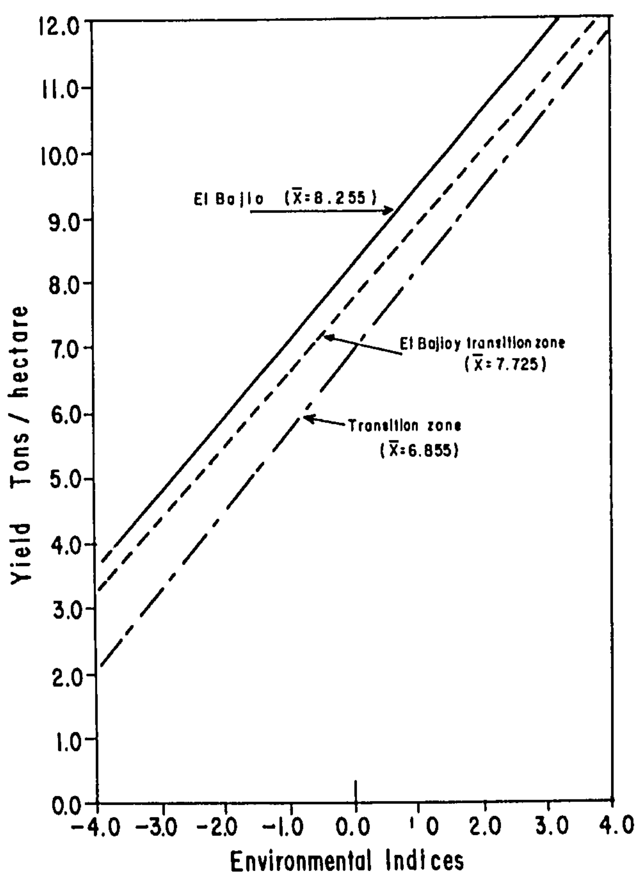
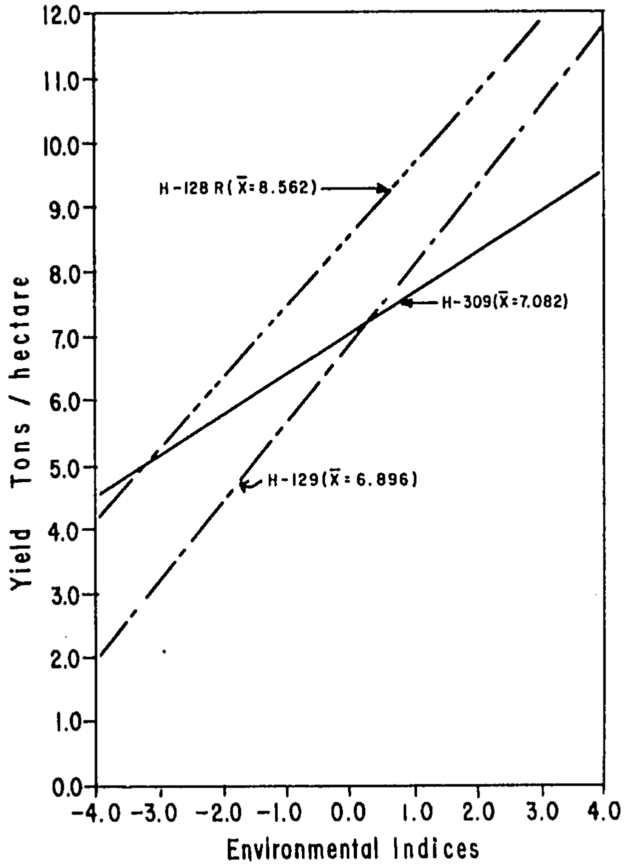


FIGURE 4. Response of hybrids from the Mesa Central (H-129), El Bajío (H-309) and transition zones (H-128R) when tested under irrigaiton at the transition zones.



Hybrid H-309 from El Bajío, maybe due to its origin, showed a lower yield than H-128 R and a regression coefficient less than one, even though it was not statiscally different from one (Y = 7.08, $B_i = 0.64$ and $S^2_{di} = 0.17$).

At present, the Postgraduate College is doing research in an attempt to pool into one varietal index all three parameters we have used to categorize varieties.

AN EXAMPLE IN WHEAT

The analysis that we have just described can be applied to any study, including different varieties evaluated under different environments. That is, the environmental differentiation can also be attained through the application of agronomic practices like level of fertilization, plant density, irrigation and depth of cultivation.

Based on these possibilities, Lalama and Márquez (unpublished data) evaluated 25 wheat varieties in 9 environments. These were a factorial combination of 3 levels of nitrogen (0, 100 and 200 kg/ha) and 3 plant densities (20, 80, 140 kg seeds/ha).

Data were recorded on characteristics like number of plants per row, number of kernels per head, plant height, grain yield, 100-kernel weight and percent protein in grain.

The overall results indicated that the varieties as well as the characters studied responded differently to the environmental changes. Although for some characters there were no significant differences for treatments, as for number of kernels and protein, generally there was a tendency for the characters to show a greater phenotypic expression under conditions of high fertility and density.

In what follows, the analysis for adaptability is shown. NOROESTE 66 (Figure 5) was one of the varieties which got closer to category *a* stable, for number of stalks, yield and protein.

On the other hand, the coefficients of regression for weight of 100 kernels, number of kernels and plant height were less than one.

FIGURE 5. Response of variety NOROESTE 66 to environmental changes in fertilizers and plant density.

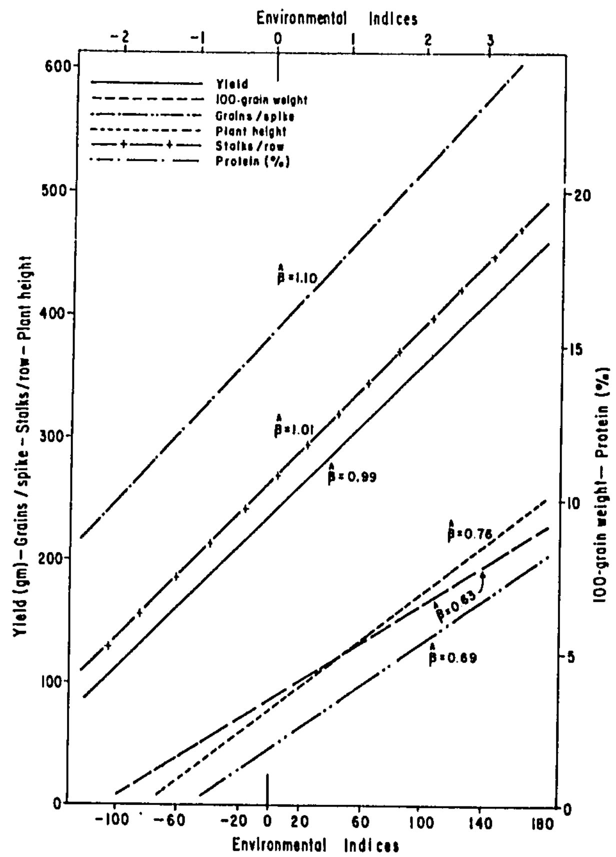


FIGURE 6. Response of a cross (INIA "s" x NAPO 63-21950-10Y-1M-0R-1R) to environmental changes in fertilization and plant density.

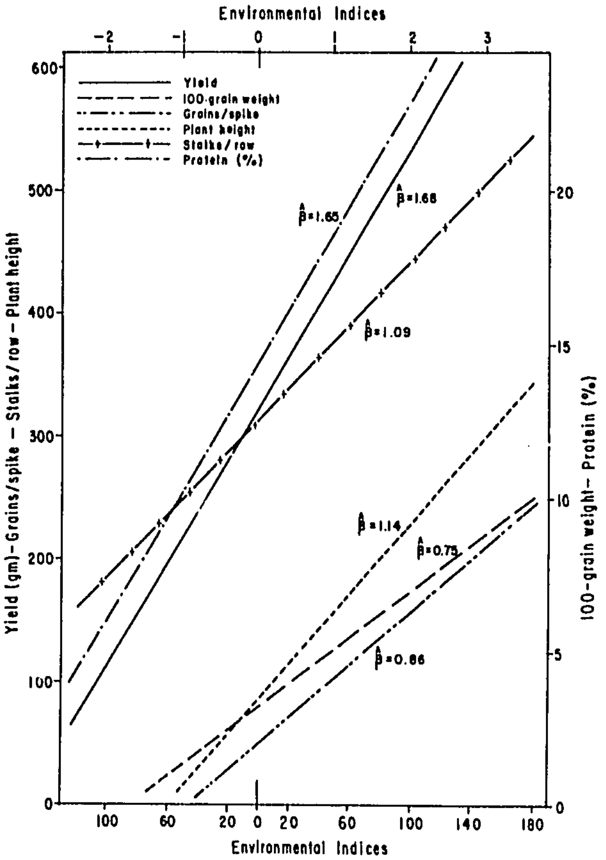
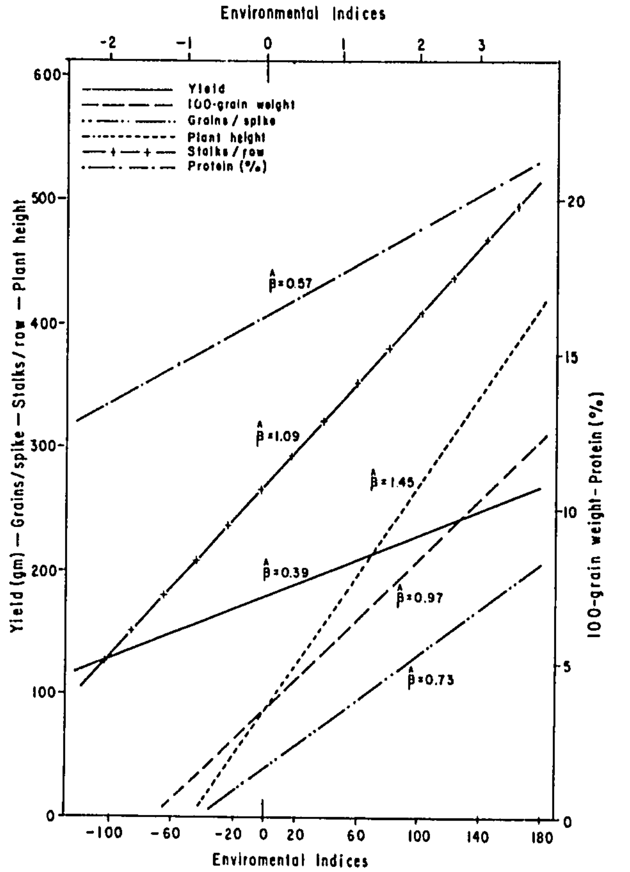


FIGURE 7. Response of variety Mayo 64 to environmental changes in fertilization and plant density.



Variety INIA "s" x NAPO 63-21950-10Y-1M-0R-1R (Figure 6) showed a good response for yield and protein under favorable environments (B_i greater than 1). Number of stalks and plant height were stable, whereas weight of 100 kernels and number of kernels showed B_i's less than 1. MAYO 64 (Figure 7) can be considered opposite to the previous variety with respect to yield ($B_i = 0.39$) and the notorious diversity in the response of the characters studied under the different environments.

SUMMARY

The analysis of the genetic-environmental component using the stability parameters is a very useful methodology which could be used by plant breeders in screening varieties for yield and adaptability.

This analysis, of course, is applicable to other breeding problems involving interaction.

Maize in Colombia

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Colombia's geographic position and mountainous terrain combine to produce climates ranging from tropical and subtropical in the lowlands to cold climates in the highlands. Maize, beans, banana, coffee, potatoes and wheat may all be grown in a radius of a few kilometers.

Of Colombia's 114 million hectares, 27.4 million hectares are farmed (1960 census). Fifty-four percent of those 27.4 million hectares are in forages and permanent ranges.

Cultivated lands account for 28% of the agricultural land with 13% arable (3.5 million hectares) and 5% is used for permanent crops (1.5 million hectares).

IMPORTANCE OF MAIZE

Colombian people consume corn as the base of their daily diet. Between 1959 and 1969, Colombia had an annual per capita corn consumption of 49.2 kilograms with a strong tendency to reduce this amount.

According to 1968 estimates, corn ranks first in area among all crops with 818,000 hectares. Estimated yields averaged 1,200 kg/ha.

MAIZE PRODUCTION

During 1968, the Cauca Valley had the highest yield of all regions with 3,390 kg/ha and a production of 171,925 tons. In the Atlantic Zone, 293,450 tons were produced with a mean yield of 1,090 to 1,950 kg/ha.

These are the most appropriate areas for corn production for export due to the excellent quality of the land and the location near major transportation terminals.

Corn is cultivated up to 3,000 meters elevation. Generally, flint corns (mostly white) are used for human consumption in the highlands. In areas of medium elevation, floury maize is used.

Distribution of the Corn Production

According to statistics available, corn utilization in 1965 is listed in Table 1.

When the 1959-65 data are compared, an increase of the industrial use and a decrease in human consumption is evident. Industry consumption during 1966 was 280,000 tons, mostly for animal feed.

TABLE 1. Corn utilization in Colombia.

	%	Tons
Seed	1.66	14,454
By-products	5.01	43,624
Industrial use	9.65	84,027
Animal use	15.46	134,183
Human consumption	[illegible].27	594,465
Total Production	100.00	870,756

THE NATIONAL PROGRAM

The maize and sorghum program is an integral part of the Colombian Institute of Agriculture (ICA), the nation's official organization for research and agricultural development.

The program's object is to develop varieties, hybrids, synthetic varieties, materials of a high nutritive value, and early, high-yielding varieties with good agronomic characteristics.

The maize and sorghum program of Colombia carries out research projects at these termic levels:

1. Turipaná is located on the Atlantic Coast at 50 meters above sea level and 15 kilometers from Montería. It represents the warm climate of Colombia.

2. Palmira is at 1,000 meters above sea level in the Cauca Valley 30 kilometers from Cali. It represents the moderate-warm climate.

3. Tulio Ospina is 1,490 meters above sea level, 10 kilometers from Medellin. Research for the temperate climate is carried out there.

4. Tibaitatá is at 2,600 meters above sea level a few kilometers from Bogotá, Colombia's capital. It represents the cold climate.

Other experiment stations at different termic levels test material from the main centers. At these stations, research on soils, entomology and so forth is also done.

Projects carried out in the main centers are breeding, regional tests, cultural practices and special studies.

Breeding. It includes collection of materials, production of varieties or hybrids, development of basic material with special characteristics, research on production, increase and testing of inbred lines, and evaluation of different breeding methods.

Regional Tests. Its objective is to determine the performance of plant materials in different regions.

Cultural Practices. Effects of population, irrigation, fertilizers and rotation on the performance of improved varieties are investigated. The chemical control of pests and weeds is also studied.

Special Studies. These are related to corn varieties of high industrial and nutritive value. Yield factors and the reaction of inbreds and varieties to foliar, stem and ear diseases are evaluated. Some physiological studies are also carried out.

Other activities of the program include conferences, education, technical consultations, visits to farmers and interchange of genetic material with other regions of the world.

Presently, ICA is planning structural changes in the crop improvement programs, including maize and sorghum. Hopefully, the pilot research centers will be at two or three termic levels. Satellite centers will be in charge of progeny tests and corresponding selections.

There will be demonstration centers where the best treatments selected by the satellite centers will be tested on a commercial or semicommercial scale. Hopefully, the program will be more functional, duplication will be avoided and there will be a saving in time and money.

Seed Distribution

The improved material obtained by the maize and sorghum program is tranferred to three government-authorized seed distributors. These are the Seed Department of the Caja Agraria (an office sponsored by the government), Empresa Agrícola de Occidente and Proacol Ltda. The last two are private.

Through its seed certification program, ICA controls seeds production. For the last few years, improved seeds have been used on about 25% of the corn area.

MAIZE PRODUCTION LIMITATIONS

Generally, improved types of maize have been obtained for the different termic levels in Colombia up to 2,800 meters above sea level. Nevertheless, it is necessary to widen the germ plasm base to provide for a wider range of adaptation instead of a specific one.

Our program could benefit from CIMMYT's collaboration in terms of composite varieties with great genetic diversity. So far, testing of some genetic materials has already been initiated. We hope this cooperation will continue.

We also need to know more about corn physiology to obtain higher yielding varieties for the warm and humid areas and, in general, for all corn growing zones.

One of the most limiting factors in corn production is the lack of technology which stops the advances achieved through seed improvement. ICA is pushing the development of the new technology through its extension division.

ICA is also supporting development plans which include application of the best technology, considering investments, credits, marketing and storage. These plans are in their initial stage and it is hoped they will be successful.

Credit and marketing are factors closely related to production. Sometimes farmers might not understand how to make use of services offered by the organizations. It is also possible that certain limitations of the organizations do not permit them to take all the advantages offered.

In developing countries, another limiting factor is the isolation of rural communities. Poor roads often make transportation of materials and supplies to distribution centers and to farmers difficult.

The Status of Maize in Kenya

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Kenya lies on the east coast of Africa. The equator almost bisects the country. Due to Kenya's position, variations in monthly temperatures are very small, usually less than 5°C. Despite this, there are significant temperature variations due to altitude and seasonal changes.

Most of Kenya lies on the high East African plateau which averages about 1,500 meters elevation although the range in Kenya extends from sea level to 3,500 meters.

Kenya has a land area of about 58 million hectares. About only one-third of this area receives a mean annual rainfall of 635 millimeters or more and has potential for agricultural development. Without any significant mineral wealth, agriculture will be the backbone of the economy for a long time. Slightly more than 60% of Kenya's exports are agricultural in origin and 40% of the gross domestic product is from agriculture and related industries.

IMPORTANCE OF MAIZE

About one million hectares of maize are grown annually in Kenya. This is a large proportion of the arable land area and is the largest area grown to any single crop. The importance of maize arises mainly from its role as the staple food for most of the 12 million people who grow it as a subsistence crop.

Even at the current low national average yield of about 1,600 kg/ha, Kenya produces 1.6 million metric tons annually, worth about US$74 million. This makes maize Kenya's most valuable crop.

Maize, although a staple food in Kenya now, has been in the country for about only 70 years. It has replaced the indigenous sorghums and millets over the past four decades.

TYPES OF MAIZE

The main type of maize grown is the Kenya Flat White. This is a mixture of several local cultivars of white maize which were introduced from South Africa about the beginning of this century. South Africa, in turn, obtained these from the southern United States which got them from Mexico. It is now known that the Kenya Flat White is related to the race Tuxpeño. Other maize types of minor importance are:

Local Yellow. A Caribbean-type flint which also came in via the same route as the flat white.

Cuzco. Large, floury-type kernel found only at altitudes of 2,500 meters above sea level. This was introduced by the missionaries before World War I.

Coast Maize. This is another flint type which still grows in the Kenya Coast and which could have been introduced by the early Portuguese explorers in the 1700's.

MAIZE UTILIZATION

Production has been characterized by considerable fluctuations. More than 90% of the total maize crop is grown by small-scale, subsistence farmers who sell only a small fraction of their product. Less than 10% of the total crop is grown by large-scale, commercial farmers, but most of their crop is sold.

Yields on these large farms do not fluctuate as much as those on subsistence holdings. In a good season, the subsistence farmers can produce a considerable surplus of maize, and in a bad season, they often produce less than their requirement.

It is impossible, therefore, for the relatively small commercial crop to compensate for the fluctuation in the relatively large subsistence crop.

The Subsistence Crop

In most years, much of the total maize production is retained on the farm where it is produced. Methods to prepare maize for consumption are generally simple. This may be because maize is a relatively new crop. Some of the food preparation methods were used with the millets and the sorghums.

In general, most maize is milled as whole grain to produce *posho* maize flour for preparing *ugali*, a thick type of bread cooked in boiling water. Maize is also eaten as boiled corn on the cob. Other preparations include the whole grain cooked with beans and vegetables, and sometimes with meat. *Njenga* is prepared similar to rice from roughly ground grain.

The Commercial Crop

Most maize from large-scale farms and surpluses from subsistence farms is marketed through a national marketing organization—the Maize and Produce Marketing Board. The Board generally markets it to millers, for livestock feed or for export. Amounts utilized in these categories depend on the supply-demand situation and the crop size.

PRODUCTION AND ALLIED PROBLEMS

Statistics for the total maize production in Kenya are usually difficult to obtain and even when the estimates are available, they have a limited reliability.

In good seasons, the Maize and Produce Board generally takes in more than can be consumed within the country. In the past, this has been exported at a very low price. After a good season and a big surplus, maize prices on the commercial market were often reduced drastically. This caused the commercial producers to reduce their acreages the next year. The next bad season yielded insufficient maize and it had to be imported at high prices to feed the population. To avoid this again and to encourage greater production, the price would be increased. The next good season would result in another surplus with the same results as before.

Government Policy on Maize

The government policy has long been to encourage maize production to satisfy the local demand or simply for self-sufficiency. But, self-sufficiency had the original implication of producing enough to feed the human population directly.

The idea of self-sufficiency, however, has now extended to encompass other local maize requirements in addition to human consumption needs.

Recognized Limitations

Some production limitations are listed.

1. In adopting the new policy of stimulating production, it was necessary to look at the present handling and transportation systems, not only to reduce the high overhead costs, but to also cope with the envisaged large production.
2. It was also recognized that there would be a greater need to strengthen the extension services to the farmer and the technical services for storage and quality control of grains.
3. The effectiveness of the distribution of major inputs such as seed, fertilizer and insecticides was recognized as a factor which could seriously limit maize production.
4. Lack of short term credit facilities for farmers is a serious limitation to their productivity. But administering credit can be very difficult in Kenya where there are thousands of farmers who may grow only one or two hectares of maize.
5. A major limiting factor is the high cost of inputs such as nitrogenous fertilizer, farm machinery and fuel.

DEVELOPING THE MAIZE CROP

Although maize has been grown in Kenya for about 70 years, maize breeding or improvement work of any consequence did not start until about 1955. Since then, tremendous strides have been made.

Achievements have been due to the dedication and foresight of the men associated with this crop. Early development of a "package deal" for maize improvement in Kenya set a solid foundation for future developments. The components of the package are discussed.

Developing Varieties

Breeding research to develop suitable varieties for various ecologies is perhaps the most important aspect of crop improvement. Farmers require something that is well adapted to their areas and before they accept it, they want to be sure that is clearly superior to what they normally grow. A good variety can be used effectively in improving husbandry standards. Therefore, breeding research has been geared to produce high-yield-potential varieties.

Agronomic Research

Maize yields are still pathetically low and this is mainly due to poor husbandry and cultural methods. Emphasis on agronomy research to support breeding work is very important.

Seed Supply and Distribution

When high-yield-potential varieties have been developed, seed production must follow. There have been many crop varieties developed without an organized source of high quality seed. A good variety remaining at the station where it was developed renders the research efforts completely useless. The Kenya Seed Company has played an effective role in this requirement.

Table 3 shows the progress that has been made in seed production since 1963.

Extension

To get results from breeding and agronomy research put into practice by farmers, extension workers must do their job extremely well and they must have something they can sell. An example is the outstanding success with hybrid maize from the one-acre method and resulting demonstration plots with everything done correctly.

The need for strengthening the extension effort cannot be overemphasized. Past efforts have paid dividends (Table 4).

Marketing and Utilization

Farmers are interested in the return for what they produce so there must be incentives if production is to expand.

NATIONAL AND COOPERATIVE RESEARCH PROGRAMS

Applied Maize Breeding

In 1955 when Kenya's first plant breeder, M. N. Harrison, started breeding maize at the Kitale Research Station, his starting point was the Kenya Flat White. This variety was later found to be related to Tuxpeño, a lowland race not the right type for Kenya's high altitudes. However, over the years, local farmers had selected and improved it so it was a good as a starting point as any available.

The first release from the Synthetic Program was Kitale Synthetic II in 1961. This synthetic was 7% higher yielding than the best local open pollinated maize, Kitale Station Maize. Lines which were further inbred went into the hybrid program.

The first hybrids were released in 1963 and 1964. These were hybrids 621 and 631, a double cross and a three-way cross. The next ones in these series, 622 and 632, were released in 1965 and are still commercially available.

The conventional hybrid program continued but slipped from the limelight in 1961 when a topcross yield trial indicated that variety-cross hybrids showed even greater promise. Among several accessions obtained in 1959 from Colombian and Mexican germ plasm banks was Ecuador 573. It combined extremely well with Kitale Synthetic II to give a cross (H-611) 40% higher yielding than Kitale Synthetic II. This hybrid was released in 1964.

In general, heterosis has been manifested in several crosses of local material and the exotic material from Central America.

The possibility of exploiting this exotic germ plasm exists. Kenya is ecologically similar to the center of origin so that most introductions are readily adapted.

The choice between the conventional breeding and composite population improvement is clear. The former takes second priority. A comprehensive breeding system developed at Kitale is put to full use in handling these variable and diverse breeding materials.

The essential features of the system are listed.

1. Evaluate local and exotic material to assess their merits for a long-term breeding program.
2. Form two or more composites of the selected material so that each population has good genetic variability and has potential for crossing well with the other population. Use recurrent selection in the populations so that their crosses are improved with each cycle of selection.
3. Release a commercial variety as: (a) the cross of two populations as a variety; (b) single, three-way or double crosses from elite lines; or (c) a synthetic variety derived from the advanced generation of the population cross.

Genetics and Methods of Breeding Study

This program was started in 1964 with USAID funds and personnel. It was the outstanding achievement in the applied program that pointed toward the need for work aimed at further exploiting the good crossing value between the local and the exotic center of origin material.

The program is in its eighth year and is comparing 17 different selection schemes to determine their relative efficiencies under different conditions. The studies include Kitale Synthetic II, Ecuador 573 x Kitale Synthetic II (H-611).

The studies are designed to obtain genetic parameters to allow predicting progress for each method. The predictions are compared against the actual results obtained.

Results are already being used in our applied breeding program and details of the Comprehensive Breeding Systems are considerably modified to suit the requirements of the three programs at Kitale, Embu and Katumani, for late-, medium- and early-maturity maize, respectively.

The improved versions, Ec. 573 and Kit. II, have been used to provide an improved commercial hybrid with much higher yield potential than the original cross.

Expanded Maize Agronomy

The maize agronomy work started in 1963 with the aid of Rockefeller Foundation funds. The achievements and the support that this unit has given to the breeding program are immense. The Kenya farmer still requires a package of simple recommendations to go with his high-yield-potential hybrid seed.

The agronomy program has clearly identified the simple factors which limit maize yields in Kenya. These are, in order of importance, time of planting, variety of maize, plant population, standard of weeding and fertilization.

It has been well established and vividly demonstrated by Allan in his maize diamond demonstration that by adopting simple, inexpensive practices, maize yields could be doubled, trebled or increased fourfold.

The impact of the agronomy research cannot be underestimated. In the Trans-Nzoia District where Kitale is located, maize yields have increased from 2,200 kg/ha in 1963 to 3,300 kg/ha in 1970.

Perhaps the limitation in the other maize growing areas is the lack of specific information from carefully conducted agronomy research. It has been possible to give, with confidence, specific recommendations on maize growing in the Trans-Nzoia district. Recommendations for most maize growing areas have been less specific due to inadequate research information and there was a danger of extrapolating too far.

Cooperative and Regional Programs

Kenya's maize program has benefited much from external help. Perhaps the most noteworthy aspect is the exchange of germ plasm. This started in 1959 when extremely valuable material was obtained from CIMMYT and has continued since. The good use to which the material has been put in the program has benefited not only Kenya, but several maize program is eastern Africa, too. Other countries in the region have benefited from Kenya's program through regional work under the East Africa Agriculture and Forestry Research Organization (EAAFRO).

The Eastern African Maize Variety Trial, organized regionally from Kitale, has been useful for getting the maize programs in the area to cooperate for mutual gain. The International Maize Adaptation Nurseries (IMAN), recently organized by CIMMYT, should prove very useful.

Developing countries with limited resources to support sustained research programs find it extremely difficult to finance exchange visits for their scientists. Organizing conferences or meetings is usually difficult, yet it is these gatherings that prove a useful forum for exchanging ideas and technical knowledge. CIMMYT has organized conferences and visits, and continued assistance will always be appreciated by recipients.

CIMMYT has had long experience with maize research and has a wealth of information which could benefit the younger programs of the world. In the near areas of research, such as breeding for improved protein quality and other specific characteristics, CIMMYT is likely to provide leadership from which the other programs could get technical advice.

Kenya's program for high-lysine maize has made progress, but without adequate laboratory facilities and competent technicians, progress will be slow unless something further is done.

CONCLUDING REMARKS

The future of maize in Kenya's agriculture will, no doubt, be dictated by government policy. The government has adopted a long-term policy to encourage maize production. The vigor with which this policy is pursued will determine whether maize continues to play a prominent role in Kenya's agriculture.

This forward-looking policy has been adopted as a result of the realization and the trust that marketable surpluses will continue. It is recognized that efficiency in production must be encouraged by appropriate measures. Steps must be taken to cut down storage, handling and transportation costs. Therefore, there is no room for complacency.

Maize workers in Kenya have recognized that to produce a positive impact with the development and the improvement of a crop such as maize, research alone is not enough. Maize breeding and agronomy research capable of providing a complete package of recommendations to farmers has been strongly supported by the extension service of the Ministry of Agriculture and by the Kenya Seed Company. This seed company has multiplied the improved material and distributed it to areas where it was required.

However, the research component has a much more specific role than just helping service the different parts of the crop improvement machinery. Maize research in Kenya has developed for about 15 years and will continue to expand in depth and scope.

The mayor objectives remain They are breeding and agronomic research to meet our varied ecological and other environmental requirements in the late-maturity maize program, medium-maturity maize program and the early-maturity maize program.

The Role of National and Cooperative Research Programs

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IMPORTANCE, TYPES AND USES OF CORN

South of the Sahara and north of the Zambesi, it is important to distinguish between the East African highlands and the West African lowlands when describing the current status and future prospects of maize.

In East Africa, most maize is grown between 1,000 and 2,000 meters elevation in the highlands associated with the great Rift Valley fault from Ethiopia to Malawi and Zambia. Potential yields are high (more than 12,000 kg/ha have been achieved experimentally several times) and maize is the staple food crop for more than half the region.

Mr. Ogada gave some details on recent developments in Kenya, papers of recent regional cereals conferences are available and the history of maize improvement has recently been reviewed.

Most of West Africa is below 500 meters altitude, yield levels are presently low and maize is not the main food crop. Though it may be possible to develop maize of wider adaptation, the present East African highland type will not grow well in the lowlands of West Africa, nor will West African lowland maize give good results in the East African highlands.

This is partly due to different diseases species (*Helminthosporium turcicum* and *Puccinia sorghi* in East Africa, *H. maidis* and *P. polysora* in West Africa). But, the main factor is probably temperature and this would merit study.

Mons. Le Conte discussed IRAT activities in French-speaking countries of West Africa. This paper therefore concentrates on English-speaking countries and International Institute of Tropical Agriculture (IITA) activities. Recent regional conference papers are available.

From the Sahara in the north to the Congo rainfall forest, West Africa readily divides into regular ecological zones.

1. The Sahal and Sudan Savannah zones have little rain and high temperatures. The little maize grown is a garden vegetable crop.
2. The main food crops of the Guinea Savannah are sorghum and millet with rice important locally. Animal protein and grain legumes are generally available. There is little problem of nutritional balance but food is short in poor rainfall years.

Maize is usually grown near the houses and much is eaten fresh as roasting and boiling ears. If fertilizer is applied, the maize yield level is about 50% higher than for sorghum and higher than in the Forest Zone where maize is currently more important.

The greatest potential for maize in West Africa is probably in the Guinea Savannah. There is only one rainfall season a year. Caribbean Flint is grown. It is yellow and mixed colors.

3. The main food supply of the Forest Zone is root and tuber crops with rice locally important. West Africa is the main center of origin of yams though in many areas cassava is more important. Tsetse fly restricts livestock production.

The quantity of food is seldom deficient but protein malnutrition is widespread and serious. Lysine and tryptophan are the main needs in the critical postweaning period to prevent adverse effects on child development. Adults also need more of the sulphur amino acids—cystine and methionine.

In western Nigeria, 48% of total carbohydrates consumed come from root and tuber crops compared to 18% from maize. This is probably typical. There are two rainfall seasons a year. Two crops are usually grown and white, soft-endosperm types are traditionally preferred. Yield levels are pathetically low.

Throughout West Africa, the main development of maize as a cash crop is just north of the Forest boundary. Diseases, pests and storage problems are serious limitations in the rain forest. Tree crops—cocoa, rubber, kola nuts and coconuts—are more remunerative and supply cash to purchase food. Poultry production has been encouraged to help supply protein. In some countries, up to 10% of the maize production is used for poultry production.

Nigeria has the greatest maize area—1.2 million hectares—but also the biggest population—50 million. Maize is relatively much more important in Dahomey with 422,000 hectares of maize for a population of only 2.5 million.

LIMITATIONS TO MAIZE PRODUCTION

More than half the maize is grown mixed with other crops and yields are difficult to estimate accurately for small patches. Estimates generally range from 500 to 1,200 kg/ha. The equilibrium has been stable over many years. Poor soil, no purchased inputs, varieties developed for survival and resultant low yields are partially justified because they are obtained with minimum effort.

What is being done to overcome these limitations will become apparent in the following description of national programs and the new IITA activity.

NATIONAL PROGRAMS

Considerable work for about 20 years has been done in maize breeding agronomy in Dahomey, Nigeria, Ghana, the Ivory Coast and Senegal. *Puccinia polysora,* when it arrived in the early 1950's, was a real killer. *Helminthosporium maidis* is equally important.

Emphasis has been on breeding for resistance to these two diseases. Standard backcrossing techniques incorporated resistance into local maize valued for its kernel type and adaptation.

But local maize has a tall, thin, weak stalk that lodges badly when plant populations are increased and when fertilizers are applied. Disease-resistant local maize has been successfully developed an drecently, high-lysine local maize, but this is still poor maize.

Agronomy results are often inconclusive because the varieties used show little response. Top varieties and recommended cultural practices produce up to 4,000 kg/ha in the Forest and 6,000 kg/ha in the Guinea Savannah —four to six times national average yields but still low.

There is a big gap between knowledge available and knowledge applied. Farmers' and national average yields are little affected and the gap must be narrowed to justify further research.

IITA PROGRAM

The IITA maize program started with the first work of the Institute in 1970. Using a multidiscipline, project-orientated approach, five main areas of activity are developing.

Environmental Factors

What factors limit maize yields in the Forest and can good yields be developed to justify a major program? There is speculation about limited light due to frequent overcast conditions. Diurnal temperature variations are small and with high night temperatures we may be loosing by respiration many carbohydrates gained by photosynthesis during the day.

The physical structure of the soil is often so poor that maize suffers drought stress and wilting within a week of a good rain and a thoroughly wet soil profile. Cooperative work of soil physics, physiology and agroclimatology is planned to study the interactions of these factors to attempt a breakthrough to much greater yield levels for the lowland, humid tropics.

Cultural Factors

As a regional program, we do not aim to compete with national programs in NPK trials. We aim to help and support national programs by making such research more efficient.

Phosphate fixation is a real problem. At IITA, less than 15% of the phosphate applied is available to the plant. Ways to overcome this are being investigated.

New forms of long-acting nitrogen are being tried to overcome leaching losses.

In regional trials, we hope to relate fertilizer crop response to leaf analysis and soil analysis. With such calibration for ecological zones and main soil types, predictions of optimum economical fertilizer levels can be made and it will not be necessary for all countries to have trials in all districts.

Breeding Program

The three main objectives are: (a) a plant type that will respond to cultural factors, especially high plant populations and increased fertilizer, to give really high yields; (b) better protein quality, using opaque-2; and (c) wide adaptation.

Recurrent selection, by the yield trial evaluation of S_1 lines as such, is being practiced in two wide-based composites. The three-generation cycle can be completed in one year using irrigation for a third generation in the dry season. One compite is now in the second generation of its second cycle.

Plant Protection

Diseases and pests are very serious with no frost or drought to reduce populations.

Stalk rot resistance is being added to blight and rust resistance, concentrating on horizontal resistance in both cases. Stalk borers are the main insect problem and breeding programs for resistance and biological control will be started.

Training/Communications

Well-motivated scientists with practical training will be a main product of IITA and its biggest contribution to strengthen national programs. Stimulation will be given to those responsible for seed production, extension and marketing-utilization for coordinated, balanced development.

Cooperative regional activities in regional trials, exchange of germ plasm, training, workshop conferences, etc., are being promoted and strengthened. In cooperation with CIMMYT, a national maize program is being launched in the Congo for production-oriented research and training.

RELATIONSHIP WITH CIMMYT

IITA is a regional agent for CIMMYT in West Africa. Requests for seed, training and so forth will be routed through IITTA. Requests that IITA cannot satisfy will be passed on to CIMMYT.

Close cooperation is needed between the four main international maize improvement programs for the lowland humid tropics: the low-altitude Mexican program of CIMMYT; CIAT; the Rockefeller Asian Program at Bangkok and ITTA. CIMMYT is best located to provide germ plasm. IITA is probably best located to study physiological and soil physical aspects of improving yields in the tropics.

There is an obvious need to avoid overlaps and cooperate to mutual advantage. We look to CIMMYT to provide the lead.

Finally, I make a personal plea to CIMMYT to increase its efforts in two fields where it has already accomplished much.

1. Collections of germ plasm have been well described and made available. Merging selected material into breeding composites for major ecological zones has started.

The next stage is to greatly improve these composites while still maintaining variability, especially for yield and plant type. ITTA and other regional and national organizations can help in this and promote wide adaptation.

2. CIMMYT has stressed development of packages of variety and cultural practices, but more could be done to integrate agronomy and plant protection research to maize breeding, especially to quickly develop higher yields for subsistence farmers.

The Puebla Project is a great achievement and has also indicated the need for greater effort on how to get results of research applied by those people who need it most.

Maize Improvement on a World Basis through CIMMYT

A. H. Shehata
Department of Agriculture
United Arab Republic

When attempts are made to achieve higher yielding maize genotypes, particularly for developing nations, it seems that new breeding methodologies must be sought. Full use of the best available sources of germ plasms should be made.

In that connection, the following points have emerged from maize research around the world.

1. Additive effects of genes seem to play a major part in heterosis expression in variety crosses.
2. The potential yield of a particular genotype derived from a population is in direct proportion to the performance of the source material. Thus, the choice of material to be used by the breeder becomes most important.
3. The best sources of maize germ plasm have a history of multiple introgression.
4. Genetic diversity is important in achieving heterotic response in crosses.
5. There is more to learn about heterosis, particularly the biological aspect.

Generally, maize breeding objectives include:

1. Higher yielding genotypes are always the basic goal upon which other objectives are superimposed.
2. Better plant types to facilitate manipulation of prevalent environmental conditions at a given locality of maize production.
3. Identification and utilization of photoperiodic-neutral genes where a wider range of adaptation is desirable.
4. Resistance to prevalent diseases.

The following scheme is suggested as a worldwide breeding effort for which CIMMYT is most suited. It is not meant for individual country programs. It does require, however, full collaboration of all countries involved.

STEP 1

Based on local data, select the best-adapted, highest-yielding, genetically broad-based population from each country or agroclimatic zone. It would be preferable if such populations had desirable plant type, too.

STEP 2

Diallel crosses are then made among every 10 parent varieties. In this process, both genetic and geographic divergence should be considered. Differences in flowering periods could be overcome by having two or three planting dates to facilitate a reasonable amount of hand pollination to obtain enough F_1 seed. F_1's are then advanced to F_2's by bulk sibmating F_1 plants. More than one diallel set could be constituted, handling two or three at a time in terms of making crosses, advancing generations and testing would be enough.

STEP 3

Yield and adaptation trials are then conducted worldwide. More than one location could be used in countries where there are wide differences in agroclimatic conditions (Mexico, India). Each of these trials will include parent varieties (10), their F_1's (45) and their F_2's (45).

STEP 4

Data collection should be comprehensive: flowering date; ear length; plant height; ear diameter; ear height; kernel rows; prolificacy; weight of grain (1,000); plant aspect; grain color and type; disease damage; grain/stover ratio; insect damage; shelling percentage; lodging; and grain yield.

STEP 5

Based on the wide test, the following points should be considered:

1. High-yielding, specific combinations for each locality are identified. Country programs could then initiate utilization of such popula-

tions, either for direct commercial use or in population improvement schemes to improve yield, plant type and other agronomic attributes, or to isolate inbred lines for the hybrid program at an increased performance level.

2. Combinations where little or no decline from F_1 to F_2 are observed could be used to build up high-yielding composite populations for individual countries.

3. The most stable populations would indicate phenotypic stability, photoperiodic neutrality, or both. Such populations should be exploited where breeding for a wider range of adaptation is desirable. This way, a "world composite" is sought through actual testing of combining ability.

4. The representative variety from each country could be used by individual country programs as a basis on which favorable additive genes are accumulated. This is done by simply identifying crosses (in which the country variety is common parent) where inbreeding depression in F_2 is lowest. These F_2's are then composited. Three to four generations of synthesis followed by mild selection should result in significant gains over the original local variety. Such new varieties could go again in another cycle of variety crossing as described above.

5. Data on prevalent diseases, and general and specific combining ability for resistance should be invaluable for local programs.

This breeding scheme has many advantages. It enables us to capitalize on the breeding efforts in collaborating countries. All countries will benefit from such efforts. Therefore, we are ahead of just exchanging germ plasm sources.

Each cooperating program will have some elite combinations identified. Further improvement through selection or transfer of desirable attributes is then taken up by individual programs.

Such a scheme facilitates the identification of photoperiodically neutral populations where a "world composite" is sought. Selecting germ plasm to meet wide adaptive zones becomes more feasible. Above all, it will provide us with basic information about the genetics of photoperiodic sensitivity.

In countries where yield levels have been levelling off, this scheme should help break that ceiling. Many of the new combinations of genes, as indicated by experience, would act additively.

The amount of basic information obtained from such a program is unlimited, both from the genetic viewpoint and to develop reliable parameters for genotype-environment interactions for all attributes evaluated. This will put the breeder on solid grounds where phenotypic stability is sought.

This program could serve as a beginning to tap the unlimited genetic resources found and maintained in the germ plasm bank. These resources, it seems, have not yet been utilized for practical breeding purposes.

Panel Discussions

Reviewing present research and training activities underway in the core program was done in the field through visits to two of CIMMYT's experiment stations and during panel discussions.

CIMMYT's maize program core staff offered a series of presentations on aspects of the core program like breeding, plant protection, physiology-agronomy, training, and their philosophy and *modus operandi* within the framework of CIMMYT's international activities and projections.

It would be a task beyond the purpose of this publication to include all the enthusiastic and profitable discussions held after each presentation plus the complete presentations by the core program staff.

Forced to use some editorial prerrogatives for brevity, what follows are only the highlights of the presentations.

CIMMYT's Protein Quality Program

S. K. Vasal
Breeder
CIMMYT

Much of the world's human population depends on maize as a principal food source for meeting its protein requirements.

It is well known that the maize grain is deficient in protein quantity and quality. The average protein content in maize varies considerably but most materials fall in the range of 9% to 10%. There are big-seeded, soft-endosperm floury types in the Andean regions which may contain only 4% to 5% protein in the endosperm.

The maize endosperm protein lacks essential amino acids (lysine and tryptophan). The deficiency of these two amino acids when maize is a staple food results in Kwashinkar syndrome and reduced body growth.

The findings that protein quality of maize endosperm can be improved genetically through use of opaque-2 and floury-2 mutants is significant in the development of quality protein material. Development of such materials will help overcome malnutrition problems and will provide better quality feed for the animal industry. The superiority of opaque-2 materials' biological value has been well demonstrated on humans, rats, swine and poultry.

I will now briefly describe our program, the problems involved in breeding opaque-2 corn and possible ways of overcoming these problems.

In the opaque-2 conversion program, a wide range of maize material is being converted to both opaque-2 and floury-2. These populations represent low, intermediate and high altitudes, and include different grain types and colors. All these materials are in different stages of a backcrossing program. Also, some opaque-2 and floury-2—brachytic-2 materials are being developed.

In addition to converting materials to opaque-2 and floury-2, we have developed several composites and these have undergone reasonably good mixing. Composite "I" is for high altitudes and "J" is for intermediate elevations. Other composites are for lowland, tropical areas, but which can be grown reasonably well at intermediate elevations, also. The seed of these composites is available upon request.

Some of these composites are being subjected to population improvement schemes for high protein of better quality, coupled with yield and other desirable agronomic characters. Even in the converted materials, there is a tremendous variation of protein and tryptophan content. This is clear from the data that we have collected from three composites.

It is well known that there are serious problems involved with opaque-2 versions of maize varieties. These have an important bearing on the acceptance of these corn types by maize growers around the world. The problems may vary in importance and magnitude. The main problems are low grain yields, acceptability of opaque-2 kernels, slow-drying opaque-2 kernels and possible contamination of normal maize types.

Low Grain Yield

One of the most serious problems is the low grain yield. In general, converted materials are 10% to 12% lower yielding than their normal counterparts. This decline in yield is attributed to low kernel density and loose packing of starch granules in the endosperm.

This problem can be overcome by: (1) extensive screening of better genetic materials in which opaque-2 and their normal counterpart kernels weigh more or less the same; (2) practicing selection for better kernel test-weight during backcrossing and segregating generations; and (3) selecting for vitreous kernels from homozygous opaque-2 populations segregating for modified phenotype kernels.

It should be possible to achieve 100-grain weight in opaques comparable to their normal counterparts. Also, it should be possible to develop opaque-2 varieties or hybrids that can compete economically with any commercial variety.

Kernel Acceptability

The second problem pertains to the acceptability of the opaque-2 kernels which look dull, lustreless and chalk-like. This is a major hurdle in the acceptance of these corn types, especially in areas where farmers prefer growing hard flint types which have a clean, shiny and lustering appearance.

However, in certain regions of the Andean Zone where farmers are already growing floury types, the opaque-2 converted materials should not be an acceptance problem.

The floury phenotype of the opaque-2 converted materials can be improved by capitalizing on modified genes which may be influencing the lysine concentration and kernel appearance of opaque-2 kernels. Little information is available on this aspect of the problem. We have done some preliminary work but more detailed studies are needed.

During the conversion program and seed increases of opaque-2 materials, we have observed considerable phenotypic variability of varying fractions of hard endosperm. It suggests that this variability can be exploited to circumvent some of the problems that seem fundamental for acceptance.

Our objectives in undertaking this type of work were to: (1) select for vitreous kernels for improving kernel appearance and kernel test-weight; (2) determine the relationship between kernel appearance and lysine content; (3) work out the inheritance of modifying gene complex; and (4) develop hard-endosperm, high-quality protein materials with good yielding ability and acceptable kernel appearance.

I will attempt to briefly summarize conclusions that can be drawn from our work.

1. There is considerable variability for modified opaque-2 phenotype and this can be exploited through proper selection procedures.

2. Genetic materials differ considerably in their ability to throw opaque-2 modifiers. Some materials throw modified phenotype opaque-2 kernels with a much higher frequency than others while some materials throw few or none. Some materials which are promising and deserve special mention are Thai opaque-2 Composite, $PD(MS)_0$-Gr. Amar., Venezuela I opaque-2 x Ver. 181-Ant. Gr. T, and $PD(M)_0$ in crosses with Cuba 11J and Eto Amarillo.

3. Regular hard endosperm patterns starting from the crown and going to the base is more common though irregular patterns do occur occasionally.

4. When divergent selection is practiced for different types of kernel categories originating from the same segregating ear, some families show an increase in protein percentage but there is a corresponding decline in tryptophan content. This is not very important because even though we get a little decline in the percentage tryptophan in protein, there is almost no decrease because of an increase in test weight. However, in other families, the protein content shows an increase but the percentage tryptophan in protein remains unaffected.

5. Test-weight, in general, goes up proportionally with increasing fractions of hard endosperm. However, some families do not follow this trend.

6. Our preliminary results suggest that there are at least two sets of modifiers. The first type of modifier improves kernel appearance and texture without affecting protein quality or tryptophan while the second set of modifiers improve the appearance of kernel but lower tryptophan content.

7. Through selection for the right types of modifiers, it is possible to have better looking opaque-2 and increased test weight without sacrificing tryptophan content.

Trying to accumulate more information on inheritance of opaque-2 modifiers, we have selected 10 lines which breed reasonably true and these will be used to develop a diallel set to generate the required information.

Also, we are carrying out a recurrent selection program for improving the phenotype of some promising opaque-2 populations and hopefully will have something available for distribution after this crop harvest. These materials can be directly used as populations. The selection program is underway in the following populations: Composite K; CIMMYT opaque-2 Composite; Venezuela I opaque-2 x Ver. 181-Ant. Gpo. 2; and Thai opaque-2 Composite.

Slow-Drying Kernels

The third problem is that opaque-2 kernels tend to dry slower than normal after reaching physiological maturity. Since the opaque kernels retain moisture longer, they are susceptible to more diseases and insects.

This problem can also be tackled by screening materials where Opaque-2 kernels differ no more than their normal counterparts in rate of drying after physiological maturity. Selection within populations can be practiced if enough variability is present.

Contaminating Normal Maize Types

Opaque-2 corn is likely to be contaminated by normal maize types. This will be a greater problem where farmers have very small holdings and they grow different corn types.

This problem can be solved genetically by introducing a superdominant gametophytic factor into some promising maize types. We are doing this, using Jalisco 188 and Michoacan 15 as source material. However, this will not work when the GaS factor is alredy present in the materials grown in a particular region.

Apart from opaque-2 and floury-2 mutants, there is a need to locate other mutants which may be affecting the quality of maize endosperm protein. Floury-10 mutant seems to combine advantages of both opaque-2 and floury-2 mutants. It increases lysine, tryptophan and methionine content. We have also identified some sources of new, improved protein quality and these are being studied.

Gene interactions between different endospermic mutants may be helpful for specific uses of maize. For instance, in countries like México where maize is used for making tortillas, combinations of opaque-2—waxy and floury-2—waxy, can increase lysine, digestibility and tortilla-making quality of the grain.

The waxy gene will contribute to increased coherence of starch granules in making the dough and this consists mainly of amylopectin which is relatively more digestible. We have combinations of opaque-2 and floury-2 with waxy in Celaya Composite II and presumably these may have some value in countries where glutinous or waxy corn is consumed.

In 1970 we started the International Opaque-2 Maize Trial (IOMT). The preliminary indications are that some materials, in general, possess fairly good yield potential and can perform well over a wide range of ecological conditions.

CIMMYT's protein quality program has made available materials of various kinds to many national and regional programs. We hope to find the answers to many pressing questions regarding the performance of the opaque-2 and floury-2 materials and some of the problems which limit their more extensive utilization in areas where protein malnutrition continued to be a serious problem.

Cooperation from many of our fellow breeders in this field is fully appreciated. We encourage all those wishing to do so to join the team for the benefit of all people concerned about protein malnutrition, especially those where maize constitutes a staple food in the diet.

Maize Training

Alejandro Violic
Training Officer
CIMMYT

Until a few decades ago, it was easy for most countries to increase their food production by expanding the area of land cropped. Since their production ceiling was high, the population boom did not affect their agricultural economy.

But in recent years, only those countries which had made great efforts in agricultural research were able to increase their food supply to equal or exceed demand since they developed varieties and techniques that enabled them to substantially increase production on the same or less area.

We are aware that research is not a matter of having extraordinarily good facilities and budget. What matters is the presence of technically well-prepared personnel with a clear idea of the problems to be solved and how to solve them in the easiest, fastest and most economical way.

No crop is perfect and this includes corn. It is amenable to improvement by breeding and better cultural practices. In many nations, the yield of this crop has been static and will remain static unless something is done to solve technical problems which constitute prerequisites to greater and more profitable production. But, technical problems are solved by good technicians who are very badly needed to improve agricultural production in many countries. Most countries can specialize qualified agronomists and breeders, but usually at a high cost and long time, and most importantly, without a new view of the problems or without considering new approaches to solve them.

Here is where CIMMYT can collaborate with the countries through its maize training program. Some of you now attending this workshop as leaders in corn research in your countries started as trainees of the Rockefeller Foundation program or CIMMYT in México. You know that the knowledge gained through exchange of people is vital to a country's economy and social development which can proceed only as fast and as far as the capabilities of the leaders permit.

The main objective of CIMMYT's training program is to give selected individuals the technical and organizational skills to rapidly increase production.

The Rockefeller Foundation and CIMMYT have been training agricultural technicians for more than 25 years in Mexico and have considered it as one of the most important aspects of their programs. Only since 1971 has training been organized to handle large groups of trainees. In the past, training has been a rather simple procedure. One or two young scientists were assigned as assistants to a CIMMYT breeder, pathologist or entomologist for a few weeks a year, or more. The results were good, but only a few technicians were trained each year.

This year the number of in-service trainees in maize is high (16) and we are sure that this number will be higher in the coming year.

The primary objective of the training program is to develop maize technicians with a knowledge of principles of varietal development and maize production. The ability to develop superior varieties is important, but so is knowledge of production practices and ability to put them to work on the farm. The ability to diagnose production problems and recommend remedies to at least partially nullify limiting factors is important, also.

The essential elements for successfully training international visitors should include factors of human relationship, the participants perception of the training to be achieved, available facilities in the right place, competent instructors, wise use of training materials, aids and resources, and a close relationship between the training, the needs of the participant and his opportunity to use the training.

It is hoped that in-service training will provide some insight to production problems and will stimulate the imagination and desires of the trainees for further personal improvement.

Our present maize training program is only two-months-old. We intended to connect trainees with all the maize projects so they could get acquainted with the know-how and the purpose of the research carried out at CIMMYT. Trainees have initiated production trials on performance of new opaque-2 populations, effects of fertilizers, effects of between row spacing, effects of different levels of populations, etc.

Weekly seminars with all staff members have been initiated. Next month we shall start a series of conferences in which the staff members shall cover the following general topics: environmental factors associated with corn growing; botany and evaluation of the corn plant; soil fertility; breeding and the methodology of corn improvement of CIMMYT; plant protection, including pathogens and pests; production practices; how to economize corn growing; the Puebla Project; experiment station operation; grain quality; and communications.

The academic background of trainees is variable. The above topics will help provide a uniform background. During and after these lectures, the trainees will continue assisting different projects.

At the end of the training period, each trainee will be requested to prepare a report of his activities, indicating what he has gained through his experience and how he hopes to apply his knowledge and experience to maize production problems in his country.

I will appreciate it very much if you could suggest new ideas about training. Many of you have potential trainees under your programs. It will be interesting to hear your opinions on this subject.

A New Look at the Assumptions Made in Conducting Research on Crop Production Practices

Antonio Turrent
Soil Scientist
CIMMYT

In 1967 a program was begun in the state of Puebla, Mexico, to learn more about how to rapidly increase maize yields in a rainfed area with moderate agronomic risks among small, subsistence farmers. The basic strategy of this program was to understand the conditions limiting farmers use of improved technology and to find means of eliminating such restrictions.

A major hypothesis made in initiating the Puebla Project was that the quality of agronomic knowledge was an important factor limiting the rate of adoption of new technology by farmers. Quality of agronomic knowledge meant precision in production practice recommendations made to farmers, taking into account the scarcity of resources.

It was expected that highly precise agronomic information would be particularly important in the project area. The area was characterized by moderate-to-high risk in the production-marketing process and by limited resources in terms of education, land, labor and capital.

To achieve an acceptable level of precision in the recommendations to farmers on how to increase their maize yields and net income, a research component was included in the Puebla Project.

It was assumed from the beginning that research on crop production practices, including varietal evaluation, would need to be conducted on farmers' fields in the project area. This assumption was based on results by many investigators that demonstrate clearly that under rainfed conditions where soil moisture limits crop yields, crop response to fertilization and other agronomic practices varies greatly among locations.

To attain a reasonable level of precision in agronomic knowledge, it was obviously necessary to identify the important producing conditions in the project area and locate the field trials so as to adequately sample the different conditions.

Since 1967, two or three agronomists have conducted trials on farmers' fields in the Puebla area and have used the experimental results to determine production practice recommendations. About 40 trials have been conducted each year and information has been collected on plant density, planting date, time to apply nitrogen, tillage, varietal adaptation and plant response to nitrogen, phosphorus, potassium, chicken manure and minor elements.

Recommendations made to farmers have become progressively more precise. They have varied from one general recommendation for the entire area in 1968 to 15 specific recommendations in 1971. Recommendations take into account differences in soil morphology, native levels of available soil phosphorus, elevation above sea level and planting date.

At the start of research in Puebla in 1967, several assumptions were made—explicity or implicity—about the production factors, characteristics of farmers and the type of information being sought. During five years of field experimentation in the project area, it has become very evident that certain of the original assumptions are not realistic for the agronomic, social and economic conditions in Puebla.

Since it is believed that the experience obtained in generating precise recommendations for farmers on crop production practices in the Puebla area is relevant to much of the rainfed agriculture of the world, a few of these assumptions will be discussed briefly.

1. There is one package of Production practices that is optimal for a given farmer.

It has generally been assumed that for a given crop on a given piece of land there is one combination of the controlled factors of production (variety, fertilizers, planting date, plant density, etc.) that maximizes profit. Moreover, it has been assumed that farmers are basically interested in maximizing profit and the purpose of research is to determine what optimal combination of factors will achieve this.

In an area of moderate-to-high risk, however, farmers have production objectives other than maximizing profit. Many farmers are much more interested in minimizing risk. Other simply do not have sufficient capital or do not care to borrow enough money to permit them to use the package of practices that will maximize gain.

Since farmer objectives are varied, research should determine what these objectives are and then generate the information needed in defining a set of alternative packages corresponding to the interests of the farmers. Farmers are rational and if presented with a set of alternatives, they will chose the one that maximizes their satisfactions.

Also, in judging a set of alternatives, farmers are influenced greatly by their expectations as to income and risk.

2. Agronomic knowledge is perfect and farmers have unlimited capital.

These are assumptions made in the conventional economic interpretation of agronomic information. For example, optimal levels of nitrogen and phosphorus are estimated from a response function by setting the partial derivatives of yield with respect to nitrogen and phosphorus equal to the respective input cost/product price ratios and solving simultaneously.

In reality, neither of the assumptions are tenable. Under conditions of moderate to high agronomic risks, information is far from perfect, even after several years of research.

The best that can be expected at present is that the investigator can determine for the farmer what the probabilities of different outcomes are from using alternative combinations of practices.

Likewise, few subsistence farmers have unlimited capital. Most of them have little or no capital and must borrow money in order to use expensive inputs like fertilizers.

The fact that information is imperfect and capital is limited leads to recommended levels of inputs below the optimal levels as conventionally determined.

3. Near the optimum combination, the effects of the controlled factors of production are additive.

Stated another way, near the optimum combination, interactions among the controlled production factors are insignificant and can be disregarded. This has led to the practice of studying production factors individually, two at a time, or at most, three at a time. Other production factors are held constant at assumed optimal levels.

This assumption has contributed to the organization of research on production practices according to disciplines with studies on varietal evaluation being carried out by one person, fertilization studies by a second, weed control experiments by a third, etc.

The assumption is implicit in most research on production practices that has been conducted in the past. This research has contributed to very rapid progress in agriculture production.

The suggestion here is not that research based on this assumption has not been valuable. Rather it is suggested that for conditions of moderate-to-high agronomic risk, a more useful approach is to proceed on the premise that the effects of many of the controlled factors of production are not additive.

In Puebla, the assumption that the effects of production factors are not additive has led to the search for more efficient treatment designs that permit the investigator to measure the simple effects and interactions of a large number of production variables in the same experiment. The investigation of all of the controlled factors of production is integrated into one program which is carried out by a single research team.

There are many difficulties yet to be resolved in studing many factors simultaneously, but it is clearly evident that this approach can be very helpful in trying to achieve greater precision in production practice recommendations.

Maize Breeding

Elmer C. Johnson
Breeder
CIMMYT

CIMMYT has been assigned a major responsibility for maize improvement in the tropical and subtropical regions of the world.

You are key people in whatever CIMMYT can do in breeding and other maize improvement efforts. We expect you to help us decide on at least some of the jobs we undertake.

The presentations on national and regional programs give us a general understanding of the situation and some of the apparent problems.

Many of you have offered valuable suggestions on what CIMMYT could do to help the many different programs. It is obvious that the facilities and capacities of CIMMYT have limitations and CIMMYT can not do everything. You and many other will be involved in work that CIMMYT does.

Hoping to stimulate thinking and discussion, I would like to talk about maize breeding. First, there are many scientists working at many institutions around the world making comparisons of breeding procedures. We do not believe that CIMMYT should compete in this or devote major effort to studies of breeding methodology.

One of the objectives of CIMMYT is the development of superior varieties of maize. It is also stated that use of such improved materials is to be encouraged to the greatest extent possible.

Therefore, emphasis is on development of materials, varieties, composites, synthetics, germ plasm pools, etc. We believe CIMMYT can contribute more in terms of materials.

We do not propose to do all breeding work here at CIMMYT's headquarters or experiment stations. We hope to be able to work cooperatively with others around the world as members of a team. Also, we hope that the results we expect to emerge will come from national and regional programs.

Secondly, we hope that all the information and materials we have will continue to be available to *anyone* and to *everyone* who wishes to use them.

I think it would be pointless to try to cover everything we are doing here in breeding, but I would like to mention a few main points.

1. Modify plant architecture. Narrow versus broad leaves; erect versus horizontal, etc. We attempt to settle some arguments about what is an ideal plant type.
2. Reduce plant height.
3. Develop disease-resistant materials.
4. Develop insect-tolerant materials.
5. A major project on protein quality.
6. Develop wide-adapted materials.

There have been some suggestions made on a coordination function for CIMMYT. Maybe CIMMYT could serve as a catalyst and expediter. Work done by CIAT in the Andean Zone, IITA in West Africa, IACP in Southeast Asia, in the Middle East, southern South America, etc., could be coordinated by CIMMYT in an overall effort to increase maize production.

Finally, I would like to propose:

1. Establishment of a uniform variety test by regions.
2. Some sort of disease nurseries.
3. Try to have annual regional meetings.
4. That IMAN or some subsequent version be continued.
5. Limited inter-regional trials be established including the best materials of each region.
6. Make provisions for some systematic evaluation of materials and exchange of information. If a new disease shows up as a problem, how to advise others on a rational basis.

7. That national and regional programs conduct supplementary studies to take advantage of new materials, plant densities, fertilizers, etc.

8. That we all make an effort to keep communications open to the fullest extent possible.

CIMMYT will always be ready to feed materials into national and regional programs upon request. These materials include shorter plant types, sources of resistance to stem borers and ear worms, sources of resistance to stem and ear rots, high yield potential and wide adaptation.

Agronomy - Physiology

Peter R. Goldsworthy
A. F. E. Palmer
Physiologists
CIMMYT

In the papers presented at this workshop, we have seen striking examples of differences in grain yield of maize, for example, the difference between yields in Brazil and the Philippines. Also, very high yields have been obtained in the Middle East and East Africa. Reports from other countries indicated very low national average yields.

Many speakers have described how different *plant* characters are being used as criteria for selection for high *crop* yield. However, we still lack much of the information necessary to achieve large increases in yield of tropical corn.

Using evidence available, we will discuss what our targets might be and how the agronomist and physiologist may help the plant breeder achieve yield targets.

The Crop as a Physiological System

Light, water, carbon dioxide and minerals are utilized by the crop during photosynthesis to produce organic matter. To improve yields, we need to understand better the process of photosynthesis and how we can manipulate the process to serve our needs to the greatest advantage.

During the last three decades, much has been learned about the photosynthetic system. Great advances have been made in our knowledge of the biological, physical and biochemical aspects of the process. In recent years there has been emphasis on the integration of this knowledge in studies on the physiology of communities of plants grown as crops in the field.

Present and Potential Yields

As examples of what has been achieved, we have yields greater than 12,000 kg/ha for maize in the US Corn Belt, for wheat in the state of Washington, U.S.A., and for improved rice varieties in the Philippines.

From measurements of radiation and basic studies in photosynthesis, it is theoretically possible to produce a crop growth rate of 770 kg/ha/day. Virtually all the dry matter produced in the plant during the grain-filling period is transferred to the grain in the most efficient cereal varieties.

So, making the assumption that the corn plant fills grain for about 35 days, we have the opportunity to produce about 27,000 kg/ha of grain. This is considerably more than the best yields so far obtained.

How Do We Approach These Potential Yields?

To do this we need to change the production factory—the community corn plants. This can be done in two ways:

1. Change the size and shape of the plants to increase light interception. By using smaller plants with erect leaf display at high densities we can greatly increase the leaf area index of the crop. This would necessitate a departure from current cultural practices, adoption of equidistant plant spacing, etc.

Under these conditions, ear size would be greatly reduced but because of a relatively larger change in ear number per unit area, yields would be increased.

2. Lengthen the grain-filling period.

Assuming a 35-day filling period, every day that this is extended will produce a 3% increase in yield.

Implementation in the Tropics

The efficiency of conversion of radiation to dry matter is about 2.5% in developed areas but less than 1% in underdeveloped areas. This discrepancy is largely due to deficiencies in agronomic practice—lack of water control, mineral element deficiencies and lack of control of diseases, pests and weeds.

Therefore, the first need is for production agronomy trials to determine how to get the best from existing varieties. This is perhaps the most formidable task in terms of volume of work, the extent of the areas covered and number of trials.

However, as new varieties become available, production technology becomes obsolete and new technology has to be developed. To do this, more agronomy trials will be needed. Thus, the task is a continuing one, just as the plant breeders' task is. Hence, institutions such as CIMMYT put emphasis on training programs to develop people with the skills needed to do the job successfully.

Continued progress depends on an active and productive corn breeding program. But in time, the progress which corn breeders can make in improving tropical corn yields will be limited unless we understand more about the reasons for low yields of tropical varieties.

CORE PROGRAM

A new program of agronomy-physiology field trials was initiated in 1970. This may be divided into two parts.

The objective of the first part is to provide plant breeders with quantitative information on the physiological factors which determine grain yield in tropical maize and to indicate the most probable ways of overcoming factors currently limiting yield.

To implement this part of the program, trials have been started at each of our main experiment stations—El Batán, Tlaltizapán and Poza Rica—to examine the rates of dry weight production of different tropical maize materials and the patterns of distribution of dry weight between the grain and other parts of the plant.

An unconventional form of field trial has been adopted to enable us to study a wider range of varieties and plant densities than possible with conventional trials. In these trials, we use semicircular plots in which plants are arranged along the radii so that the distance between adjacent plants on a radius increases at the same rate as the distance between adjacent radii. This provides a range of populations from 25,000 to 250,000 plants/ha. Ten varieties from the breeding program are included in the trials representing the range from the shortest, earliest to the tallest, latest materials. Our aim is to ensure that water, nutrients, weeds, pests and diseases are not limiting in these trials so that we can see the potential performance of materials under different environmental conditions.

Computer programs are being prepared for the growth analysis of this series of experiments. There are two main possibilities for the limitation of yield in tropial maize varieties. Either, (1) it is the seasonal variation in crop growth rate and the capacity of the canopy to produce dry weight which limits yield, or (2) it is the distribution of dry weight and the capacity of the ears to accept the assimilate produced which is limiting.

The direction of further work will depend on which of these possibilities seems the most important. If the dry matter production is the primary limiting factor, then more effort would be devoted to studying the effectiveness of modifying canopy structure.

If, as already seems more probable, it is the partitioning of dry matter that is the main limitation to yield, then we should investigate ways of increasing the number and size of grains as sinks for assimilates.

Other work in temperate areas can provide us with valuable pointers, but remains for us to seek answers to these questions from experiments with tropical materials grown in tropical locations. We propose to use these trials to screen the most promising materials coming from the breeding program.

The second part of the program concerns the phenology of tropical corn. Dr. Joginder Singh commented on the relative lengths of the vegetative and grain-filling periods. Many speakers have indicated that earliness is associated with low yield.

However, dry weight formation in the vegetative period is not directly related to grain yield. Therefore, to what extent is it possible to shorten the vegetative period without detrimental effects on the grain-filling period?

In phenology studies we are trying to determine how the length of the vegetative period is governed by day length and temperature. The time from germination to floral initiation is determined by photoperiod and temperature. At floral initiation the number of leaves has been determined. The rate of expansion of leaves during the period between floral initiation and flowering is temperature dependent.

To study these responses, we are planting a selection of materials at monthly intervals at our main experiment stations in Mexico covering a wide range of altitudes at essentially the same latitude. In cooperation with Dr. Crane at Purdue University and Dr. Francis at CIAT, we are trying to include a wide range of latitude as well.

In addition to the above studies designed to provide the plant breeder with guidelines for selection, we are initiating program in production agronomy, particularly as this relates to the training of production agronomists.

Plant Protection

Alejandro Ortega
Entomologist
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Plant Pathologist
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The maize entomology and pathology programs of CIMMYT are now operating as a plant protection program fully integrated into the overall breeding effort to incorporate resistance to the economically important insect and plant pathogen complexes during development of widely adapted and improved germ plasm pools.

In searching for resistance to insects, efforts were concentrated on identifying sources tolerant or resistant to the maize budworm *(Spodoptera frugiperda)*, the earworm *(Heliothis zea)*, stem borers *(Diatraea saccharalis, Zeadiatraea lineolata* and *Zeadiatraea grandiosella)* and thrips *(Frankliniella occidentallis)*. Pathogen emphasis was on ear rots *(Diplodia maydis* and *D. macrospora)*, stalk rots *(Macrophomina phaseoli, Fusarium moniliforme* and *Cephalosporium acremonium)* and stunt disease.

These insect and pathogen complexes are of economic importance from the southern United States to Argentina. A written survey during 1969-1970 revealed that similar pathogen and insect complexes contribute to yield instability in Asia and Africa (see list*). Of course, in any given season, in any given region, only a few noxious agents are or become limiting factors.

Natural incidence of other important pests *(Diabrotica)*, leaf blights *(Helminthosporium)*, rusts *(Puccinia)*, downy mildew *(Sclerospora sorghi)* and other important foliar diseases are being considered in the evaluation of the germ plasms, also. However, it will also be desirable to conduct evaluations under artificial inoculations, infestations or both with these latter noxious agents.

In this context, our efficiency in assisting the overall breeding efforts to select appropriate resistant sources should be enhanced considerably with the development of facilities to mass produce inoculum and insects, minimizing the possibility of selecting "escapes."

Most maize improvement programs around the world give normal-to-heavy insecticide protection against field pests, eliminating the possibility of discarding highly susceptible materials. In our overall population improvement program, selection is being conducted by planting each family in pair rows. One row receives no protection. The other row is protected with a granular insecticide and is used for artificial pathogen inoculation.

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

The developed or identified tolerant or resistant sources have been made available to the Inter-Asian Corn Improvement Program and maize programs in Egypt, Argentina, Bolivia, Colombia, Central America, the United States and Mexico.

These materials are: a synthetic resistant to thrips; a synthetic tolerant to maize budworm; a composite and a synthetic resistant to corn stunt; a composite resistant to stalk rots; a composite resistant to *Diplodia* ear rot; and several sources which have been identified as possessing tolerance or resistance to stem borers and earworm.

Attempts to improve the resistance level are being continued for most of these populations. Also, efforts to incorporate resistance traits into one population continue.

Recognizing the widespread use of Caribbean germ plasm and its insect and pathogen tolerance, recombination under isolation of

* We would greatly appreciate any additions, corrections or deletions.

about 160 Caribbean entries from CIMMYT's germ plasm bank was started in 1969. After three cycles of synthesis, 3,500 S_1 lines were generated to be utilized in screening for insect and disease resistance.

With the widely-adapted, foliar disease-, stalk rot- and budworm-tolerant lines selected at Pergamino, Argentina, Farm Swan, Thailand, and Tlaltizapán and Poza Rica, México, a synthetic is being developed. To make use of the available genetic variability for economic levels of field resistance to the major insects and pathogens, about 5,000 entries from most areas of the world have been recombined for three cycles. This population has been designated World Composite.

During 1970, 1,000 lines (generated at Poza Rica, Cotaxtla, Tlaltizapán and El Batán) plus 300 open-pollinated entries (from Tlaltizapán) were selected. Presently, these materials are being evaluated at Poza Rica, Obregón, Río Bravo, Tlaltizapán, Toluca and El Batán in México, and at Ithaca, New York, under conditions of different insect-disease complexes (Table 1).

Simultaneously, a crossing block has been established at Tlaltizapán from which entries will be selected on the basis of their performance in the seven environments indicated.

Also, subsamples of the World Composite are being selected and advanced under isolation to the fourth cycle of recombination in the same environments, except Ithaca. These subsamples will serve as back-up populations to foster genetic variability when it becomes necessary.

Within these wide genetic backgrounds and others developed by CIMMYT, conventional methods of selection for resistance to one insect pest or pathogen will receive less attention. Simultaneous selection for several traits has been initiated and looks promising.

Chemical control of maize insect pests will continue to be a necessity in the predictable future. We have stressed ecological selectivity of chemical insect control by enforcing the use of granular formulations economically accessible to any farmers.

Through our granular insecticide testing program, conducted at high, intermediate and low altitudes, we have identified adequate substitutes for those efficient materials that gradually will be removed from the market due to other undesirable effects on the environment. Our information indicates that granular insecticide applications are less noxious to the benefical entomophagous insects than are sprays or dusts.

Finally, for evaluation of granular insecticides, an optimum experimental sample size of 24 plants per plot in 5 rows, each 5 meters long has been established. The assessment is based on the number of injured internodes per plant.

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

TABLE 1. Environments, localities and their insect-disease complexes.

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

The opaque-2 corns do not seem to provide any better substratum for development of the cosmopolitan grain moth *(Sitotroga cereallella)* and maize weevil *(Sitophilus zeamaiz)* than other endosperm types such as floury, semidents or flints.

As with field pests, chemical control is presently the most efficient procedure to reduce losses from stored-grain insects. Relative effectiveness of some grain protectants is enhanced when treated grain is moved from a temperate climate (where the insecticide protection has ceased to be effective) to a tropical or subtropical environment.

Such performance associated with temperature and insect activity is of value for grain protection, but also needs to be considered in the establishment of legal tolerances to protect the consumer.

Feeding six-day-old chicks infected kernels has shown that a powerful mycotoxin is synthetized in *Diplodia*-rotten ears. Ears infected with this fungus are normally used by farmers in the tropics for feeding animals. Cooperative efforts are being made with the National Institute for Livestock Research in Mexico to isolate and purify mycotoxins produced by *Diplodia*-infected ears.

In connection with training activities, the plant protection program has provided guidance, materials and facilities to 9 Latin American graduate students and to 4 Ph.D. candidates. In Thailand. one members of our team has, during the last two years, developed a dynamic and successful program, connected with the entomological aspects of the maize and sorghum crops in that country.

DISEASES

(L) = Low (M) = Moderate (S) = Severe

Africa

VIRUS DISEASES

Mosaic (L)
Egypt.

Maize streak disease (M) (S)
South Africa, Nigeria.

STALK ROTS

Sclerotium bataticola (L) (S)
South Africa, Egypt.

Diplodia maidis (S)
South Africa.

Gibberella zeae (S)
South Africa.

Pythium arrhenomanes (L)
South Africa.

P. debaryanum (L)
Egypt, Nigeria.

EAR ROTS

Diplodia spp. (L) (M) (S)
South Africa, Nigeria.

Gibberella zeae (M) (S)
South Africa, Nigeria.

Fusarium moniliforme (M) (S)
South Africa, Nigeria.

Rhizoctonia sp. (L)
Nigeria.

SMUTS

Ustilago maidis (L) (M) (S)
South Africa, Nigeria.

Sphacelotheca reiliana (M) (S)
South Africa.

RUSTS

Puccinia sorghi (L) (M)
South Africa, Egypt, Nigeria.

Puccinia polysora (L) (S)
South Africa, Nigeria.

LEAF BLIGHTS

Helminthosporium turcicum (M) (S)
South Africa, Egypt, Nigeria.

H. maydis (L) (S)
South Africa, Egypt, Nigeria.

Piricularia oryzae, Curvularia spp.
Colletotrichum spp., *Rhizoctonia* spp. (L)
Nigeria.

DOWNY MILDEWS

Sclerospora sorghi (M) (S)
South Africa, Egypt.

S. rayssiae (L)
Egypt.

BROWN SPOT

Physoderma maidis (L)
Nigeria.

LATE WILT

Cephalosporium maidis (L) (S)
South Africa, Egypt.

ROOT ROTS

Helminthosporium pedicellatum (S)
South Africa.

Fusarium monoliforme (S)
South Africa.

Fusarium spp. (S)
South Africa.

Aspergillus flavus (S)
South Africa.

Mycena root rot (L) (M)
Egypt.

America

VIRUS DISEASES

Corn stunt (L) (S)
Guatemala, México, El Salvador, Costa Rica, Nicaragua, Bolivia, Colombia, Uruguay, Brazil.

Corn mosaic (M)
Nicaragua, Brazil, Guatemala, México.

Streak mosaic V (L)
Brazil.

Maize Dwarf mosaic V (L)
Brazil.

Others, nonidentified (L)
México, Argentina.

STALK ROTS

Gibberella zeae (L) (S)
Ecuador, Bolivia, Colombia, Perú, Uruguay, Brazil, Argentina, Costa Rica.

Diplodia maidis (L) (S)
Bolivia, Colombia, Perú, Brazil, Argentina, Nicaragua.

Sclerotium bataticola (L) (S)
Colombia, Argentina, México.

Pythium butleri (L)
Brazil, Argentina, Costa Rica, Guatemala.

Rhizoctonia spp. (M)
Argentina.

Fusarium graminearum (M) (S)
Chile.

Pythium spp. (L) (M)
México, Argentina.

Xanthomonas stewartii (L)
México.

Fusarium moniliforme (L)
Brazil, Argentina.

Helminthosporium spp. (L) (M)
Argentina.

Nigrospora, spp. (L)
Argentina.

EAR ROTS

Diplodia spp. (L) (S)
Guatemala, México, Costa Rica, Nicaragua, Brazil, Colombia, Perú, Uruguay, Argentina, Bolivia.

Gibberella zeae (L) (S)
Guatemala, Costa Rica, Ecuador, Bolivia, Colombia, Uruguay, Brazil, Argentina, México.

Fusarium moniliforme (L) (S)
Guatemala, Costa Rica, Nicaragua, Bolivia, Colombia, Perú, Brazil, Argentina, Chile, México.

Penicillum verdicatum (L)
Argentina.

Aspergillus spp. (L)
Argentina.

Fusarium graminearum (L)
Argentina.

Cephalosporium acremonium (L)
Argentina.

P. oxalicum (L)
Argentina.

Sclerotium bataticola (L)
México.

SMUTS

Ustilago maidis (L) (M)
Guatemala, México, Costa Rica, Nicaragua, Ecuador, Bolivia, Argentina, Colombia, Brazil, Perú, Uruguay.

Sphacelotheca reiliana (L) (M)
Costa Rica, Colombia, Brazil, Argentina, Guatemala, México.

RUSTS

Puccinia sorghi (L) (S)
Costa Rica, Nicaragua, Ecuador, Bolivia, Colombia, Perú, Brazil, Argentina, Guatemala, México.

P. polisora (L) (S)
Costa Rica, Colombia, Uruguay, Argentina, Guatemala, México.

Physopella zeae (M) (S)
Costa Rica, Guatemala, México.

LEAF BLIGHTS

Helminthosporium turcicum (L) (S)
Costa Rica, Nicaragua, Ecuador, Colombia, Perú, Uruguay, Brazil, Argentina, Guatemala, México.

H. maidis (L) (S)
Costa Rica, Nicaragua, Bolivia, Colombia, Uruguay, Brazil, Argentina, México.

H. carbonum (M) (L)
Colombia, Argentina, México.

Cercospora maydis (L)
Brazil, México.

DOWNY MILDEWS

Sclerophthora macrospora (L)
Colombia, México.

Sclerospora sorghi (M) (S)
México, Argentina.

S. graminicola (?) (L)
Brazil.

ROOT ROTS

BROWN SPOT

Physoderma zeae (L) (M)
Perú, Brazil, México, Argentina, Guatemala.

LATE WILT

Cephalosporium maidis (L) (M)
Nicaragua, Colombia, Brazil, Argentina, México.

OTHER DISEASES

Physalospora zeae (L)
Brazil.

Phyllachora maidis (tar spot) (S)
Colombia, México.

Cladosporium hervarum (L) (M)
Brazil, Ecuador, Colombia.

Septoria maydis (L)
Brazil, México.

Scolechotrichum graminis (L)
Brazil.

Phyllosticta hispida (maidis) (L)
Brazil, México.

Basisporum gallarum (ear rot) (L)
Brazil, Colombia.

Curvularia spp. (M) (L)
Guatemala, México.

Nigrospora oryzae (ear-rot) (M)
México.

Gleocercospora zeae (zonate leaf spot) (L) (M)
México.

Ustilaginoidea virens (false smut) (L)
México.

Asia

VIRUS DISEASES

Corn stunt (L)
Thailand.

Sugar cane mosaic V (SCMV) (L)
Thailand.

Corn stripe V (L)
Thailand.

Maize mosaic (strain of SCMV) (L)
India.

STALK ROTS

Charcoal rot *(Sclerotium bataticola)* (L) (M)
India.

Diplodia maidis (L)
India.

Gibberella zeae (L)
Thailano, India.

Pythium aphanidermatum (L)
Thailand.

Pythium butleri (L) (S)
Thailand, India.

Pythium arrhenomanes (L)
Thailand.

Colletotrichum graminicolum (L)
Thailand.

Botryodiplodia phaseoli (L)
Thailand.

Erwinia carotovora f. sp. *zeae* (L) (S)
Thailand, India.

Xanthomonas stewartii (L)
Thailand.

Rhizoctonia zeae (L)
Thailand.

Nigrospora oryzae (L)
Thailand.

Ascochyta zeicola (L)
Thailand.

Pseudomonas lapsa (L)
India.

EAR ROTS

Diplodia macrospora (L)
India.

Gibberella zeae (L)
India.

Fusarium moniliforme (M)
Thailand, India.

Cephalosporium acremonium (M) (S)
Thailand, India.

Aspergillus spp. (L)
Thailand.

Penicillum spp. (L)
Thailand.

Rhizopus spp. (L)
Thailand.

Helminthosporium carbonum (L)
Thailand.

Botryodiplodia phaseoli (L)
Thailand.

Fusidium sp. (L)
Thailand.

SMUTS

Ustilago maidis (L)
Thailand, India.

Sphacelotheca reiliana (L)
Thailand, India.

RUSTS

Puccinia sorghi (M) (S)
Thailand, India.

Puccinia polysora (M) (S)
Thailand.

LEAF BLIGHTS

Helminthosporium turcicum (M) (S)
Thailand, India.

H. maydis (M) (S)
Thailand, India.

H. carbonum (L)
India.

Curvularia lunata (M) (S)
Thailand.

Xanthomonas rubrilineans (?) (L)
Thailand, India.

Helminthosporium rostratum (L)
India.

DOWNY MILDEWS

Sclerospora sorghi (?) (M)
Thailand.

S. philippinnensis (L)
Thailand, India.

S. sacchari (L)
Thailand, India.

S. spontanea (L)
Thailand.

Sclerophthora rayssiae var. zeae (L) (S)
Thailand, India.

Physoderma maidis (brown spot) (L) (M)
Thailand, India.

LATE WILT

Cephalosporium maydis (L)
Thailand, India.

Cephalosporium acremonium (M) (S)
India.

OTHER DISEASES

Alternaria leaf spot *(Alternaria tenuis)* (L)
Thailand.

Phaeosphaeria leaf spot (L)
India.

Gleocercospora sorghi (L) (M)
India.

Nematodes (4 genera involved) (L) (S)
India.

False smut *(Ustilaginoidea virens)* (L)
India.

INSECTS

(L) = Low (M) = Moderate (S) = Severe

Africa

STEM BORERS

Busseola fusca (L) (S)
Nigeria, South Africa, Kenya, Tanzania, Uganda.

Eldana sacharina (L)
Nigeria, Uganda, Tanzania.

Coniesta ignefusalis (M)
Nigeria.

Chilo partellus (L) (S)
Egypt, Uganda, Kenya, Tanzania.

Ostrinia nubilalis (S)
Egypt.

Sesamia cretica (S)
Egypt, Kenya, Uganda.

S. calamitis, S. poephaga (L) (S)
Nigeria, South Africa, Uganda, Tanzania, Kenya.

S. penniseti, S. nonagriodes (L) (S)
Nigeria.

Chilotraea argyrolepia (L) (S)
East Africa.

Marasmia spp. (L) (S)
East Africa.

ARMYWORMS AND CUTWORMS

Spodoptera litoralis (S)
Egypt, Uganda, Kenya, Tanzania.

S. exigua (L) (S)
Egypt, South Africa, Uganda, Tanzania.

S. exempta (L) (S)
Nigeria, South Africa, Kenya, Tanzania.

Agrotis ipsilon (L)
Egypt, Kenya.

A. segetis (M)
South Africa, Kenya, Tanzania.

EARWORMS

Heliothis armigera (L) (S)
Nigeria, Egypt, South Africa, Kenya, Tanzania, Uganda.

Busseola fusca (L) (S)
Nigeria Uganda.

Sesamia spp (L) (S)
Nigeria Uganda.

Argyroploce leucotreta (L) (M)
Nigeria Uganda.

SUCKING INSECTS

Rhopalosiphum maidis (L) (S)
Nigeria, Egypt, South Africa, Uganda, Kenya, Tanzania.

Peregrinus maidis (L) (S)
Kenya, Tanzania, Uganda, Nigeria.

Cicadulina spp. (L) (S)
Nigeria, Uganda, Tanzania, Kenya.

Dysdercus supertitiosus (L) (M)
Nigeria Uganda.

ROOTWORMS

Elateridae (L)

Heteronychus spp. (L) (S)
South Africa, Kenya.

Astylus astromaculatus (L) (S)
South Africa.

Phyllophaga spp. (L)
Egypt.

Termites (L) (S)
Kenya, Tanzania, Uganda.

GRASSHOPPERS AND OTHER FOLIAGE FEEDERS

Epilachna sp. (L) (S)
East Africa.

Zonoceros varigatus (L) (S)
Nigeria, Uganda.

Locusta migratoria (L) (S)
Nigeria, Kenya.

Schistocerca gregaria (L) (S)
Kenya.

STORED-GRAIN PESTS

Ephestia cautella (L) (S)
Egypt, South Africa, Uganda, Kenya, Tanzania.

Plodia interpuntella (L) (S)
Egypt, South Africa, Uganda, Kenya, Tanzania.

Rhyzoperta dominica (L) (S)
Egypt, South Africa, Uganda, Kenya, Tanzania.

Sitophilus granarius, S. oryzae and *S. zeamais* (L) (S)
Egypt, South Africa, Uganda, Nigeria, Egypt, South Africa, Kenya, Tanzania and Uganda.

Tribolium spp. (L) (S)
Egypt, South Africa, Nigeria, Kenya, Tanzania, Uganda.

Sitotroga cerealella (L) (S)
Kenya, Tanzania, Egypt, South Africa, Uganda.

Cathartus quadricollis (L) (S)
Nigeria.

Mussidia nigrivenella (S)
Nigeria.

America

STEM BORERS

Chilo plejadellus (L) (M)
México.

Nomophila noctuella (L)
Brazil.

Diatraea saccharalis (L) (S)
Southern U.S.A. to northern Argentina, including Caribbean area.

Zeadiatraea lineolata (L) (S)
México, Central America, Colombia, Venezuela, Caribbean area.

Z. grandiosella (L) (S)
México, U.S.A.

Elasmopalpus lignosellus (L) (M)
Nicaragua, Perú, Brazil, Argentina, Chile, México, U.S.A.

Ostrinia nubilalis (L) (M)
U.S.A., Canada.

ARMYWORMS AND CUTWORMS

Marasmia trapezalis (M)
Perú.

Prorachia daria (M) (S)
México.

Prodenia ormithogalli (L) (S)
Costa Rica, Colombia.

P. eridania, P. sunia, P. latisfascia (M) (S)
Costa Rica, Colombia, Perú.

Pseudaletia unipucta, P. adultera (M) (S)
Costa Rica, Argetina, U.S.A.

Agrotis ipsilon (M) (S)
Costa Rica, Ecuador, Bolivia, Colombia, México, Perú, Brazil, Argentina, Chile.

Spodoptera frugiperda (M) (S)
Southern U.S.A. to northern Argentina and Chile, including the Caribbean area.

Mocis latipes, M. repanda (L) (M)
Ecuador, México, Brazil.

Dargida gramnivora, Feltia anexa (M)
Colombia.

EARWORMS AND EAR MAGGOTS

Heliothis zea (L) (S)
Canada to Argentina and Chile, including the Caribbean area.

Pyroderces sp. (L)
Colombia.

Pococera atramentalis (S)
Perú.

Protoleucania albilinea (S)
Argentina.

ROOTWORMS

Diabrotica spp. (L) (S)
Costa Rica, Bolivia, Ecuador, México, Colombia, Perú, Brazil, Argentina, U.S.A.

Phyllophaga spp. (L) (M)
Costa Rica, Nicaragua, México, U.S.A.

Chaetocnema spp. (L) (S)
Perú, México, U.S.A.

Dyscinetus, Ligyrus, Eutheola (M) (S)
Argentina.

GRASSHOPPERS

Melanoplus spp. (L)
U.S.A., México.

Schistocerca paranensis (L) (S)
Bolivia, Colombia, Perú.

S. impleta (L)
Colombia.

SUCKING INSECTS

Dalbulus spp. (L) (S)
Costa Rica, Nicaragua, Bolivia, Colombia, México, Brazil, U.S.A.

Peregrinus maidis (L)
Central America, México, U.S.A.

Blissus leucopterus (L)
Costa Rica, U.S.A.

Rhopalosiphum maidis (L) (S)
Nicaragua, Ecuador, Bolivia, Colombia, México, Perú, Brazil, Argentina, Chile, U.S.A.

Hercothrips fasciatus (M)
Bolivia.

Franklinella spp. (L) (S)
México, Colombia, Perú, Chile.

STORED-GRAIN-INSECTS

Sitotroga cerealella (S)
Costa Rica, Nicaragua, Ecuador, Bolivia, México, Colombia, Perú, Brazil, Argentina, Chile, U.S.A.

Sitophilus spp. (M) (S)
Costa Rica, Nicaragua, Ecuador, Bolivia, México, Colombia, Perú, Brazil, Argentina, Chile, U.S.A.

Carpophilus dimidiatus (L)
Costa Rica, Colombia, Perú, México, Nicaragua.

(M)

Tribolium spp. (L) (M)
Nicaragua, Ecuador, Bolivia, México, Colombia, Perú, Brazil, Chile, U.S.A.

Cathartus quadricollis (S)
Costa Rica.

Dinoderus spp. (L) (M)
México, Colombia, Perú.

Oryzaephilus surinamensis (L) (M)
México.

Plodia interpunctella (M) (S)
Colombia, México, Perú, Brazil, Chile.

Rhyzopertha dominica (L) (M)
Colombia, México, Perú, Brazil, Chile.

Anagasta kuehniella (M)
Colombia, México, U.S.A.

Pagiocerus frontalis (M)
Perú.

Araeocerus fasciculatus (M)
Brazil.

Asia

STEM BORERS

Ostrinia salentialis (S) (M)
Thailand, Philippines, Malaya.

Chilo partellus (S) (M)
India, Pakistan.

Sesamia inferens (L) (M)
India.

ARMYWORMS AND CUTWORMS

Agrotis sp. (M)
India.

Marasmia trapezalis (M)
India.

Spodoptera exempta (S) (M)
Plusia chalcytes (M)
Philippines.
Philippines.

Prodenia litura (S) (M)
Philippines, Thailand.

Pseudaletia spp. (S) (M)
Thailand.

Myllocerus spp. (M)
India.

Tanymecus indicus (M)
India.

EARWORMS

Heliothis armigera (S) (L)
Philippines.

Ostrinia salentialis (S) (M)
Philippines.

ROOTWORMS AND MAGGOTS

Holotrichia consanguinea (M)
India.

Odontotermes spp. and *Microtermes* spp. (L) (M)
India.

Leucopholis irrorata (S) (M)
Philippines.

Atherigona spp. (M) (S)
India, Pakistan, Indonesia, Philippines.

SUCKING INSECTS

Peregrinus maydis (L)
India.

Cicadulina sp. (L)
India.

Rhopalosiphum maydis (M)
Philippines.

Aphis sacchari (M)
Philippines.

Pyrilla perpusilla (L) (M)
India.

GRASSHOPPERS

Hieroglyphus nigrorepletus (M)
India.

Patanga succincta (S) (M)
Thailand.

Locusta migratoria (S) (M)
Philippines

STORED-GRAIN INSECTS

Sitotroga cerealella (L) (S)
India.

Sitophilus oryzae (L) (S)
Philippines, Thailand.

Rhyzopertha dominica (L) (S)
Philippines, Thailand.

Tribolium castaneum (L) (S)
Philipines, Thailand.

Oryzaephilus surinamensis (L) (S)
Philippines.

Carpophilus dimitatus (L) (S)
Thailand.

Cryptolestes pusillus (L) (S)
Thailand.

Trogoderma granarium (L) (S)
India.

CIMMYT's Regional Program

Willie Villena
Breeder
CIMMYT

CIMMYT is actively involved in the regional corn improvement phase of the Central American Cooperative Program for Food Crops. It began with the participation of the Central American countries. Presently, some countries from the Caribbean and South America are collaborating with this program.

Basically, the objective of the program is to exchange ideas, information and breeding materials. Each year, the cooperators meet to discuss the year's work, present papers on their local programs, discuss the results of the cooperative work and plan programs for the coming year.

One phase of the program is four different series of uniform trials in each country. These trials include: white and yellow commercial varieties; experimental materials such as new improved populations and new hybrds; a new series including populations into which the opaque-2 gene has been introduced; and open-pollinated populations and experimental hybrids into which the brachytic gene has been introduced. All four series comprise 162 experiments.

Through this cooperative work, it is possible to evaluate, in a single year, commercial and experimental material in a wider area and under more diverse environmental conditions than those found at a single experiment station.

CIMMYT provides the seed and experimental procedures, then processes the collected data.

Our major concern is to develop populations with broad adaptability and great yield potential. The improved populations could be distributed to farmers and, at the same time, be used as source materials by the national programs. CIMMYT's breeding program has developed several broad genetic base populations with attributes that make them suitable for use in this program.

Three such populations are under selection: (1) Tuxpeño Crema I, a composite in which plant height has been drastically reduced and which was originally formed by the "cream" of the Tuxpeño race collections; (2) yellow-flint populations, obtained from a divergent selection program for flint and dent endosperm; and (3) a population which includes most of the tropical material that has been converted to brachytic-2.

The method used to improve these populations is based on recurrent selection with full-sib family testing procedures. Replicated experiments of 225 full-sib families are grown at experiment stations in Central America and México.

The program has been planned so that a complete cycle could be carried out every year as follows: (1) form full-sib families at Poza Rica, México during the winter season; (2) test the material at experiment stations in Central America, Panamá and México during the first planting season (May-August); and (3) process data at CIMMYT and form new full-sib families at Poza Rica using remnant seed of selected families.

At any stage of the program, reconstituted populations for each cycle of selection will be made available to cooperating countries and to any other interested party upon request.

We have access to the main experiment stations in areas with diverse climatological and ecological conditions. Our collaborators are mostly technicians from the local programs who received training in CIMMYT's corn program and are doing an excellent job.

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