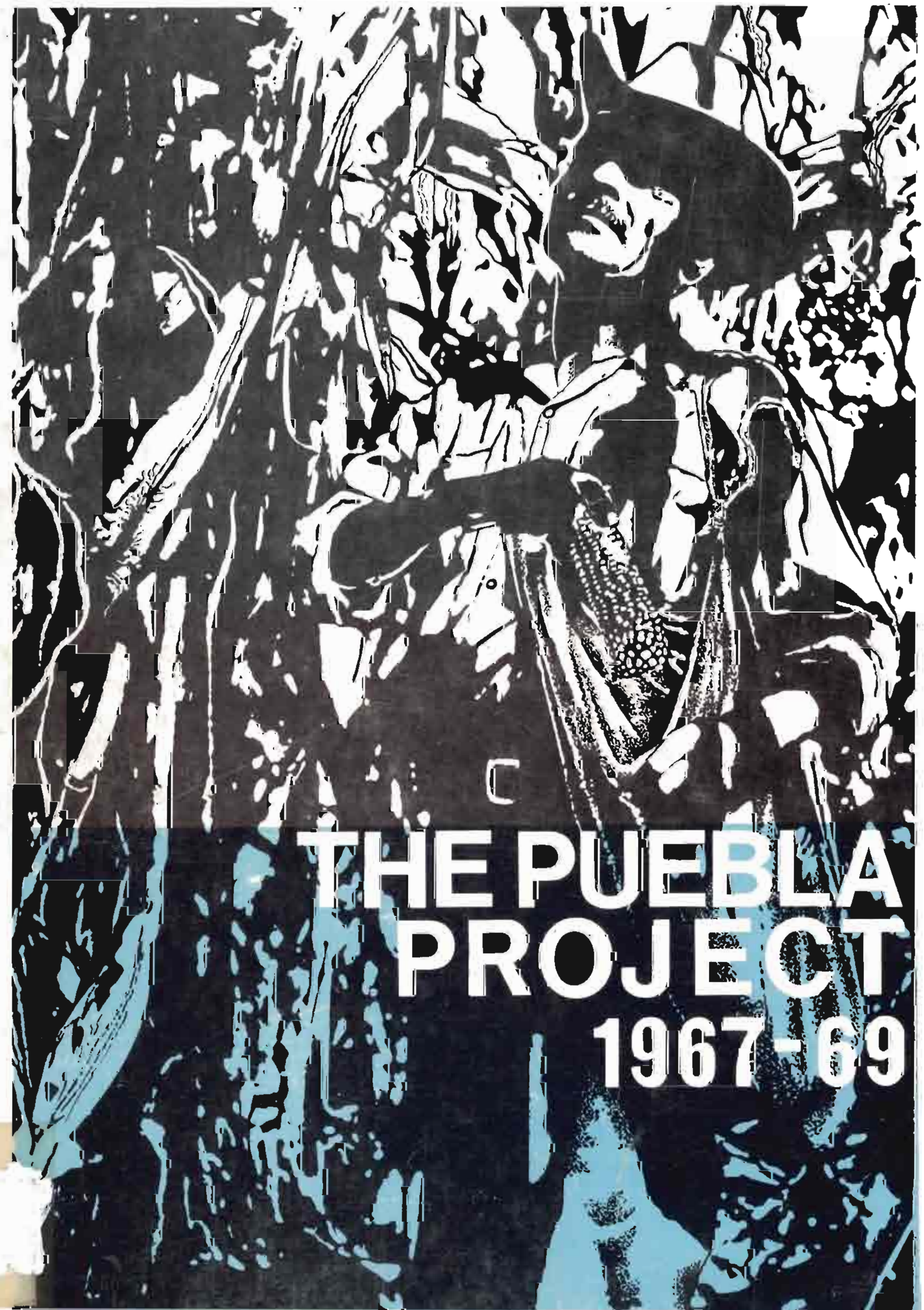
PROGRESS REPORT OF A PROGRAM TO RAPIDLY INCREASE CORN YIELDS ON SMALL HOLDINGS



THE PUEBLA PROJECT 1967-69

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

THE PUEBLA PROJECT 1967 - 69

CIMMYT

participating institutions

EXECUTIVE

Ministry of Agriculture, Government of Mexico
Government of the State of Puebla

COORDINATION OF THE TECHNICAL PROGRAM

International Maize and Wheat Improvement Center (CIMMYT)
Graduate College of the National School of Agriculture, Chapingo.

OPERATION (Fertilization Committee of the State of Puebla)

Ministry of Agriculture
Government of the State of Puebla
The national fertilizer company, "Guanos y Fertilizantes"
Ministry of Water Resources
Department of Agrarian Affairs and Colonization
National Agricultural Credit Bank
National Ejido Credit Bank
National Agropecuario Credit Bank
League of Agrarian Communities
Association of Small Private Farmers
National Crop and Livestock Insurance Agency
National Seed Producing Agency
National Price Regulating Company for Basic Foods
Fertilizer distributor, "Agrónomos Unidos"
Fertilizer distributor, "Impulsora Agrícola"
Fertilizer distributor, "Fertilizantes Olmeca"
Fertilizer distributor, "Fertiton de Puebla"

preface

This report has been prepared to provide as complete a picture as possible of what the Puebla Project is, the nature of the joint effort of those participating, and the social and economic implications of the progress achieved up to now.

The project had its origins in the concern of various CIMMYT staff for the need to develop a methodology for bringing about rapid yield increases among farmers currently producing near subsistence levels. As the project developed, it put down solid roots among farmers and in all of the participating organizations — listed on the previous page.

The Puebla Project could not have achieved the success it has without the firm support of the highest authorities of the Mexican Government. The Ministry of Agriculture has given strong backing at both the federal and state levels. The Government of the State of Puebla, where the Project is located, views it as an effective means for beginning an economic and social transformation of the area. The backing given by high governmental authorities and private enterprises has made it possible to improve credit facilities and to make more readily available the essential inputs and services.

The Chapingo Graduate College, through its Departments of Statistics, Agricultural Communications and Genetics, is providing advice and direct service. The National Institute of Agricultural Research, through its Maize Department, has provided genetic materials for developing new high yielding varieties for the area. The CIMMYT provides technical advice and direct assistance through its Departments of Maize, Soils and Communications. It also provides an administrative structure with a minimum of the bureaucratic impediments which could restrict the functioning of the Project.

The Rockefeller Foundation made the initial grant for the Project and has continued its financial support for the technical aspects of the program — coordination, research, extension, and evaluation. Up through 1969, this contribution totals US $183,000.

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Technical Staff

ARMANDO PUENTE BERUMEN, Ph.D. In charge of soils research, Mar.-Nov. 1967
J.C. DORANTES DE LA ROSA, Ing. Agr. Associate in soils reseach, July 1967 - January 1968
ANTONIO TURRENT F., Ph.D. In charge of soils research, March - December 1968
ALVARO RUIZ BARBOSA, Ing. Agr. Presently in charge of soils research
NESTOR ESTRELLA CHULIN, Pas. Ing. Agr. Research associate in soils
MARIO CASTRO GIL, Ph.D. Genetic improvement, March 1967 - March 1968
HERNAN CORTES, Ing. Agr. Associate in genetic imp. June 1967 - May 1969
FACUNDO BARRIENTOS P., M.S. Genetic improvement. March 1968 - Jan. 1969
TARCICIO CERVANTES E., M.S. Presently in charge of genetic improvement
FIDEL MARQUEZ S., Ph.D. Geneticist, Graduate College, Special collaboration in the Project
HUGO MEJIA A., Pas. Ing. Agr. Research associate in genetic improvement
HELIODORO DIAZ C., M.S. In charge of evaluation
GILDARDO ESPINOSA, PAS. Ing. Agr. Extensión advisory work, zone 1
FRANCISCO ESCOBEDO, Pas. Ing. Agr. Extension advisory work, zone 2
J. DE JESUS GUERRA, Pas. Ing. Agr. Extensión advisory work, zone 3
FELIPE RODRIGUEZ CANO, M.S. In charge of the radio program and extension advisory work in zone 4.

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INTRODUCTION

World agriculture faces two problems of great urgency: the threat of an absolute shortage of food on a global scale, and the fact of continuing low incomes and malnutrition among the majority of the rural population.

The program described in this report, the Puebla Project, is an attempt to tackle simultaneously both problems by obtaining a massive increase in yields of a basic food crop among small holders — those who are usually the last to adopt new technology. On a world-wide basis this sector represents a great, largely untouched, potential for national development.

A substantial portion of the world's food production is carried out on small holdings where the farm family produces mainly for human and animal consumption on the farm and has little or no surplus to sell. In most of the less-developed countries, commercial production is carried on by a relatively small number ot farmers.

How can the large traditional sector be transformed into viable modern farming?

Because of lack of resources and lack of knowledge on how to reach the large number of small farmers, governmental yield increase programs are usually aimed primarily at the commercial farming sector. Yet attention to the traditional sector is crucial for at least three reasons: 1) it accounts for an important part of the arable land in many countries and, consequently, yields must be increased to satisfy total food requirements; 2) in many nations most of the human resources are being used in traditional agriculture and the most likely source of increased capital from within is an improved agriculture, and 3) traditional farmers make up a large portion of the population of many countries and continuous improvement is needed to attain humanitarian goals of national policy. These considerations lead to the conclusion that efficient strategies must be developed to stimulate traditional farmers to adopt better production methods.

Of course, traditional farming may consist of three quite distinct types: 1) that conducted on irrigated land, (2) that of rainfed areas where soil and climate should favor higher yields of present crops, and (3) that of ecologically unfavorable areas. The Puebla Project is concerned with the second type of area; soil and climate are generally adequate, but farmers' yields have remained extremely low.

The Puebla area is typical of a vast number of densely populated mountain valleys, small plateaus, and river basins around the world, where the diversity of soil and climate generally makes it impossible to write one single agronomic recipe for increasing yields. Field research and adaptation trials are necessary in order to arrive at production knowledge of value to individual farmers.

Unfortunately, the strategies currently being used to bring about development in this kind of an area are largely modeled after extension programs in the commercial farming areas of the more developed countries. The problem in developing countries is not how to maintain a competitive commercial agriculture, but rather how to transform areas of traditional subsistence agriculture into commercial production— and accomplish the task at a cost which a developing nation can afford to pay.

The Puebla Project is basically an experimental approach to develop and test strategies for quickly increasing yields of a basic food crop— in this case corn— among farmers producing at subsistence levels with traditional methods.

The objectives of the Puebla Project are: 1) to develop, field test, and refine a strategy for rapidly increasing yields of a basic food crop among small holders; 2) to train technicians from other regions in the elements and successful use of this strategy.

Prerequisites

The over-all strategy under test demands two general prerequisites: 1) an ecological environment that will permit substantial yield increases, and 2) a general political environment favorable toward increased production. Many regions in most countries satisfy these conditions.

The essentials of the physical environment were considered to be mainly rainfall and temperatures adequate for good to high maize yields and reasonably deep, permeable soils free from toxic amounts of salts. The principal temperature consideration is that frosts be light and limited to the first quarter of the growing season. The total amount and distribution of the rainfall should be such that maize suffers severe drought damage in less than 10% of the years and moderate damage in no more than 30% of the years.

The essential aspect of the political environment is that government must warmly support the objective of rapidly increasing maize yields and have the will and the power to modify existing policies and agencies as necessary for achieving this goal. This is especially important in respect to availability of key inputs, orderly marketing of the grain, and the relationship between the cost of principal inputs and the price of grain at the farm. The government must more than passively approve of the idea; it must actively participate in removing obstacles that prevent or slow down farmer use of modern technology.

Having these prerequisites, the success of the project itself would depend on: 1) the appropriateness of the strategy employed, 2) the form of organization, and 3) the skill and dedication of its personnel.

The strategy is essentially a simultaneous and integrated plan of attack on the many problems limiting farmer use of adequate production technology. The action program is expected to rapidly bring into existence any of the following essentials for change that are lacking in the area: 1) high-yielding maize varieties,

2) information on optimal production practices, 3) effective communication of agronomic information to farmers and agricultural leaders, 4) adequate supplies of agronomic inputs at easily accessible points when they are needed, 5) crop insurance, 6) favorable relationships between input costs and crop values, 7) adequate production credit at a reasonable rate of interest, and 8) accessible markets with a stable price for maize. This means that the program must conduct applied research, convince farmers to use a package of improved practices, and work closely with political leaders, agricultural agencies, and suppliers of agronomic inputs.

Organization

The philosophy of organizational structure is that the production of information and its dissemination are part of a continuum and cannot profitably be compartmentalized. The program calls for an integrated approach to producing and disseminating knowledge in which there is a constant interaction and feedback along the continuum. This means that the action program should consist of a small team of well-trained scientists with an adequate budget and freedom to operate at any political or technical level. The team should live and work in the project area and cooperate closely in carrying out the field trials, demostrations, farmer meetings, etc., that are needed to achieve the goals of the program.

Personnel

At an early stage it was hoped that a specific over-all model could be defined and field tested. However, it soon became apparent that an adequate general strategy was a **necessary** but not **sufficient** condition. It would be possible to identify most of the essential factors for a general model, and even to make an over-all definition of priorities, but success or failure within the over-all strategy would depend on a large number of decisions taken over time. This is where skillful administration plays its role— above all in constantly defining and redefining priorities.

Many of the decisions must take into account simultaneously both knowledge and expectations related to weather, attitudes of farmers, institutional organization, the personal goals of individuals in key positions, and other factors. These kinds of decisions require high skill in giving appropriate weight to various factors at different points in time.

The only way that this decisive aspect can be taken into the model is to say that a basic requirement is to select staff with the vision, initiative, and personality characteristics needed to work well in a group effort, plus good basic training in the discipline for which they will have primary responsibility. Then we must add that equally important is the ability to identify opportunities and limiting factors and then make prompt decisions on priorities. This is a most useful quality for the corn breeder, the agronomist, the evaluation specialist, and the farm advisor; it is crucial for the coordinator.

THE PROJECT AREA

BASIS OF SELECTION

THE PRIMARY CONSIDERATION in choosing the area was that it should fulfill the ecological requirements mentioned earlier. The area selected includes 32 municipios of the State of Puebla as shown in Figure 1.1. A detailed description of the physical environment is given in the following pages.

Several other characteristics of the Puebla area made it a desirable location for the Project. It was felt that an area of 50,000 to 100,000 ha of corn was necessary to adequately study the effectiveness of this approach in rapidly accelerating yields; the selected area comprises about 116,000 ha, used largely for corn production. Also, the land is divided into very small holdings, average yields are low, production practices are traditional, and most of the harvest is consumed directly on the farm. These aspects of agriculture are generally thought to be related to a slow rate of growth in agricultural production and, consequently, were desirable characteristics for the project area.

With a tentative selection made, based on the above criteria, the next question was the interest of public agencies. This was forthcoming from both state and federal officials as will be described in the section on "operation of the project".

The project area can be reached in about two hours from Mexico City or the National Agricultural Center at Chapingo. This was desirable so that con-

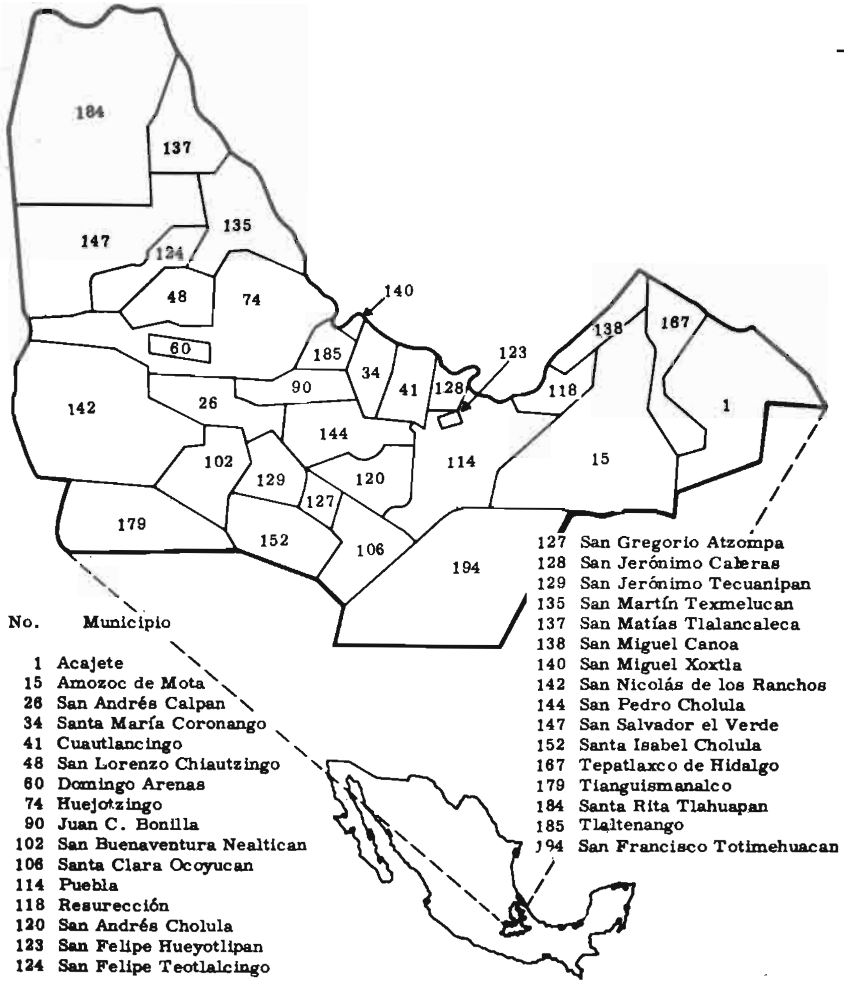


Fig. 1.1. The Project area covers about 116,000 hectares of crop land in 32 municipios of the State of Puebla. The identification numbers are those used in the national census. Most municipios have a dual name, first that of a Christian saint and then the Indian name.

The Project area consists of a long valley and the rising slopes of three extinct volcanoes. Here in the background can be seen the cone of Popocatepetl and elongated peak of Iztaccihuatl.

sultants at both locations could maintain close contact with the project. Communications within the project area are adequate, and most villages are connected with a network of all-weather roads.

THE PHYSICAL ENVIRONMENT

The project area occupies much of the valley drained by the Atoyac River and lies mostly between the rising slopes of Popocatepetl and Iztaccihuatl to the west and La Malinche to the north and east. It is located between latitudes 18°50′ and 19°25′ north and between longitudes 97°55′ and 98°40′ west of Greenwich. The lowest part of the valley lies southeast of the city of Puebla at an elevation of 2100 m above sea level. Most of the project area lies between 2150 and 2700 m above sea level, but corn is produced on the mountain slopes up to elevations above 2800 m.

Climate

The climate over most of the region is temperate with mild winters. Average monthly temperatures during the period May-October at five locations are given in Appendix Table I. May and early June is the warmest part of the year. Temperatures remain fairly constant during the last of June, July, and August and gradually decline during September and October.

As is seen in Appendix Table II frosts occur mainly during the fall and winter months from October through March, when they can cause little or no damage to corn. Frosts occur in April in about one-third of the years at Huejotzingo, Acajete, and Tepeaca, but these would be expected to cause mainly leaf burning and have little effect on yield. Frosts occurring during the period May-August would be expected to significantly reduce yields. Frosts can be expected in May in about one year in ten at Huejotzingo, Acajete, and Tepeaca, and there is almost no danger of frost during June, July, and August.

The average number of hail storms per month at 5 locations is given in Appendix Table II. Hail in April and May would be expected to cause some shredding of corn leaves but little reduction in yield. Severe hail storms during July, August, and September would be expected to reduce corn yields. At Acajete there is little danger of hail damage during this period. At the other locations hail storms occur about once a month, on the average, through July and August and about half that often in September. This suggests that some reduction in corn yields due to hail damage can be expected, but information on the severity of hail storms is needed in order to estimate the importance of this factor.

Monthly precipitation data for 5 locations covering the April to October growing season over several years are presented in Appendix Tables III-VII. The average rainfall during the 7-months period varied from 777 to 863 mm at the 4 locations within the project area and was somewhat less at Tepeaca, which lies a short distance to the east of the area. The rainfall during this 7-months period represents approximately 94% of the total for the year.

Although the average rainfall during the corn growing season at these locations should be adequate for the needs of the crop, drought damage to corn does occur whenever: (a) the total rainfall during the year is considerably less than the average, or (b) the amounts of precipitation during the critical months of July and August are very small. A study of the rainfall data in Tables III-VII quickly reveals certain years when drought probably occurred. For example, in Table III it is seen that the rainfall during the 7-months period was less than 600 mm in 1949 and 1961; furthermore, the rainfall during either July or August was less than 75 mm in 7 out of 24 years.

Existing information on soil characteristics, evapotranspiration losses, and water needs of corn at critical periods was used to estimate the incidence of drought from the daily rainfall data for the locations and years given in Tables III-VII. The estimated drought damage for individual years was designated as zero, light, or severe. As an average for the 4 locations within the project area, it was estimated that there would have been zero drought damage in 60% of the years, light damage in 30%, and severe damage in 10%. The probabilities for Tepeaca were: zero-10% of the years; light-50%; severe-40%. Corn growing in soils with a high moisture supplying capacity would suffer less from drought than the above percentages indicate, while corn on soils with a low moisture supplying capacity would suffer more. A light effect of drought would be expected to reduce yields by about 25%; a severe effect by about 50%. These indications on the probabilities of drought effects on corn yields are approximate, but are based on the best information available at present.

Soils

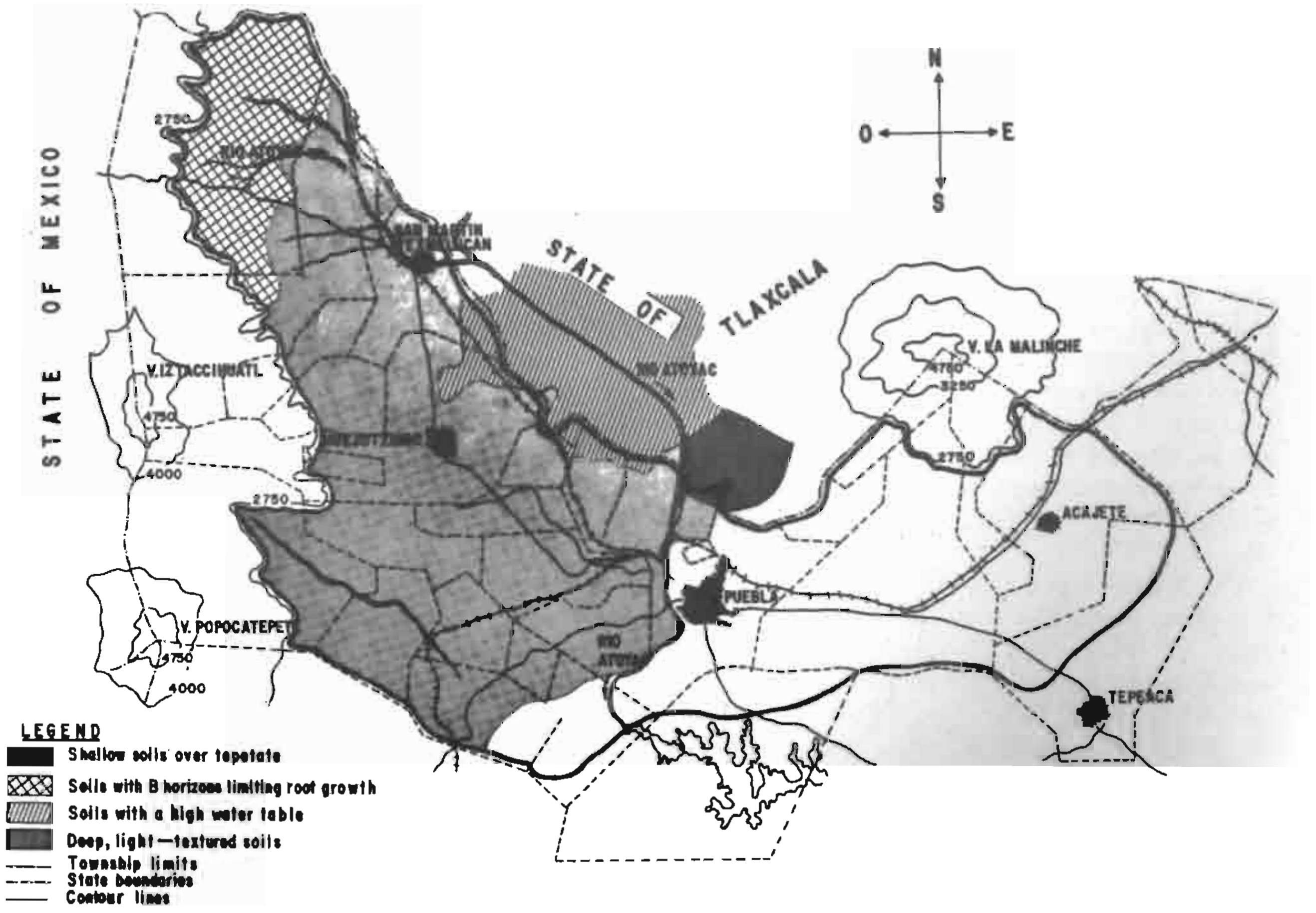
The soils in the project area have formed from volcanic ejecta, mainly from the three volcanoes: Popocatepetl, Iztaccihuatl and La Malinche. The parent material ranges in size from very fine ash to pumice particles several centimeters in diameter. The coarser materials are found on the upper slopes of the volcanoes and the finer materials near the center of the valley. The ejecta has probably been water reworked over much of the area; some of the ash and cinders, however, have been deposited directly on the land surface during eruptions of the volcanoes. The parent materials are distinctly layered due to sorting during these depositional processes.

On the upper slopes of the volcanoes the streams are very deep, and the land surface is being continuously eroded away. Little of the eroded material, however, reaches the Atoyac River. Most of the material is deposited as alluvial fan debris. Alluvial fan building is still occurring in the area and is especially noticeable along the San Martin Texmelucan-Huejotzingo highway where the stream beds are higher than the adjacent land surface.

The external drainage system is well developed on the upper slopes of the volcanoes but is poorly developed toward the center of the valley where alluvial fan formation is taking place. This has resulted in a region west of the Atoyac River between San Martin Texmelucan and the city of Puebla where external drainage is deficient. A drainage system consisting of a network of open ditches was constructed in this area many years ago and has been effective in maintaining the water table low enough for the soils to be farmed quite successfully.

The soils in the project area have not been mapped, and it is not expected that the project will be able to conduct a detailed soil survey. Profile descriptions, however, were made at each experimental site in 1967 and 1968. Also, Dr. B. L. Allen, soil morphologist, Texas Technological College, Lubbock, Texas, spent one week studying the soils of the region in September, 1968. Information obtained in these studies permits a general description of soil properties and gives some indication of the important edaphic differences that will influence optimal management practices for corn. The map in Fig. 1.2 gives a rough delineation of important soil differences as they are understood at present.

Fig. 1.2. This map shows approximate boundaries of the major soil conditions in the Western part of the Project area based on observations in 1967 and 1968.



Corn is grown up to altitudes of 2,800 meters. However, the soils are thin in part of the higher area with a horizon near the surface which restricts root penetration. On the steeper slopes erosion is also a problem.

The shallow soils of the northwestern part of the area are characterized by the presence of a horizon near the soil surface that greatly restricts root penetration. Detailed descriptions of soil profiles at three locations in the northwest — San Rafael Ixtapalucan, San Miguel Tianguistengo and Guadalupe Zaragoza — are given in Appendix Table VIII. The horizons in these soils whose designations include an x were found to be weakly to moderately developed fragipans. These horizons are relatively friable when moist but "set up" when dry and become hard and brittle. They represent a definite impedance to root development and have a low moisture supplying capacity.

The fragipans in the northwestern region are most strongly developed in soils occupying the gently sloping areas between the streams. It is unlikely that mechanical procedures can successfully alter the genetic fragipan. These compacted horizons limit the yielding capacity of the soils in this region and are being taken into account in defining general management recommendations.

South and east of the soils with fragipan development is a large extension of deep, light-textured soils that are potentially highly productive. Profile descriptions of soils near San Andres Calpan, Xometitla, San Jeronimo Tecuanipan, and San Mateo Capultitlan are included in Appendix Table VIII. The San Andres Calpan profile is representative of the soils on the gently sloping alluvial fans of the western part of the area. Although the surface horizons are sands or loamy sands, the subsoils contain considerable clay and serve as good moisture reservoirs. The Xometitla profile is typical of the soils on the gently sloping lower part of the alluvial fans. It is similar to the San Andres Calpan profile except the texture of the horizons is somewhat finer. There is no morphological feature that would suggest a problem in either the San Andres Calpan or Xometitla profiles.

The San Jeronimo Tecuanipan profile is an example of the soils in the southern part of the region. The material through the B horizon (0 to 75 cm) is gravelly sand, and the soil would undoubtedly be droughty were it not for the underlying heavy loam horizon. The fourth soil in this region whose profile description is included in Appendix Table VIII is located near San Mateo Capultitlan. This profile is characteristic of immature soils that occur adjacent to clogged streams on the lower parts of the alluvial fans. The most surprising feature about this soil is its moisture supplying capacity. Usually, stratified sandy materials as found in this soil are very droughty. However, this soil is apparently able to retain in an available form fairly adequate amounts of moisture.

The region with external drainage west of the Atoyac River between San Martin Texmelucan and the city of Puebla has a high water table that may come to within a few centimeters of the surface during periods of heavy rainfall. The soils in this region are deep sandy loams to loams and are potentially very productive. At present the high water table adversely affects yields during the latter part of the rainy season. Steps will need to be taken in the future to provide a more adequate external drainage system in the area.

In the north central part of the project area the soils have a dense, impermeable C horizon composed of partially consolidated volcanic ash and known locally as *tepetate.* This horizon may often lie within 20 cm of the surface on the stronger slopes and be considerably deeper in the relatively flat areas. An example of these soils is the San Lorenzo Almecatla profile described in Appendix Table VIII. Apparently the parent materials in this region have been derived largely from La Malinche. The tepetate layer limits both the depth of soil available for plant growth and the internal drainage of the profile. Consequently the yield potential of the soils is relatively limited and there is serious erosion on the stronger slopes.

Research and extension activities in 1968 were restricted to the western part of the project area. Consequently, little is known about the characteristics of the soils in the eastern zone. Preliminary observations indicate that the region of shallow soils in the vicinity of San Lorenzo Almecatla extends into the eastern zone, but the limits of this region cannot be established at present. Hopefully, work to be carried out in 1969 will permit the delineation of the regions of soils with limited agronomic potential.

Soil profiles were described and sampled at the 27 sites where fertilizer trials were conducted in 1967. Soil samples from selected horizons were analyzed by the Soil Testing Laboratory, Iowa State University, Ames, Iowa. These analyses, together with textural classifications made in the field, are given in Appendix Table IX.

The pH values which indicate the soil reaction varied in the surface samples from 6.0 to 8.1 with an average of 6.9. All of these pH values are favorable for corn production. The levels of ammonifiable nitrogen in the surface samples were less than 90 kg/ha, corresponding to low and very low categories, in all cases except one. The available phosphorus levels in these same samples placed 19 of the soils in low or very low categories and the others in medium and high groups. Nineteen of the surface horizons were high in available potassium, 6 were medium, and two were low. The available moisture percentages in the surface samples were less than 5 in 6 soils, 5 to 15 in 18 soils, and greater than 15 in 3 soils. Twenty-three of the surface horizons were sands, loamy sands or sandy loams, 3 were silt loams, and one was a sandy clay loam. In general these results indicate that nitrogenous fertilizer will be needed in most soils, phosphorus will increase yields in about two-thirds of the cases, and potassium will seldom be required. The available moisture percentages indicate that the moisture supplying capacity of these light-textured soils is surprisingly high.

THE FARMING POPULATION

Most of the farmers in the region are descendents of the Indian populations present in the area at the time of the Spanish conquest. In certain villages, Nahuatl, or "Mexican" as it is known in the area, is still the language of the playground. However, Spanish is now in common use and understood by all.

Number of farmers

According to the survey data,* an estimated 47,536 farmers operate land in the project area. On the average they farm 2.457 hectares per family. These farm operators include all who operate any land in the area, whether as owners, renters, sharecroppers or ejidatarios. Altogether they grow about 80,000 hectares of corn, or an average of about 1.7 hectares per family.

The average family, according to the survey data, consists of 5.537 members. This means that the total population included in the families of farm operators is approximately 260,000. In addition, there are village families in which no one is involved in farming. Two kinds of data are compared in Appendix Table X to arrive at an estimate of the number of such persons.

The Population Census provides a division by "rural" and "urban", based on place of residence, where "urban" refers to residence in a village or city with more than 2,500 inhabitants and "rural" to residence in a place with 2,500 or less inhabitants. However, this classification frequently has very little relation to occupation — in some cases 50% of the population is classified as rural whereas 95% are engaged in farming.

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* Three main sources of information are used in describing the project area: 1) statistical data from government agencies, 2) survey data obtained through interviewing a probability sample of farmers in the area, and 3) personal observations made before initiating the Project and during the first two years of work.

The Project area was the seat of various ancient civilizations, all based on the production of maize. This photo reveals part of the extensive diggings now underway near Cholula. For the most part, people live together in villages such as the one that can be seen in background.

The Agriculture, Livestock and Ejido Census has other limitations and unfortunately cannot be compared directly with the Population Census. For example, in 16 of the 32 municipios the sum of the farm family members is greater than the sum of the rural plus urban inhabitants in the Population Census. One reason for this, given by the agency which conducts the census, is that many farmers are tabulated twice because they have both ejido and private land. Our survey data show that 1/3 of the farm operators have both ejido and private land, so that the lack of information about the extent to which farmers and family members are included twice, is a potential source of error. In view of this, the fairest approximation of the total rural population in the area can be made by taking the total rural and urban population of the Population Census and subtracting from it the urban populations of Puebla and San Martin Texmelucan. This leaves a total of 264,574 persons as of mid 1960. If we calculate a compound growth rate of 2%, similar to that at which the rural population of Mexico has been growing in recent years, this would give a population seven years later of 303,911. Subtracting the survey estimate of farm operators and their families (263,207), this leaves 40,704 of rural people — approximately 7,351 families (13%) who do not operate farm land but probably depend heavily on agriculture for employment and sustenance.

Size of holdings

Although the amount of land per farm operator is small thoughout the area, there is considerable variation as can be seen in the following survey data.

Amount of land operated	No. of farmers
.25 or less ha.	7
.26 - .50	16
.51 - .75	12
.76 - 1.00	32
1.01 - 1.50	47
1.51 - 2.00	27
2.01 - 2.50	31
2.51 - 3.00	21
3.01 - 3.50	11
3.51 - 4.00	16
4.01 - 5.00	11
5.01 - 7.50	10
7.51 - 10.00	7
10.00 or more	3
Total	251

Type of land tenure

The prevalence of different land holding systems in the area is indicated by the following survey data. Of special interest is the frequency of combined private and ejido holdings.

	No. of farmers	% of farmers	Area operated (ha)	Average farm size	% of total area
Ejidatarios	96	38.2	196.70	2.05	31.96
Private small holders	69	27.5	189.19	2.74	30.34
Ejido-Private	84	33.5	231.95	2.33	37.19
Rented	1	0.4	3.00	3.00	.48
On shares	1	0.4	0.18	0.18	.03
Total	251	100.0	621.02	2.47	100.00

Beginning about 50 years ago, at the time of the agrarian revolution, the large haciendas in the area were broken up into small private holdings and ejidos. In nearly all cases the ejidatarios in the area have also chosen to operate their land individually. Consequently there are 50,000 individual decision makers who have the final say on whether to introduce new production practices.

Farmers commonly have several parcels at various locations, on different kinds of soil and at varying distances from the farmstead as can be seen in the next table.

Numbers of Parcels Per Farm Operator

No. of parcels	No. of farmers	% of farmers
1	42	16.7
2	70	27.8
3	62	24.7
4	28	11.2
5	25	10.0
6	10	4.0
7	4	1.6
8	6	2.4
9 or more	4	1.6
Total	251	100.0

This phenomenon is explained in large part by the farmers' awareness of different qualities of land surrounding the village. To be fair to all, when the ejidos were organized the farmers frequently decided that each ejidatario should, instead of having his land together at one place, have a piece of each of the two or three different qualities of land. A similar procedure is often followed by private owners in leaving land to their children. The ejido land, by law, cannot be further subdivided; the ejidatario can name a single heir to take over the use rights to his ejido land.

At the time of the bench mark survey a widespread feeling of insecurity was found in respect to tenure rights.

The family and the home

The most prevalent farm unit throughout the area is the family farm. The family, with an average of 5.537 members, provides both the management of the resources used in agricultural production and most of the labor used on the farm. The small amount of hired labor used is shown in the following table.

No. of days per year	No. of cases	%
None	110	43.8
1-12 days	41	16.3
13-24 days	28	11.2
25-60 days	55	21.9
More than 60 days (average 75)	17	6.8
Total	251	100.0

Where labor is hired, it is usually for short periods of peak activity such as harvest time when there may in fact be a shortage of labor in the region. Much of this hired labor is offset by members of the family working off the farm at other periods when labor needs on the farm are low.

Although 77% of the farm operators indicate ability to read and write, the average educational level is only 2.36 years. The impression is that at least half of those who read and write do so with considerable difficulty.

Education of Farm Operators

	No.	%
Illiterate	57	22.7
Self taught, literate	11	4.3
1 year of school	25	10.0
2 years	43	17.1
3 years	56	22.3
4 years	24	9.6
5 years	11	4.4
6 years	20	8.0
More than 6 years	4	1.6
Total	251	100.0

Average schooling of all farmers = 2.36 years

At certain peak labor periods, such as planting and harvest, the whole family helps in the field and additional workers may be hired. As the fields are often far from the village, the women sometimes bring the noon day meal.

It is customary in the area for farmers to live together in villages. Homes are usually (76%) made of sun-baked adobe bricks. The floors are frequently of brick, cement or tile, but 36% are of dirt. The dwellings are small as indicated in the next table.

Rooms Besides the Kitchen in the Farm Home

	No.	Percent (N=251)
One which is also the kitchen	3	1.2
One room	110	43.8
Two rooms	81	32.2
Three rooms	37	14.7
Four rooms	13	5.1
Five or more rooms	7	2.8

Though most of these families live humbly, many have some of the minimum comforts associated with modern living as can be seen in the following table.

Living Comforts

	No.	Percent (N=251)
Have electric lights	158	62.9
Have radio	150	59.8
Have a sewing machine	113	45.0
Cook with gas, electricity or fuel oil	72	28.7
Have piped water in home or street	33	13.1
Have television	20	8.0
Have drainage	15	6.0
Have refrigerator	4	1.6

In nearly every case the family diet depends heavily on home produced food. The cornerstone of this diet is corn of which the average family consumes about one metric ton during the year. The poorest families eat practically nothing besides corn and beans with small quantities of chiles, onions and tomatoes for seasoning. Those with more resources occasionally consume wheat bread, eggs and meat, and their children drink milk.

The small amount of income available for purchase of food, clothing, medical attention and other needs is suggested by averages for the 251 families included in the survey.

Family Income Measures

	Pesos	$ US
Value of crops sold	1,693	135.44
Off-farm wage income	1,940	155.20
Other non-farm income	1,388	111.04
Income from livestock production	1,290	103.20
Total income	6,311	504.88

Contact with ideas from outside the community

There exists excellent potential for contact with the large urban society outside of the villages. Local roads are rough and eroded, but in most cases passable during the entire year. The local buses are battered with years of wear, but provide a regular and inexpensive means of transportation for both people and produce. Traveling outside of the village, however, is not undertaken casually. Only 24% of the farmers

Although erosion is frequently a problem in road maintenance, most of the roads are kept passable the year round. Buses provide daily opportunities to take products to market in the larger towns. For local travel, the bicycle is of growing importance.

leave the village at least once a week. Another 14% leave every two weeks or every month, 43% rarely leave the village and the remaining 19% state that they never leave the village.

In spite of limited physical mobility, there is a growing contact with ideas from outside of the villages, principally through radio, as suggested by the following table.

	No.	Percent (N=251)
Radio		
Have a radio	150	59.8
Listen to it daily	126	50.2
Listen to a farm program	55	21.9
Television		
Have a television set	20	7.9
See TV at home or somewhere else at least once a week	31	12.4

The farm radio program heard at the time of the survey was the national "Hora del Granjero", broadcast by a Mexico City station. Because of its broad coverage, it had little information of practical value for this specific region.

As would be suggested by the literacy data, printed material does not play an important role.

Readership of Newspapers and Magazines

	No.	Percent (N=251)
Read farm magazines regularly	4	1.6
Read newspapers regularly	20	7.9

PRESENT LEVEL OF PRODUCTION TECHNOLOGY

Solid evidence exists * that primitive wild corn was domesticated as long as 7000 years ago in the highland region of which the project area is a part. Corn was clearly the basis of the numerous civilizations which flourished over the centuries within the area.

The archeological study of corn cobs has also revealed a substantial genetic improvement over the centuries. The selection methods used by the ancient indigenous populations obviously bore results. In spite of this, the yield levels at the time this project began were very low by the standards of modern corn production. They ranged slightly above one ton per hectare, under 20 bushels per acre. Centuries of cropping had removed most of the nitrogen from the soil and yields had stabilized at this low level.

At the time of the bench mark survey in January-February 1968, small quantities of fertilizer were being used. However, in general production was being carried out in traditional ways, with little thought given to maximizing returns to land, labor or capital.

In the statistical sample of 251 farmers, all but one grew corn in 1967. When asked why they plant corn every year, the following replies were obtained.

Why Do You Plant Corn Every Year?

	No.	Percent (N=251)
Because this is what the family lives on	131	52.2
The land is only good for corn	88	35.0
It is the easiest crop	5	2.0
Do not know any other crop	5	2.0
Other reasons	22	8.8

Although no one suggested profitability as a reason, the use of one important input of modern agricultural — chemical fertilizer — is widely known as can be seen in the following table.

Use of Chemical Fertilizer

	No.	Percent (N=251)
Knows of chemical fertilizer	239	95.2
Has used it on at least one occasion	200	79.7
Used it in 1967	174	69.3

The following tables provide further information about the kinds of fertilizer, quantities used and periods of application. These data may be compared to the recommendations presented in the agronomic section of this report.

Fertilizer Used in 1967

	No.	Percent (N=251)
Formula 10-8-4	111	44.1
Other formulas	8	3.2
Superphosphate	3	1.2
Ammonium Nitrate	23	9.2
Ammonium Sulfate	9	3.6
Combination	18	7.2
No answer	2	.8

* Richard S. MacNeish. Second Annual Report of the Tehuacan Archaeological-Botanical Project. 1962.

Over centuries of cropping the fertility levels of many soils have become so low that it is nearly impossible to produce a crop without fertilization. At the time the Project was initiated many farmers were applying some fertilizer; some had also diversified by interplanting fruit trees.

Average Application of Fertilizer in 1967

	By the 69.3% who used it in 1967	Overall average
Elemental nitrogen	49.3 kg/ha	34 kg/ha
Phosphorus (P_2O_5)	25.2 kg/ha	17 kg/ha

Time of Fertilizer Aplication

	No.	Percent (N=251)
At planting	5	2.0
At first cultivation	121	48.2
At second cultivation	46	18.3
At both 1st and 2nd cultivations	19	7.6

Obviously the quantities applied, the formulas used and the time of application are far from optimum, yet the farmers have a good reason for each. The quantity is determined, not in terms of maximizing gains, but rather of, "if I don't use fertilizer, I don't harvest enough to feed the family". They see a need to use some fertilizer as a way to avoid a crop failure.

The most common formula, 10-8-4, was that for which the Ejido Bank provided credit and consequently was the most readily available locally. The time of application — not using any at planting — is the way that farmers avoid losing the fertilizer in case of poor germination or failure of the planting for any other reason. They prefer to wait until the stand is well established and the rains appear to be coming regularly.

Actually, the use of chemical fertilizer has been known for a long while in the region: over 80% have used it at one time or another and 27% used it for the first time as long as 10 years ago.

In What Year Did You First Use Chemical Fertilizer?

	No.	Percent (N=251)
Have never used	50	19.9
1967	19	7.5
1966	19	7.5
1965	26	10.4
1964	16	6.4
1963	16	6.4
1962	15	6.0
1961	5	2.0
1960	17	6.8
1959 or before	68	27.1

However, for the reasons mentioned, frequently combined with inadequate weed control, the average yield in the area in 1967 was 1,310 kg/ha, only 20 bushels per acre.

Hybrid corn is fairly well known, but little used, in the region.

Use of Hybrid Corn

	No.	Percent (N=251)
Know of hybrid corn	137	54.6
Has planted in on at least one occasion	38	15.1
Planted hybrid in 1967	2	0.8

Some of the reasons given by farmers are presented in the following table.

Farmers Who Know of Hybrid Corn in 1968 But Had Never Planted it, Gave the Following Reasons

	No.	Percent (N=251)
Have seen that it doesn't give results	41	16.3
It just works with irrigation	11	4.4
The local variety is better	9	3.6
Wasn't interested	8	3.2
I don't trust it	5	2.0
Not used to it	5	2.0
It requires fertilizer	4	1.6
Lack of money	3	1.2
Other reasons	9	4.4

The relevant question then, is whether there was in fact available a hybrid which would yield better than the local varieties. Actually there may be more than one answer because of the interaction between variety, soil and climate. Because of the variation in soil in the area and the differences in climate from year to year, over the years each locality has selected its own local varieties. It is common for a community to have at least three varieties — one for early March plantings on residual moisture, one for the main plantings in April, and one for late plantings in May and early June. The manner in which the 1967 plantings were spread over more than three months is shown by the following survey data.

Date of planting	Ha. planted	No. of farmers
Before March 1	18.7	10
March 1-14	60.7	37
March 15-31	111.6	71
April 1-14	86.8	61
April 15-30	99.2	71
May 1-14	59.5	41
May 15-31	29.4	22
After June 1	31.8	15
TOTALS	497.6	328 *

* 78 farmers planted during more than one period.

To compare the local varieties with the adapted hybrids would require plantings at different dates and during several years in order to sample climate variability. The 1968 data, reported in the breeding section of this report, appear to indicate yield superiority of the hybrids which were recommended for the region before the Project began. At six locations H-28 varied from 5% under the local criollo to 39% above. H-129 varied from 9 to 19% above the criollo. However, these potential yield differences were either not great enough to be noted visually by the farmers or were not sufficiently consistent from year to year to impress them. Less than 1% of the farmers planted a hybrid in 1967.

As to other aspects of modern technology, very little use is made of insecticides and herbicides. Forty one per cent know of chemical insecticides and 22% have used one on some occasion, but principally to control insects on beans. There is rather broad acceptance of the idea that you cannot obtain a decent harvest of beans without using an insecticide. On the other hand the high cost of dusting beans interplanted with corn in the traditional way has caused many farmers to discontinue interplanting. The survey showed that interplanting has been gradually declining and accounted for only 22% of the corn acreage in 1967. Many farmers now plant a small plot of beans alone, and attempt to control the insects.

In corn, on the other hand, there appears to be only one insect pest of importance — the rose chafer. Its attack was noted by 10% of the farmers in 1967, but few of them used insecticides to combat it.

At some locations gophers caused difficulty in maintaining plant populations for experimental work, but were mentioned as a problem by only 1% of the farmers in the survey.

Inspections of farmers' plantings in 1967 and 1968 indicate that inadequate weed control is a serious yield limiting factor. The weed control practice usually employed is as follows. At planting, seed is placed in hills at the bottom of a deep furrow. At approximately 3 to 4 weeks, when the corn is between 20 and 30 cm high and usually after a rainfall which has adequately moistened the top soil, the farmer plows, turning the high mound of soil between the rows into the furrow and around the plants. After this first plowing the field is more or less level and the farmer has to take care to immediately uncover those plants which may become covered with chunks of soil. When well done this deep plowing competely covers the weeds, including those within the rows. Frequently, however, weeds are left uncovered which continue to grow and compete with the corn. About 3 weeks later the soil is plowed deeply again, this time making a high mound along the plant rows and leaving a deep trench in between. In 1967 only 1% used a tractor for this work and 1% used an herbicide.

After the second cultivation, the broad-leafed weeds which escape covering because of their proximity to the corn plants, often begin to grow rapidly and provide competition for soil nutrients and moisture. These weeds are commonly cut back by sickle and used as forage for cattle, donkeys and mules.

CORN MARKETING

Corn marketing problems have not been serious in the Puebla area. Part of the reason can be seen in the following estimates for the region based on survey data.

Disposition of the 1967 Harvest, metric tons

Family food on the farm	46,680	
Animal feed on the farm	24,481	
Total Harvest Used on Farm		71,161
Payment for land rent, custom work and wages	2,662	
Sales	46,538	
Total Sold		49,200
Total Production		120,361

Net sales were actually 44,000 tons — the total sales minus 5,200 tons purchased by the 21% of the farmers who bought corn during the year. Based on urban consumption figures developed by the Bank of Mexico * it is estimated that all of the remaining sales are absorbed by human consumption in the city of Puebla.

Although consumption among urban families is well below that of rural families, and decreases with increasing income, on the average families with monthly incomes between 1,000 and 4,500 pesos consume slightly above 6.5 kg per month per person, and 78 kg per year. If we multiply this by the estimated present population of the city of Puebla (500,000) we find that the region as a whole is barely self-sufficient with probably no net out-movement of corn from the area. This is substantiated by the price support agencies (CONASUPO and ANDSA) which together purchased about 15,000 tons from each of the 1967 and 1968 harvests. Data are not presently available on the amount of corn moved into the area during the months prior to the new harvest. However, the state as a whole has a corn deficit and the project area is the best potential source of supply.

Pricewise the market functions acceptably. The most common price obtained in 1967 was 850 pesos per metric ton or about $ 1.73 dlls. per bushel of shelled corn. The low end of the range was 800 pesos, right at harvest time. The high was 940 pesos for those who sold directly to the price support agency at 12% moisture or below.

On the average in 1967 each farm operator sold 979 kilos. However the amount and portion of the harvest varied greatly as can be seen in the following survey data.

Do You Sell Part of Your Corn Harvest?

	No.	Percent (N=251)
No	154 *	61.2
Yes	97	38.8
Up to ⅛ of the crop	22	8.8
Up to ¼ of the crop	18	7.2
Up to ⅜ of the crop	15	6.0
Up to ½ of the crop	21	8.4
Up to ¾ of the crop	12	4.8
More than ¾ of the crop	8	3.2
No reply	1	.4

* One of these farmers did not grow corn.

Sales are pretty well spread throughout the year as indicated by the response to the question.

When Do You Generally Sell Your Corn?

	No.	Percent (N=251)
Do not sell	154	61.2
Sell at harvest	9	3.6
Oct., Nov., Dec.	10	4.0
Jan., Feb.	15	5.9
March, April	6	2.4
May, June	9	3.6
July, Aug.	6	2.4
When have needs	11	4.4
During the year	16	6.4
No reply	15	6.1
	251	100.0

The reasons given for deciding when to sell indicate, however, that price criteria play a limited role in this decision. Of primary importance are the needs of the moment.

* "Encuesta sobre ingresos y gastos familiares en México, 1963". Banco de México, S. A. México, 1965.

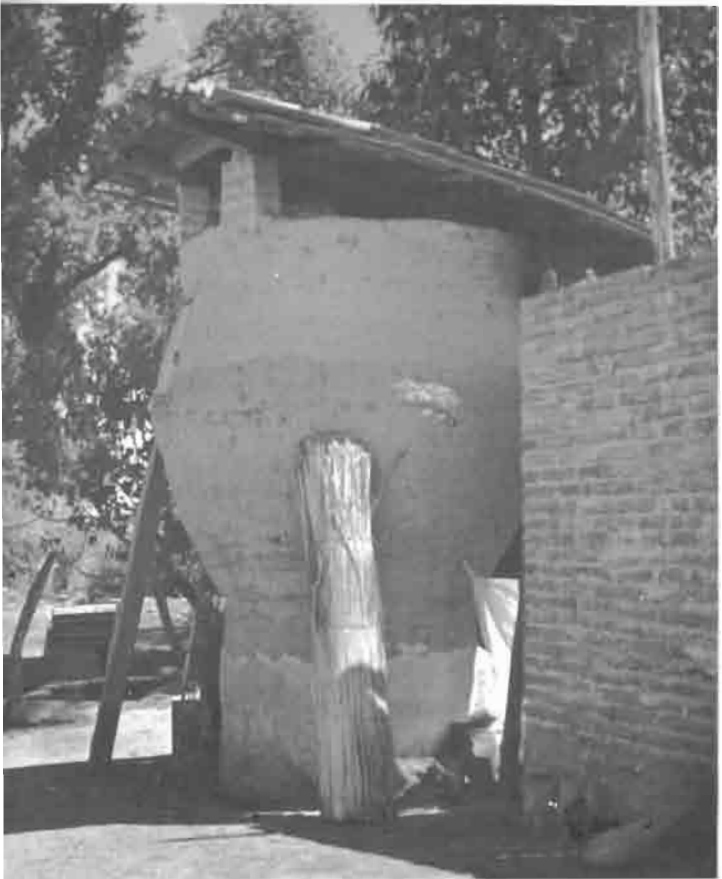
How Do You Decide When to Sell Your Corn?

	No.	Percent (N=251)
Sickness in the family	68	27.1
To repay credit	10	4.0
When can obtain the best price	10	4.0
To buy fertilizer	3	1.2
As soon as I can shell it	2	.8
No clear criteria	4	1.6

CREDIT

By most measures the Project area is capital poor, even though the natural ecological resources are good. The concentration of population, the small holdings and the traditional farming methods, have kept production per family at a level which barely provides for consumption and in most cases has left no excess for savings.

Traditional corn storage facilities are effective in keeping out moisture, rodents, and larger animals. The main problem at the time the Project was initiated was how to produce enough to fill the crib.



In terms of human capital the lack of resources is especially notable. The average educational level of farm operators is just slightly more than second grade with only 1.6% having gone beyond the 6 years of primary. At the same time very few of these people are knowledgeable about the simplest of gasoline motors or mechanized equipment.

The knowledge and techniques they have accumulated over the years are mostly of the kind which have helped them to subsist and prevent inroads on their present way of life. New skills which could be considered of value in moving to a higher level of technology in agriculture or industry are possessed by very few.

To the extent that there are more productive inputs with which greater or more efficient production can be achieved, investment in such inputs offers potential for building capital. In a poor area, this means that capital must be brought from outside of the region. Such use of credit is very limited as shown by the following survey data.

	No.	Percent (N=251)
Have had credit on some occasion	56	22.3
Had credit in 1967	30	12.0
With the Ejido Bank	16	6.4
With the Agricultural Bank	1	.4
With a private store	1	.4
With another institution	1	.4
Private lenders	11	4.4
Have used credit every year	10	4.0

Interviews with the official banks further clarified this picture. There are presently three official banks in the region: the National Ejido Credit Bank, the National Agricultural Credit Bank, and the National Agropecuario Bank which began operating in the area during 1968. Appendix Tables XI through XVI show the extent to which these banks have operated in the 32 municipos of the project area. In 1968 the three banks provided credit for 2.7% of the farmers in the area and for 5.1% of corn land. The Ejido Bank alone provided for 93% of these farmers and 75% of this area, but provided just over half of the total funds as the amount loaned per hectare is smaller in the case of the Ejido Bank.

At the time the Puebla Project began, the typical farm family was largely self-sufficient. Only 12% used any credit in 1967 and very little outside labor was employed.

CROP INSURANCE

Adequate protection against risks takes on a growing importance as farmers increase the amounts of purchased inputs used in crop production. In those countries where crop insurance is available, farmers can obtain such protection by paying an annual fee. Mexico is quite well advanced in this field as she has a crop insurance program initiated in 1953 and now operating on a national scale.

The big problem with crop insurance in early stages in all countries is that of establishing rates which will cover losses and costs of operation and still provide low cost protection for farmers. The integral crop insurance provided in Mexico attempts to cover losses from all causes which cannot be controlled by man.

In practice, up to now it has functioned principally as a corollary to the credit programs of the official banks (Appendix Table XVII). A such it protects the banks from crop losses due to natural causes. The insurance premium is deducted from the bank loan for which the farmer signs and the bank is paid off first in case of a crop loss.

Although this would appear to be a sound financial procedure, farmers, rightly or wrongly, feel that the cost is too high and that they receive too little in return. Instead of viewing crop insurance as a desirable thing, they cite it as an important disadvantage of official credit. This, in spite of the fact that the federal government provides approximately three-fourths of the premium, as can be seen in Appendix Table XVIII.

The high cost of providing the insurance appears to be related to two principal causes: 1) a high cost of inspection because of the numerous small holdings and 2) a high rate of crop damage. Both of these points should be studied carefully to determine how crop insurance costs can be reduced.

The high rate of crop damage is somewhat surprising in view of Project experience in 1968 with 141 plantings spread throughout the area. Although there was frost damage in two cases, in no case did the yield reduction reach the point of being an indemnifiable loss, whereas 23.0% of the farmers and 22.8% of the total land area insured in the 32 municipios registered losses for which indemnification was provided.

As farmers strive for higher yields by using more fertilizer and better seed, and attempt a more complete control of weeds and pests, an efficient crop insurance system will become increasingly important to protect them against loss on their increased investment. It is hoped that new procedures can be found to reduce costs and provide greater coverage.

FERTILIZER DISTRIBUTION

As mentioned earlier, although the quantity of fertilizer used is far below the optimum, the use of fertilizer is quite common in the region. The rudiments of a distribution network also exist. In a rapid survey of the villages in the summer of 1968 it was found that, in addition to the main distribution centers of Puebla, San Martin, Huejotzingo and Cholula, 42 other villages had a total of 80 store keepers who bought fertilizer and resold it at the local level. Most of these individuals operate on their own capital and many sell a ton or less. At one stage it was thought that this rudimentary network might be used to channel increased quantities of credit and fertilizer into the area, but an alternative approach was found which will be described later.

Most of the fertilizer comes into the area through three private distributors in Puebla authorized by the national fertilizer company "Guanos y Fertilizantes de Mexico", S. A. In addition, one dealer in San Martin buys directly by the car load from the main office of Guanos in Mexico City. The Ejido Bank has two distribution points — Puebla and San Martin, whereas the Agricultural Bank distributes only at its main office in Puebla.

OPERATION OF THE PROJECT

THE PROJECT AREA WAS SELECTED in early 1967 after making a general reconnaissance before corn harvest in the fall of 1966, reviewing the results of earlier experiments, and studying weather data from several locations in the region. The information available at that time indicated that the principal factors limiting corn yields probably were deficiencies of nitrogen and phosphorus, low plant populations, and weed competition. Research on varietal improvement and production practices was planned for 1967 and the initiation of extension activities was tentatively scheduled for 1968 when preliminary recommendations of varieties and production practices would be available.

SELECTION OF PERSONNEL

The production agronomist and maize breeder were selected in March and April of 1967 as the first members of the project staff. The coordinator was named in July. In January, 1968, the evaluation expert was selected and in March of the same year the farm advisor was chosen. At the end of the first year of operation, both the production agronomist and maize breeder left the project for graduate training and were replaced. The evaluation expert will be replaced in late 1969 for the same reason.

From the beginning it was recognized that the quality of the project staff would be the most important factor in assuring the success of its operation. Certain screening procedures were followed which,

The success of a regional program such as the Puebla Project depends in many cases on key decisions, taken at the state and federal levels. This photo was taken in 1967 during a visit to the area by the President of Mexico, Lic. Gustavo Diaz Ordaz, and other high officials of the federal government.

hopefully, would assure the selection of the best candidates available.

1. Motivation. Prospective employees were informed in detail of the objectives, organization, and functioning of the project. They visited the area, discussed the project with the other staff members, and talked with farmers. It was emphasized that the staff worked together as a team in carrying out experiments, working with farmers, and collaborating with public and private agencies. In this way, the candidates came to understand that the project offered an opportunity to make an important contribution to agricultural development, but it also meant long hours and absolute dedication. Only those candidates who responded enthusiastically to the challenge of the project were considered further.

2. Technical ability. Previous employment and especially the academic preparation and professional goals of the candidate were given important weight in evaluating his technical qualifications.

3. Maturity. By observing their reactions in field interviews, every effort was made to select only those people capable of working smoothly with other staff members and all kinds of farmers. Also, candidates were judged on their ability to communicate effectively with technical people, and with representatives of agricultural institutions from small distributors of inputs to high government officials.

4. Ethics. In interviewing candidates and studying their previous activities, every effort was made to assure that they employed the scientific method with complete honesty and were eager to present their plans and results for the criticism of others.

5. Age. Because of the strenuous nature of the work and the need for flexibility and innovation in resolving problems, a preference was shown for people between 30 and 35 years of age. However, the physical condition of the candidate and his intellectual attitude were given more importance than age.

6. Health. Only candidates with perfect health, both physical and mental, were considered.

Once chosen, to hold the best people available requires that they feel challenged by the program and that they be compensated adequately for their participation. Salaries, travel expenses, and fringe benefits were set up to do this. Also, the young, highly qualified agronomists selected for the project are in many cases interested in additional graduate training. Provisions were made so that staff members could continue their formal preparation after a period within the project.

ESTABLISHING CONTACT WITH NATIONAL, STATE, AND LOCAL INSTITUTIONS

A basic premise of the Puebla Project was to work with existing agricultural institutions. It was believed that if these agencies were adequately informed of the objectives, organization and functioning of the project, they would participate effectively in promoting a rapid increase in maize yields.

On joining the project in August, 1967, the Coordinator proceeded immediately to get existing agricultural institutions more completely involved. Interviews were held with the leaders of the different institutions and they were informed of the program and the part they could play in assuring its success. The Puebla Project was presented as a coordinated effort of the project staff, farmers, and these agricultural agencies. The importance of the role of each institution was emphasized, and it was made clear that all were a part of the project.

The Coordinator used these interviews, together with other information, to become familiar with all the national, state, and local institutions, as well as private organizations, involved in agricultural development. The objectives, organization and operating procedures of each institution were studied. Also, every effort was made to understand the responsibilities of key individuals in the different organizations and their relationships one to the other. It was necessary to study the chains of command of both federal and state agencies and learn how federal and state agricultural activities were meshed. In this way it was possible to understand the level at which different decisions are made and to know which individual or agency should be consulted when seeking the solution to a particular problem.

This study of the agricultural institutions led gradually to an understanding of the capacity of each to fulfill its obligations within the Puebla Project. For example, in the case of credit, the amount of capital needed for purchasing fertilizers, insecticides, and other inputs will increase sharply as the program begins to reach most of the farmers in the area. Much of this capital will have to be supplied in the form of short term loans. At present, the agricultural credit banks do not have sufficient credit allotted to corn production to cover the potential demand. Consequently, either the banks must find a way to increase the credit available for corn or new sources of financing will have to be found.

An understanding of the resources and functioning of the agricultural institutions, together with a projection of the needs of the project for the coming years, provides a basis for seeking change within an institution. It seems clear that as the agricultural institutions strive to fulfill their obligations to the project, they will pass through a series of modifications on the way to attaining a form of organization and operating procedures adequate for their role in modernizing a traditional agriculture.

"Seeing is believing", also at the administrative level. Here a group of individuals, influential in the infrastructure of the area, review experimental plots and listen to the explanations of the soil scientist.

The Ministry of Agriculture has given whole-hearted support to the Project. Here, the Secretary of Agriculture, Prof. Juan Gil Preciado (2nd from left) and the General Agent for Agriculture in the state, Ing. Hector Porras Howard (2nd from right), visit plantings in 1968.

ACTIVITIES IN 1967

The fertilizer experiments and breeding studies mentioned earlier were carried out in farmers' fields well distributed over the project area. A detailed description of these studies will be given in later sections. Conceptually, it was assumed that all the project area was the experiment station. By carrying out the experiments in the area it was expected that recommendations could be obtained more quickly and these, in turn, would be more reliable.

On joining the project in August, 1967, the Coordinator initiated a general reconnaissance of the area, traveling over most of the all-weather roads in the area, defining regions where corn production was concentrated, and observing characteristics of farmer's plantings such as population density, fertilization, weed controls, etc. Farmers were interviewed informally about their production practices, average yields, relationships with agricultural institutions, and possible interest in participating in the project.

This exploration revealed that many farmers were using some chemical or organic fertilizers, and a few were using insecticides and improved corn varieties. It also called attention to the advantages of making the evaluation an integral part of the project. Obviously, accurate information was needed as soon as possible on the characteristics of the agriculture, present levels of production, and attitudes of the farmers toward change. Decisions were taken that led to the initiation of the evaluation study in late 1967.

Although close coordination of the activities of all members of the project staff was established as a principle at the beginning, such team action was not immediately achieved. Men trained in different disciplines were inclined to associate with others of the same discipline and not seek closer ties with other project colleagues. The idea that all members of the staff should participate actively in all phases of the program was emphasized over and over, and gradually became accepted as the operating procedure.

The fertilizer and corn breeding experiments were harvested as soon as the corn reached maturity, the results were analyzed, and a general recommendation for producing corn in the area was formulated. This stated that a fertilizer treatment of 130-40-0 should be used together with a plant density of 50,000 per hectare, along with early control of weeds and chemical control of high infestations of the rose chafer at flowering. It was recommended that farmers continue to plant their native varieties for the present.

The first "Annual Meeting of the Puebla Project" was held at Puebla in December, 1967. Representatives of all agricultural institutions were invited, and the project staff explained their experimental findings and recommendations for 1968. It was considered important that the meeting be held in December, as this is when institutions such as the agricultural credit banks prepare their plans for the following year. Since the recommendations of the project implied operational changes for certain institutions, it was important that they be completely informed while there was still time to modify plans.

ACTIVITIES IN 1968

As soon as the 1967 results had been analyzed and interpreted in detail, the project staff formulated plans for 1968. These included several studies of agronomic practices, varietal improvement trials, and approximately 100 "high yield plots". These latter consisted of an area of 0.25 to 1.0 ha on which the farmer employed the recommendations of the project under the supervision of the project staff. Experiments on agronomic practices and corn improvement were located together with a high yield plot at two sites which were used later for field days. The experiments and high yield plots were limited in 1968 to the western two-thirds of the project area in order to concentrate the efforts of the available staff.

The package of recommended practices for 1968 implied three principal changes for the agricultural infrastructure: 1) An increase of about 25% in the amount of credit per hectare needed to purchase fertilizers, 2) Substitution of ammonium sulfate and ordinary superphosphate for the formula 10-8-4, and 3) Availability of the credit and fertilizer materials at the local level in March rather than in May. This latter change was due to the recommendation that a part of the nitrogen and all of the phosphorus be applied at planting time instead of at the first or second cultivation, as had been done previously.

Following the annual meeting of the project in December, 1967, the changes implied by the new recommendation were discussed individually with representatives of the different institutions. The purpose of these discussions was to determine the interest and capacity of each institution to participate in getting farmers to use the recommendations in 1968. In general, it was found that the institutions now accepted the findings of the project, but were uncertain as to their participation. In the case of the three official banks, there was reluctance to introduce changes of the suggested magnitude before their value had been demonstrated in a network of commercial plantings. One bank agreed to make credit available for a few plantings following the recommendation. The general feeling was that more information was needed before the local institutions could recommend to their superiors at the national level that credit policy be changed.

At the time the project was initiated the formula distributed by the Ejido Bank was 10-8-4. This was generally provided in mid-May in time for application as side-dressing in the first cultivation. This formula and procedure gave observable results and the bank was satisfied as it had been able to maintain a high rate of loan recovery. They also indicated that there had been no complaints from farmers. In addition, the existing loan procedures fitted in well with those of the crop insurance agency which was able to inspect the plantings before extending crop protection.

These observations indicate that the responsible people at the state and local levels considered that the changes recommended by the project implied new risks, not only in terms of the additional credit, but also with respect to the prestige of the institution in the eyes of the farmers and the national leaders.

The crop insurance agency maintained that once the new recommendation had been accepted by the credit banks and their clients, such operations could qualify for insurance. However, this agency was found to have well-defined operating procedures that did not permit coverage for individual small farmers. Again, change was necessary for the crop insurance agency to participate, and this meant the presentation of proposals to higher authorities and favorable action at that level.

What changes, if any, were needed for the public banks to become an important factor in raising corn yields? Three stand out as a result of the survey and subsequent experiments in the area: 1) Increased funds were needed to finance fertilizer for a much larger area; 2) The amount allowed per hectare for fertilizer would have to be increased from the existing rates of $411 and $467 to about $700 per hectare; 3) As fertilizer is generally provided instead of cash, the formulas provided and the time they are made available would have to be changed to correspond to results of the soils research in the Puebla Project. This would entail: a) eliminating the potash application which appears to elicit no response in these volcanic soils, and b) applying the fertilizer in two applications — all of the phosphorus and part of the nitrogen in the furrow at planting time, and the rest of the nitrogen in the second cultivation. With these changes in formula and time of application plus greater plant population and better weed control, it appears that the return in additional corn for each peso invested in fertilizer can be nearly doubled in most cases.

A key decision in regard to credit was made by the coordinator and project officials before planting the first "high yield plots" in 1968. Potentially the fertilizer for these plantings could have been considered a demonstration cost. However, as ½ hectare would represent for many farmers as much as half of their total planting, it was thought that providing this free would establish a difficult precedent. Also, it was desired to immediately test procedures for obtaining credit and channeling it to more farmers in the area.

After the three agricultural banks decided not to change their procedures in 1968, alternative private credit was sought. Difficulties were also found in convincing private fertilizer distributors to substitute ammonium sulfate and superphosphate for 10-8-4. The main problem was that distributors had already ordered the 10-8-4, and were not sure they could sell an additional order of fertilizer materials. Also, the distributors were uncertain that farmers would accept the new recommendation and know how to use it properly.

Fortunately, a distributor was found who was willing to provide the fertilizer on credit at a rate of 1½% per month to those farmers recommended by agronomists of the project, with the understanding that the project would underwrite the loans. Credit was also made available for some high yield plots by one of the banks, and some farmers financed their own high yield plots. The total number of these plots, 141, exceeded appreciably the number originally proposed.

The procedure used by Project personnel to authorize credit from the distributor consisted of a simple form with an original and two copies. The technician filled out the form indicating the quantity of simple superphosphate and ammonium sulfate. One copy was given to the farmer, one to the fertilizer dealer and one kept by the agronomist. The farmer then had the obligation to take his form to the fertilizer dealer in Puebla, sign a loan agreement to repay the loan no later than Dec. 10, and transport the fertilizer to his farm to have it on hand well before the time for planting his high-yield plot.

With the initiation of the field trials in 1967, recommendations of agricultural institutions in the area were followed in locating farmers to cooperate in the studies. During the remainder of 1967 and early 1968 this procedure of contacting individual farmers was followed as the program continued to develop. This procedure for contacting farmers was changed in early 1968, largely because of the experience obtained in the evaluation study. As will be described in detail later, a benchmark study was conducted in January and February, 1968, that involved the interviewing of a statistically selected

Signs on the high-yield plots call attention to the fields and to the various organizations participating in the Project.

In general, farmers in the region are not organized. To work with large numbers, in 1969 it was necessary to stimulate the formation of cooperator groups.

sample of 251 farmers. In several villages the reaction of the farmers to the evaluation group was negative and sometimes openly hostile. This experience, together with other observations in the area, made it clear that contact should be made directly with the local or municipal authorities of each community. The Coordinator proceeded to establish contact with each village in the area and hold meetings to explain the objectives and functioning of the project and assess the interest of farmers.

From the time the corn began to flower until harvest the experimental plantings and the high yield plots were used as demonstrations of the importance of improved production practices. Field days were held for representatives of the agricultural infrastructure and for groups of farmers. The field days for the former groups had two principal objectives: 1) convince the leaders of these organizations that recommendations based on these field experiments represented the most reliable information available for increasing yields, and 2) have these leaders become acquainted with the project staff. It was felt that an appreciation for the technical preparation of the staff would enable these leaders to accept the recommendations with greater confidence.

The field days for farmers sought to demonstrate the results they could expect by employing the recommended practices. The following conclusion was stressed: "The experimental results obtained in a given year show how to obtain immediate yield increases. Nevertheless, the information available at any time should be considered tentative, inasmuch as research in subsequent years will almost certainly result in better recommendations." In this way it was hoped to teach the farmers that change is a dynamic and continuous process.

During 1968, audio-visual materials of different kinds were prepared using the results obtained in 1967 and the experimental plantings and high yield plots available. These were prepared specifically for use in reaching large numbers of farmers when the extension effort would be expanded.

As the corn reached maturity a study was carried out to determine average grain yields of farmers' plantings in 1968. Experimental plantings were harvested in October and November and the yield data were analyzed and interpreted. Grain yields of the high yield plots were measured.

At the time of the Second Annual Meeting of the Puebla Project in December, 1968, it was clear that the project demonstrated the following points: 1) Large increases in corn yields could be readily obtained throughout the project area, 2) The results obtained in research, extension, and evaluation had stimulated greater commitment of representatives of the local, state, and national institutions, who now realized that without their participation in the Project its progress would be greatly limited, 3) The farmers who had cooperated in the high yield plots were convinced of the value of the recommendation and were ready to assist other farmers in applying it, 4) The project staff, farmers, and agricultural institutions could be effectively coordinated in working to achieve the goals of the project.

In August 1969 the governor of the State of Puebla, Dr. Rafael Moreno Valle, received a 13-man Guatemalan delegation headed by the vice-minister, Ing. Hector Cabarus Conde. The purpose of the visit was to study the Puebla Project.

INITIATION OF ACTIVITIES IN 1969

The accomplishments by the end of 1968 made it feasible to proceed in 1969 with two major modifications in the operation of the project: 1) research activities were extended to cover the entire area, and 2) extension activities were increased several fold in the western two-thirds of the area.

The major question at this point was how many farmers or how large an area should be reached by the project in 1969. The corn production recommendations, as discussed elsewhere, were modified somewhat for 1969 and were looked upon as highly reliable. The farmers who had cooperated in previous years were prepared to assist in extending the recommended practices to other producers. The agricultural institutions were committed to active participation in the project. Also, some 20 non-technical assistants were trained to assist the project staff in expanding their activities. One further consideration was that the project was committed to doubling the average corn yield in the area by 1972, and to achieve this goal it was important to reach a significant part of the total farming population, perhaps 5 to 10%, in 1969.

A decision was taken only after careful consideration and discussion by the project staff and state representatives of national agricultural institutions. In fact, the decision took the form of a recommended plan of action which was transmitted by the institutions for approval at the national level.

It was decided to increase the number of high yield plots from 141 in 1968 to a goal of about 5,000 in 1969. This meant an increase in the area planted according to the recommendations of the project from about 80 to 10,000 ha. It was expected that the income of approximately 20 to 25 thousand inhabitants of the area would be affected.

To expand the program in this way required a larger project staff. Five young agronomists, who had just completed their professional training, were added. The agronomic practices and corn breeding programs each received one new man, while the extension program received three. A second reason for increasing the project staff was so that a larger number of people would gain experience in the project and thus be available at a later date to help organize similar projects in other areas.

The first annual meeting was held in Puebla in December 1967 and the second in December 1968, in time for cooperating agencies to take into account the experimental results in drawing up plans for the following year. Every effort was made to obtain the full understanding and support of all agricultural institutions in the area.

Expansion of the program to reach 10,000 ha of corn meant that needed credit for fertilizer alone would total about seven million Mexican pesos. Discussions with the different institutions led to the proposal that the Ejidal Bank would finance 2,000 ha, the Agropecuario Bank 1,500 ha, the Agricultural Bank 1,500 ha, and the national fertilizer company, Guanos y Fertilizantes, S. A., through its distributor Impulsora de Puebla, S. A. and the private firm "Agronomos Unidos, S. A.", would finance 5,000 ha. This proposal was approved at the national level.

A modification was also made in the operation of the crop insurance agency. In 1968, each farmer that participated in the project was insured individually. For 1969, it was decided that farmers would have to be organized in groups of 10 or more to qualify for crop insurance.

The plan of action for 1969 implied a drastic change in operating procedures by the four extension agronomists. In 1968 the two farm advisors had worked individually with each cooperator. In 1969, four people had to work with up to 5,000 farmers. Obviously, these farmers had to be organized into groups so that each farm advisor would be working with a reasonable number of groups. The western portion of the project area was divided into four regions, and one of the farm advisors was given the responsibility for extension activities in each.

His first task was to contact any existing organized groups working with any of the credit institutions and then to stimulate the organization of other groups. This work began in early 1969 and continued up to planting time. Meetings were held in each community with a clear exposition of how the farmers could work together to reach higher levels of production. The farmers who cooperated in 1968 were key persons in forming many of the groups.

In working with these groups in his region, the farm advisor informed them of the recommended agronomic practices, credit facilities, availability of inputs, etc. A 16 mm movie and a bulletin prepared in 1968 were very useful at this stage. In addition, a radio program was initiated and used for keeping the farmers continuously informed of new developments.

The field personnel of the participating institutions, especially the credit banks, federal price-support agency, and the crop insurance agency, also assisted in informing farmers of how to employ the recommended practices. Field meetings were held to instruct this personnel in the details of carrying out the agronomic recommendations.

Early 1969 was perhaps the most crucial period in the development of the project. Although the specific functions of the project staff and participating institutions were defined well in advance of planting, there still remained the task of coordinating all activities so that the farmers would have their fertilizers on time. This coordination was made especially difficult by the fact that planting dates in the area vary from early March to late May. The correct fertilizer materials had to be ordered early, freight cars had to be available to transport the material to Puebla, this had to be received by the distributors and despatched to their representatives in the villages, and the farmer had to have credit arranged so that he could pick up the fertilizer that he needed. Problems developed at all points in this chain of events and only through continuous contact by the Coordinator and a clear understanding of the operation of each institution was it possible to reduce to a minimum delays and loss of prospective cooperators.

The four farm advisors played a critical role at the farmer level in assuring an efficient operation of the program. They kept the farmers informed, assisted them in arranging for credit, prepared them for receiving the fertilizers, and instructed them in the correct use of the materials. In their relationship with the farmers, however, the farm advisors operated in such a manner that arrangements for credit and fertilizers were always made between the representatives of the institutions and the leaders of the groups of farmers. In this way the responsibility for procuring credit and agricultural chemicals remained with the individual farmer or the group leader.

AGRONOMIC RESEARCH

THE AMOUNT OF CORN produced on a given area depends upon the soil and climatic conditions, the variety employed, and the management practices used in growing it. The physical environment cannot be readily changed and thus determines the yield potential of a region. Varietal characteristics and management practices, on the other hand, are readily changed by man, and improvement of these factors is his means of achieving higher yields. The objective of the agronomic research in the Puebla Project is to produce information on how to manage the soils and the best available varieties so that farmers may realize maximum returns from their production investments.

GENERAL STRATEGY

Production practices that can be expected to greatly influence corn yields include land preparation, planting date, seeding rate, amount and kind of fertilizers applied, time and method of applying the fertilizers, control measures for weeds, insects, rodents, and diseases, and depth of plowing. With the resources available in 1967, it was not possible to begin research on all of these management aspects. Therefore, the existing information on agronomic practices relevant to the project area was reviewed in order to determine which management studies should be given priority.

Several visits were made to the project area to question farmers concerning their production practices and to observe soil characteristics at many locations. Also, agricultural scientists with experience applicable to the region were interviewed to obtain their ideas on management practices being used by farmers. In this way it was possible to arrive at the following tentative description of existing production methods in the region.

Shortly after harvest in November and December most farmers plow their land and smooth the surface by dragging it with a heavy log or similar object In February and March they plow and smooth the surface a second time. At planting, the land is rowed-out quite deeply and the seeds are placed about 10 cm below the bottom of the furrow by opening the soil with a hand shovel. Generally two to three seeds are planted in hills about one meter apart in rows 90 cm wide. This planting procedure results in about 15 to 25 thousand plants per hectare. The date of planting in different parts of the region was found to vary from early March to the middle of May, depending largely on the amount of residual moisture conserved by the soil and the time and intensity of the rains. Many of the farmers were accustomed to applying a small amount of a fertilizer containing nitrogen, phosphorus and potassium as a side dressing at the time of the first or second cultivation. Weeds were controlled by two cultivations given at about 30 and 60 days after planting. There were no indications that soil insects were a problem, but the rose chafer (*Macrodactylus* spp.) reportedly damaged the corn at time of pollination in certain years. The soils in some areas were found to be quite heavily infested with pocket gophers, which were known to cause significant losses in yield.

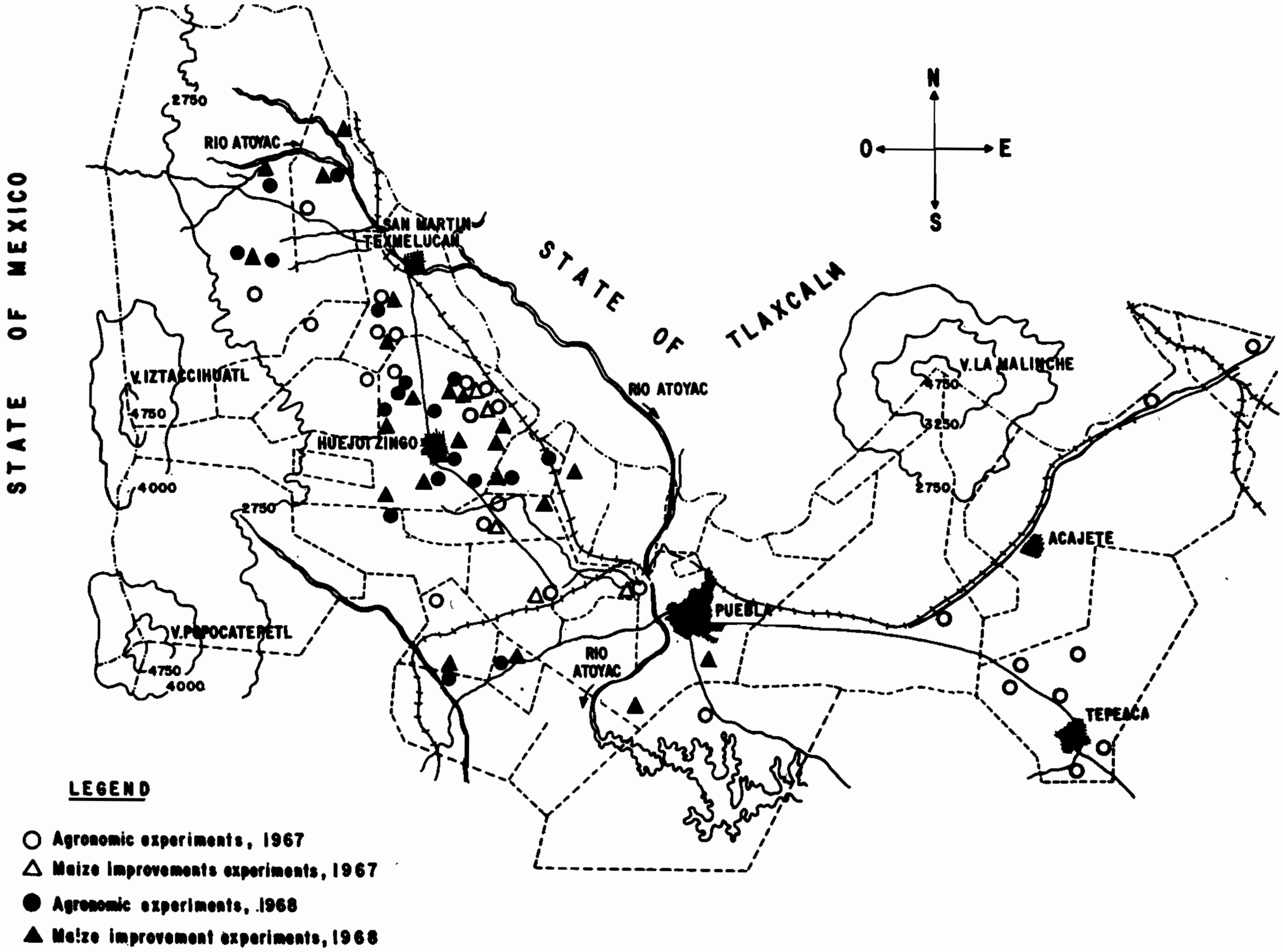


Fig. 2.1. Distribution of agronomic and maize improvement experiments in the summers of 1967 and 1968.

After viewing plantings in the fall of 1966 and studying existing information on agronomic practices, it was decided to focus the first agronomic research on kind, amount and time of application of fertilizer. This is one of the fertilizer trials in 1967.

Research information from the Project area and similar regions indicated that existing management practices were irrational in several ways. Available information suggested that the optimal plant population for the area should be 50,000 per hectare for well-fertilized plantings, instead of the 15 to 25 thousand per hectare that farmers were using. The amount of fertilizer in use was obviously too small, and it seemed likely that the proportion of nitrogen to phosphorus should be increased and potassium should not be applied. Also, it was expected that, in contrast to existing practice, the phosphorus and a small amount of the nitrogen should be applied near the seed at planting time, and the remainder of the nitrogen should be added as a sidedressing.

Although all the production practices were in need of study, it was decided that plant density, kind and amount of fertilizer, and time of applying the fertilizers should be the aspects receiving first priority. Furthermore, it was felt that information from other regions on plant population and time of applying the fertilizers could be extended to the project area with reasonable success. Therefore, it was decided to concentrate the research effort in 1967 on determining the amounts and kinds of fertilizers to apply and postpone other agronomic studies until 1968. The general strategy was to keep the agronomic research program flexible, so that the experimental studies conducted in a given year would take into account the findings of the previous years.

FIELD RESEARCH IN 1967

Description of the experiments

The set of treatments corresponding to a "triple square" matrix was selected for studying the amounts and kinds of fertilizer needed. This consists of 17 treatments comprising seven rates each of nitrogen and phosphorus. The rates used in this study varied from 0 to 360 kg of nitrogen per hectare and 0 to 150 kg of P_2O_5 (phosphorus pentoxide) per hectare.

Mixing ammonium sulfate and simple superphosphate in preparation for the experimental plantings.

This set of treatments was selected because it is particularly efficient when yield data are to be used in describing the quantitative response of a crop to applications of nitrogen and phosphorus. The design also included an additional treatment with either potassium or zinc. Each experiment consisted of 3 replications of the 18 treatments using a randomized complete block design.

Twenty-seven of these fertilizer rate studies were conducted on farmer's fields during the summer of 1967. The experiments were distributed throughout the Project area as shown in Fig. 2.1. The objective was to distribute the experiments uniformly over the area in the hopes of adequately sampling major variations in climate and soils. No information was available at that time on soil variability in the region. Also, only sites that had been used for corn production in 1966 were selected for the study; it was felt that the corn-following-corn sequence was the most important in the region and should receive major consideration. Unfortunately, the time available for selecting the experimental sites was limited, and the distribution of experiments over the area was not as uniform as had been planned. Standard, non-recording rain gauges were installed near each experiment

The fertilizer mixtures corresponding to the experimental treatments were prepared and bagged well before planting time in order to establish the experiments rapidly as soon as soil moisture was adequate.

so that the cooperating farmers could maintain a record of daily rainfall.

The installation of the experiments was begun on April 18 and the last one was planted on June 3; 25 of the experiments had been planted by May 11. The individual plot consisted of 6 rows 8 meters long, so the total area occupied by an experiment was approximately 0.3 ha. The phosphorus, potassium, zinc, and one-tenth of the nitrogen was applied in a band in the bottom of the furrow. The insecticide, Aldrin, was applied as a dust along the furrow for the control of subterranean insects. The local variety, Pinto de Salvatori, was seeded in 10 experiments, Amarillo de Salvatori in 13 experiments, and Amarillo Rubin in 4 experiments. Four or five seeds were placed in hills 44 cm apart and at a depth of 10 to 15 cm below the bottom of the furrows. The experimental areas were usually smoothed by dragging the surface with a log after completing the plantings.

When the young seedlings were about 15 cm tall, the plants were thinned to two per hill, corresponding to a population of 50,000 plants per hectare. At the time of the second cultivation, when the corn was about 60 cm tall, the remainder of the nitrogenous fertilizer was applied as a sidedressing. Weeds were effectively controlled by the two usual cultivations. Rose chafer infestation was sufficently severe to warrant control at only one location. Pocket gophers caused limited damage at about one-third of the sites and were controlled.

During the course of the growing season the experiments were visited regularly and observations were made on the conditions affecting growth. A pit was dug near each experiment and a description of the soil profile was made. The principal factor limiting yields was drought during the month of July and early August. As the corn in these experiments tasseled during the period July 10-August 15, most of the drought occurred at the time when the crop was most susceptible to damage. According to the observations on plant wilting, the corn was severely affected by drought at 10 sites, slightly affected at 11, and unaffected at 6. Monthly precipitation values for each experiment, estimated rooting depths of corn, and the severity of plant wilting are shown in Table 2.1. The degree of wilting is related to the

Soil samples were taken from all experimental sites and laboratory measurements were made later to determine levels of available plant nutrients.

amount of rainfall, especially in July and August, and to rooting depth, but other factors are obviously also involved.

As soon as the grain reached maturity, the ears were harvested from the four inside rows of each plot. These ears were weighed and the moisture content of the grain was determined gravimetrically. Observations were made on the percentage of rotten kernels, pollination percentage, and shelling percentage. The experiments were harvested from October 6 to 28.

Experimental sites were over-planted to make some allowance for damage by rodents and gophers. Control measures were taken as soon as there was evidence of damage.

Discussion of the results

The yield data from each experiment were converted to yield of grain with 12% moisture. Plot yields were adjusted for differences in plant population by means of a covariance analysis. Average grain yields in kilograms per hectare for the 18 treatments at the 27 locations are given in Appendix Table XIX.

A significant increase in yield due to the application of nitrogen was observed in 22 experiments. Phosphorus applications increased yield at 15 sites. Application of potassium and zinc did not increase yield at any location.

In five of the experiments, yields were not significantly increased by the application of fertilizers. At two of these locations the lack of response was due to severe drought damage; at one site the land had been in alfalfa previously and produced 6800 kg/ha without fertilizers; at the other two sites yields from the unfertilized plots were unaccountably high (3.2 ton/ha) and soil variability within the experiments was very great.

The maximum yield increases at the 22 locations where applications of nitrogen and phosphorus gave

Experiments were located on the land of 27 cooperating farmers in 1967. The farmer himself prepared the land, did the cultivations, etc., following the instructions of the soil scientist. The Project also hired and trained a number of field assistants, young local farmers, who assisted in the planting and gave additional hand weeding where needed in order to assure a perfectly clean stand.

TABLE 2.1. Monthly precipitation in millimeters during the period May-October at the sites where experiments were conducted in 1967. The estimated rooting depths of corn in the soils and the severity of plant wilting due to drought are indicated.

Experiment No.	Name	Precipitation in mm May	June	July	Aug.	Sept.	Oct.	Est. rooting depth cm	Degree of wilting Before tasseling	After tasseling
Northern Zone										
15	El Verde	*6.0* *	101.5	109.5	124.5	182.0	*41.0*	60	Severe	None
16	Atzizintla		97.0	108.5	127.5	166.5	51.7	68	Severe	None
21	Tlalancaleca		104.0	95.5	148.0	255.9	*82.0*	49	Severe	None
Central Zone										
1	Xalmimilulco	*33.0*	144.0	65.0	126.5	87.0	*9.0*	160	None	None
4	Moyotzingo		115.1	79.0	135.8	117.5	136.0	120	Light	None
8	Cuanalá	*48.5*	183.0	39.0	217.7	155.5	*73.0*	200	None	None
9	Cholula	*29.5*	163.0	28.0	141.5	88.5	*20.5*	120	Light	None
11	Mextla	*42.0*	101.5	78.5	151.0	172.5	94.5	55	Severe	None
12	Cerritos	*42.0*	101.5	78.5	151.0	172.5	94.5	62	Severe	None
13	Xalmimilulco	*33.0*	144.0	65.0	126.5	87.0	*9.0*	82	Severe	None
14	Chautenco		175.5	28.0	192.0	142.0	*89.0*	30	Light	None
19	Tlacoligian	90.0	239.0	84.5	204.0	197.0	*62.0*	180	Light	None
20	Teotlaltzingo		131.5	97.0	123.0	207.0	78.5	150	Severe	None
25	Zacatepec	*25.0*	128.5	42.5	162.5	214.5	*40.5*	160	Light	None
Eastern Zone										
2	Hueyapan	*35.5*	203.0	81.5	113.0	105.8	*141.0*	75	None	None
3	Amozoc	*35.5*	205.5	68.0	128.2	194.0	*86.0*	150	None	Light
10	Xilotzingo	*40.0*	152.5	48.0	280.5	205.5	*63.0*	50	Light	None
17	Nopalucan	*34.0*	112.0	60.5	90.0	121.0	*117.5*	200	Severe	Severe
18	Bautista Mier	*41.0*	143.5	68.0	95.0	110.0	61.5	160	Light	Light
22	Ocotitlán	*30.0*	145.0	64.0	76.0	138.0	*45.0*	80	None	None
23	Memetla	*30.0*	145.0	64.0	76.0	138.0	*45.0*	85	None	None
24	Tolentino		213.5	69.5	133.0	152.0	117.0	160	Light	None
26	Tepeaca		142.0	18.0	114.0	219.0	162.0	60	Severe	None
27	Tepeaca		117.5	16.5	115.0	157.0	*80.0*	110	Severe	None

* Italicized values represent the recorded rainfall for months with incomplete records.

significant effects are shown in Table 2.1. Yields without the application of fertilizer varied from 30 to 3540 kg/ha, with an average value of 978 kg/ha. Maximum increases due to fertilization varied from 720 to 6990 kg/ha, with an average increase of 3672 kg/ha.

Recommendations

The average treatment yields from each location were used to calculate the quadratic equations that express the relationship between corn yield and the amounts of applied nitrogen and phosphorus. These

To assure a population of 50,000, plantings were thinned back to two plants per hill. Spacing between hills was approximately half that normally used by farmers in the area.

equations, which are given in Appendix Table XX, were used to estimate the optimal rates of fertilization for the conditions studied in the experiments. The partial derivatives of yield with respect to nitrogen and phosphorus were calculated for each equation and were set equal to the cost-price ratios for nitrogen and phosphorus, respectively (C_N/C_Y and C_P/C_Y in Table 2.3). The two equations, corresponding to the two partial derivatives in each case, were solved simultaneously to obtain the optimal rates of nitrogen and phosphorus. This procedure for estimating optimal rates was considered appropriate for those farmers who would be purchasing fertilizers with credit backed by crop insurance. The information in Table 2.3, which was used in calculating the cost-price ratios, was obtained from farmers and representatives of the agricultural credit banks in the project area.

In 17 of the 22 experiments with significant responses to applied nitrogen, the estimated optimal rates of nitrogen fertilization for farmers operating with insured credit varied from 79 to 221 kg/ha, with an average of 142 kg/ha. The magnitude of corn response to applied nitrogen at the other 5 locations was very small due to drought damage. Four of these sites were in the Grajales and Tepeaca areas which were to be eliminated from the project. As mentioned earlier the corn was severely affected by drought at 10 locations and slightly affected at 11 others, which

To avoid defective pollination, in one planting it was necessary to control the rose chafer at flowering time.

TABLE 2.2. The maximum effects of fertilization in the experiments carried out in 1967. Yields are expressed in kilograms per hectare of grain containing 12% moisture.

No. of experiment	Yield without fertilizer	Yield with best fertilizer treatment	Increase due to fertilization
02	100	6470	6370
04	150	5750	5600
05	30	5290	5260
06	510	4620	4110
07	250	5520	5270
08	510	7500	6990
09	1010	4100	3090
10	410	3210	2800
11	30	5660	5630
12	200	3790	3590
14	630	2600	1970
15	2880	4100	1220
16	1490	6510	5020
17	1990	2710	720
18	3540	4660	1120
19	480	3580	3100
20	830	4640	3810
21	2290	4600	2310
22	1490	4480	2990
23	970	4450	3480
25	320	5050	4730
27	1400	3020	1620
Average	978	4650	3672

TABLE 2.3. Information used in estimating the optimal rate of fertilization employing the equations calculated for each experiment. All costs and prices expressed in terms of Mexican pesos.

Costs involved in using fertilizers:

1. Kilogram of nitrogen = $4.00
2. Kilogram of P_2O_5 = $2.81
3. Transportation of fertilizers = $80/ton = approximately $0.40 per kilogram of nitrogen or P_2O_5
4. Application of fertilizers = $160/ha = approximately $1.00 per kilogram of nitrogen or P_2O_5
5. Harvest = $100/ton of grain
6. Shelling = $180/ton of grain
7. Crop insurance = 5.9% of amount insured

Total costs per kilogram of nitrogen = $5.93 = C_N

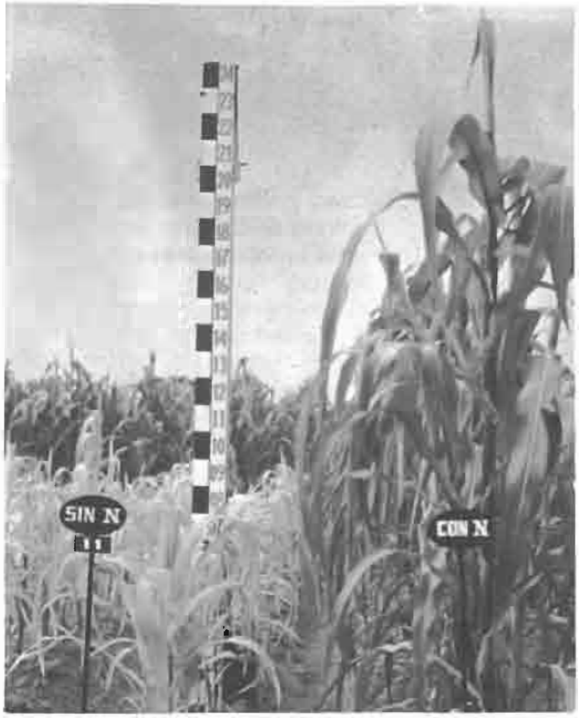
Total costs per kilogram of P_2O_5 = $4.74 = C_P

Price of grain = $815/ton

Price of grain after discounting costs of harvest and shelling = $535/ton = $0.535/kg = C_Y

$$C_N/C_Y = \frac{5.93}{0.535} = 11.08$$

$$C_P/C_Y = \frac{4.74}{0.535} = 8.86$$

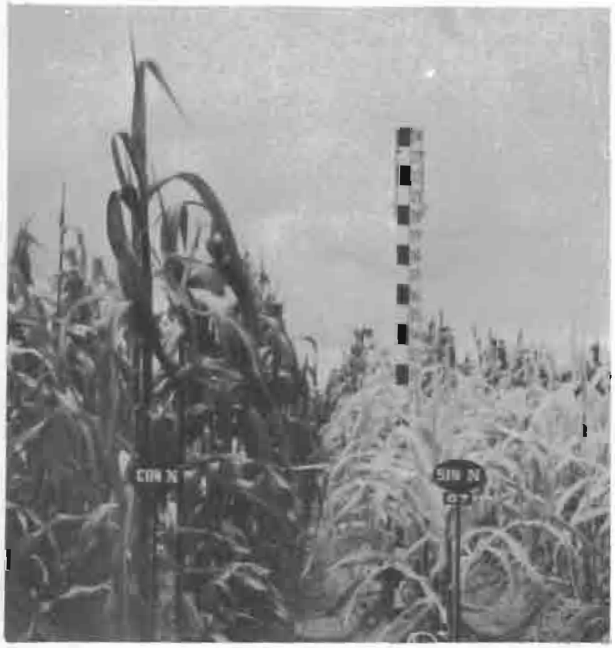

SIN N
11
CON N

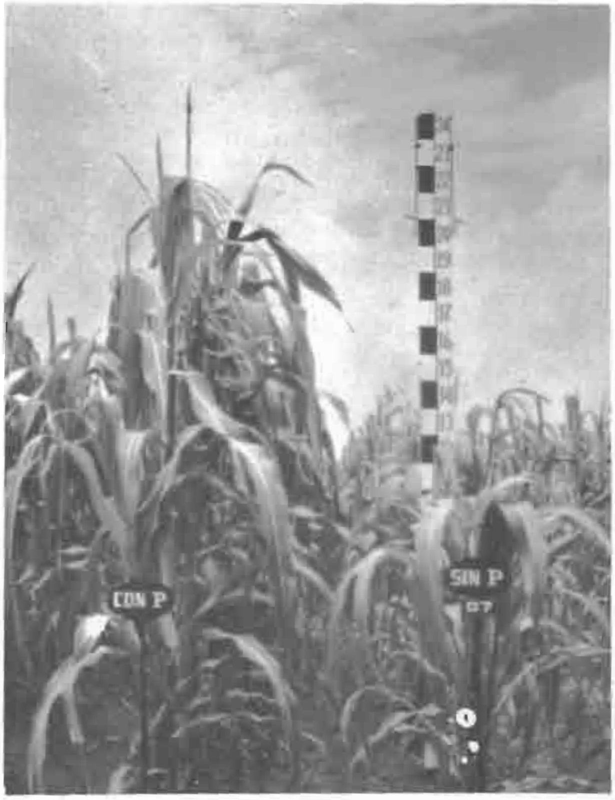
SIN P
CON P

SIN N
CON N

CON N
SIN N
20

Plantings responded to nitrogen fertilization at 22 of the 27 experiments, in many cases dramatically as can be seen in the photos on these pages. There was also a response to phosphorus in 15 of the 27 plantings, but it was less and usually appeared in the form of an interaction with nitrogen. In one extreme case the difference in yield between the no-fertilizer treatment and the best application was 6,990 kg/ha of shelled corn.





represents a drought effect much greater than the average estimated from historical rainfall records. Eliminating the results from the Grajales and Tepeaca regions and assuming that 1967 was a drier than average year, it was concluded that the recommended rate of nitrogen fertilization for farmers with insured credit should be about 130 kg/ha.

At most of the 15 sites where maize responded to applications of phosphorus, the effect appeared mainly as an interaction between nitrogen and phosphorus. Consequently, it was not possible to make a reliable estimate of the optimal level of phosphorus fertilization for the several sites. The available information indicated that farmers with insured credit should use about 40 kg of P_2O_5 per hectare. Thus, the general fertilizer recommendation for the 1968 season for those farmers with insured credit was 130 kg of nitrogen plus 40 kg of P_2O_5 per hectare. It was suggested that one-tenth of the nitrogen plus the phosphorus should be banded in the furrow at planting time, and the remainder of the nitrogen should be applied as a sidedressing at the second cultivation when the corn plants were about 50 cm tall. The plant population used in the fertilizer experiments, 50,000 per hectare, was made a part of the general recommendation.

Farmers whose investment in fertilizers is not insured may occasionally suffer a loss and, consequently, should probably expect a higher marginal gain than those with insured credit. For the former category of farmers it was assumed that the marginal gain should be 50% greater than the marginal cost. Based on this economic consideration optimal rates of fertilization were again calculated for the several experiments. The recommended fertilizer practice for uninsured farmers was found to be 100 kg of nitrogen plus 30 kg of P_2O_5 per hectare. The recommended time of application of the fertilizer, as well as the plant population, were the same as for farmers with insured credit.

The costs of the recommended fertilizer treatment in terms of kilograms of grain were calculated using the data in Table 2.3. Also, the yield equations for the several experiments were used to estimate the average expected increase in yield from the use of the recommended practices. As seen in Table 2.4, the average expected increase from each of the recommendations was approximately double the total cost of the practice.

Farmers will also receive two additional benefits from using the recommended fertilization practices: (a) The production of stalks which may be sold or used as forage will be increased in roughly the same proportion as that of grain, and (b) farmer employment, and consequently his income, will be increased by the time spent in applying fertilizers and harvesting and shelling the ears.

TABLE 2.4. The general fertilizer recommendations for two categories of farmers, the costs of the practices, and the average expected increases in yield resulting from their use.

	Farmers with insured credit	Farmers without insured credit
Recommendation	130-40-0	100-30-0
Cost of practice expressed in kg of corn	1795	1374
Expected average increase from practice (kg/ha)	3300	2600

FIELD RESEARCH IN 1968

Description of the experiments

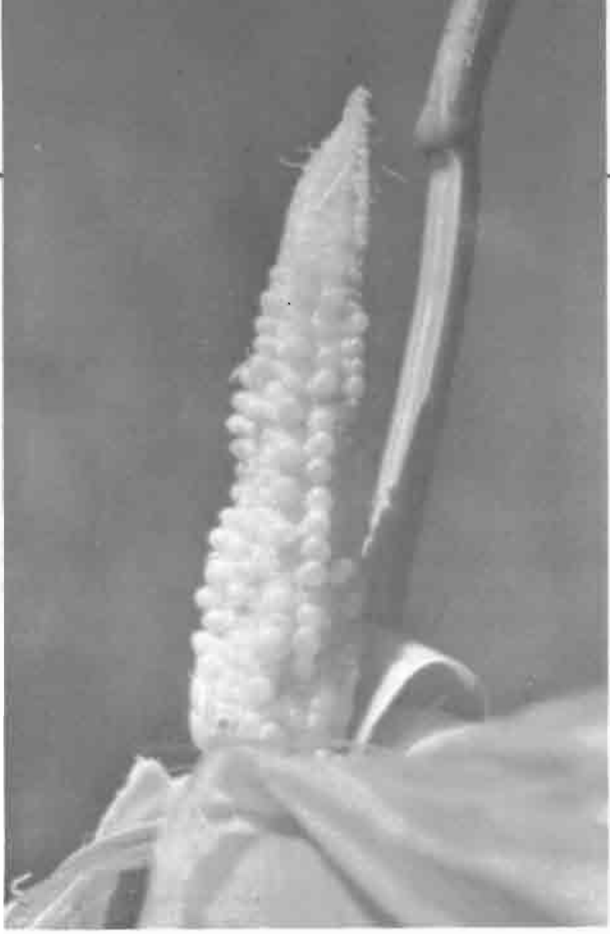
The agronomic research program was broadened in 1968 to include several new types of studies:

Line of research	No. of expts.
Fertilizer rates and plant densities	8
Dates of planting	4
Time of applying fertilizers	2
Depth of the second cultivation	2
Fertilization of corn in orchards	2
Residual effects of fertilizers	1

The randomized complete block experimental design was used in all experiments except those for dates of planting which employed a split-plot design. As in 1967, the individual plot consisted of 6 rows 8 meters long, except in the residual effects experiment.

The set of treatments selected for studying fertilizer rates and plant densities corresponded to the "double cube" matrix, quite similar to that used in the fertilizer experiments in 1967. It consists of 23 treatments comprising five levels each of nitrogen, phosphorus and population. Rates of nitrogen in these experiments varied from 0 to 200 kg/ha, rates of phosphorus from 0 to 100 kg of P_2O_5 per hectare, and densities from 30 to 70 thousand plants per hectare. Three additional treatments were included in each experiment to measure the effects of potassium and zinc. Two replications of the 26 treatments were used at each location.

The 8 rates-densities studies were distributed as uniformly as possible over the western two-thirds of the project area as shown in Fig. 2.1. The procedures followed in installing the experiments and in taking observations were similar to those described earlier. Monthly precipitation values for each experiment, estimated rooting depths of corn, and the severity of plant wilting are given in Table 2.5. According to the field observations the corn was severely affected by drought at 4 locations, slightly affected at 2, and unaffected at 2.



The evidence of drought, rose chafer attack, or other factors which may affect pollination, appear later in the form of incomplete seed set.

The experimental data from 1967 gave a good idea of the soil variability in the area. Consequently, for 1968 only 8 fertilizer rate trials were planted, but 3 levels of plant population were added. In addition, other studies were initiated such as dates of planting, time of fertilizer application, effects of deep cultivation, and the study shown here to determine the best rate of fertilization on corn interplanted with fruit trees.

Four dates of planting studies were carried out in the central part of the project area. These experiments consisted of 6 varieties, 6 dates of planting spaced approximately 15 days apart, and 3 replications. Two experiments were installed in soils with a high water table which made it possible to initiate the plantings during the first 10 days of March. The other two trials were carried out under average rain-fed conditions, and the first planting was made during the last half of April.

The correct time for applying both nitrogen and phosphorus was studied at two locations in the central part of the area. Each experiment consisted of 21 treatments involving 3 rates of nitrogen (0-150 kg/ha), 4 rates of phosphorus (0-90 kg/ha of P_2O_5), and three times of application (planting, first cultivation, second cultivation). Three replications were used.

The effects of deep plowing when the corn plants were 6 and 8 weeks old were compared with shallow plowing at 8 weeks in studies carried out at two locations. The plants were about 50 cm tall at 6 weeks and one meter tall at 8 weeks. The three treatments were replicated 13 times.

A significant part of the corn in the project area is planted in the spaces between rows of fruit trees. The distance between rows of trees varies from 5 m to

TABLE 2.5. Monthly precipitation in millimeters during the period April-October at the sites where the rates-densities experiments were conducted in 1968. The estimated rooting depths of corn in the soils and the severity of plant wilting due to drought are indicated.

Experiment No.	Name	April	May	June	July	Aug.	Sept.	Oct.	Est. rooting depth cm	Degree of wilting Before tasseling	Degree of wilting After tasseling
Northern Zone											
10	Guadalupe Zaragoza		89.2	262.7	124.7	179.0	215.5	142.4	20	None	Severe
11	Ixtapalucan	*21.9* *	74.3	188.2	63.4	80.2	98.2	*29.3*	50	None	Severe
12	Tianquistengo			*53.3*	95.7	83.5	92.0		120	Light	Severe
Central Zone											
06	Tlaltenango	71.0	68.5	232.0	78.0	75.5	68.5	74.0	200	None	Severe
07	San Esteban			212.0	91.6	97.5	119.0	37.2	200	None	Light
08	Atzompa	21.3	68.0	267.9	55.0	48.0	188.0	*46.0*	200	Light	Light
09	Calpan	*66.8*	92.1	166.2	136.0	98.5	110.5	134.5	200	None	None
13	Tecuanipan	31.6	102.1	113.3	81.8	68.5	105.9		200	None	None

* Italicized values represent the recorded rainfall for months with incomplete records.

more than 10 m. Information is needed as to how corn grown under these conditions should be fertilized. Two experiments were carried out in which 3 rates of nitrogen (0 to 160 kg/ha) and 3 distances between the row of trees and the first row of corn were studied. Three replications of the 9 treatments were used.

Nitrogen and phosphorus applied to the soil in a given year may affect growth during subsequent years. To measure the importance of the residual effects of fertilizers under the soil and climatic conditions of the project area, an experiment with 3 replications of 4 fertilizer treatments was established. Information will be obtained from this study in 1969

Seed samples were taken at harvest in all plots, moisture percentages were determined, and grain weights were converted to a constant 12% moisture.

when the plots, consisting of 14 rows 14 meters long, will be subdivided and different rates of nitrogen and phosphorus applied.

The experiments were harvested as soon as possible after the grain reached maturity. Observations were made on percentage of rotten kernels, pollination percentage, and bird damage. The moisture content of the grain was determined gravimetrically. The experiments were harvested during the period Sept. 28-Oct. 31, except for certain dates of planting.

Results and Recommendations

Average grain yields for the 26 treatments in the 8 rates-densities studies are given in Appendix Table XXI. Yields were significantly increased by applying nitrogen and increasing plant density at the 8 locations. The addition of phosphorus significantly increased yields in all experiments except number 12. Applications of potassium and zinc did not significantly affect yield in any of the trials.

The maximum increases in yield due to the application of fertilizers and the modification of plant densities are shown in Table 2.6. The average yield without fertilization and with 30,000 plants per hectare was 1171 kg/ha, slightly larger than the average unfertilized yield in the 1967 experiments, 978 kg/ha. The average maximum increase due to fertilization and higher plant density was 5760 kg/ha. This is 57% larger than the average maximum yield increase reported in 1967. The larger increases in yield in 1968 were due to the effect of plant density, a less severe effect of drought, and possibly to other more favorable climatic or soil conditions.

The fertilizer trials in 1968 confirmed the desirability of heavy nitrogen applications and made possible specific recommendations for the main soil types in the area.

TABLE 2.6. The maximum effects of fertilization and population in the rates-densities studies carried out in 1968. Yields are expressed in kilograms per hectare of grain containing 12% moisture.

No. of experiment	Field without fertilizer and with 30,000 plants/ha	Yield with best fertilizer and density treatment	Increase due to fertilization and population
06	210	7610	7400
07	810	8790	7980
08	2200	7770	5570
09	1280	8630	7350
10	870	4500	3630
11	850	7040	6190
12	2510	5600	3090
13	640	5510	4870
Average	1171	6931	5760

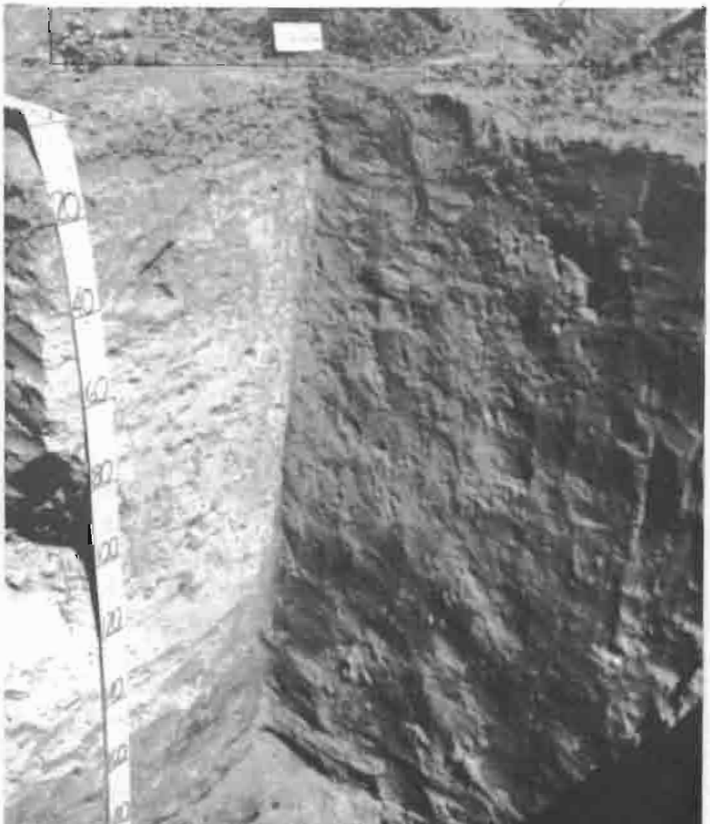
The quadratic equations that express the relationship between yield and the amounts of applied nitrogen and phosphorus and plant density for the results obtained in the 8 experiments are presented in Appendix Table XXII. The optimal rates of nitrogen, phosphorus, and population were calculated for each equation following the procedure mentioned earlier and the cost-price ratios given in Table 2.3. Optimal rates were calculated for farmers without insured credit, as the experience in 1968 indicated that this was a more realistic assumption at the present time.

The estimated optimal rates of fertilization and optimal plant densities for the 8 experiments are given in Table 2.7. Optimal rates of nitrogen vary from 102 to 200 kg/ha, optimal rates of P_2O_5 from 0 to 95 kg/ha, and optimal plant densities from 42 to 70 thousand plants per hectare.

As mentioned in a previous chapter, the study of soil profiles in 1967 and 1968 led to a separation of the project area into several sub-areas on the basis of

TABLE 2.7. The estimated optimal rates of fertilization and optimal plant densities for the experiments carried out in 1968.

No. Name Location	Estimated optimal levels Nitrogen kg/ha	P_2O_5 kg/ha	Thousands of plants per hectare
06 Xometitla	200	40	70
07 San Esteban	199	50	70
08 Atzompa	148	65	70
09 Calpan	189	86	70
10 Guadalupe Zaragoza	117	73	46
11 Ixtapalucan	137	95	50
12 Tianguistengo	102	0	53
13 Tecuanipan	133	76	42



Pits such as this one were dug at each experimental site in order to obtain an accurate description of the soil profiles.

morphological differences of the soils (Fig. 1.2). Five of the experiments conducted in 1968 were located in the region of deep, light-textured soils; the other three (10, 11, 12) were in the region of shallow soils in the northwest.

The estimated optimal rates of nitrogen for the 5 experiments located on deep, light-textured soils varied from 133 to 200 kg/ha with an average of 174 kg/ha; estimated optimal rates of P_2O_5 varied from 40 to 86 kg/ha with an average of 63 kg/ha; and estimated optimal plant densities varied from 42 to 70 thousand per hectare with an average of 64 thousand per hectare. Thus, the average optimal practice should be 174 kg of nitrogen, 63 kg of P_2O_5, and 64,000 plants per hectare. However, this is considerably greater than the recommended practice estimated in 1967 for farmers without insured credit (100 kg of nitrogen, 30 kg of P_2O_5, and 50,000 plants per hectare). Therefore, it was decided to select an intermediate practice — 130 kg of nitrogen, 50 kg of P_2O_5, and 50,000 plants per hectare — as the general recommendation for deep, light-textured soils for 1969.

The averages of the estimated optimal levels of nitrogen, P_2O_5 and plant density for the three locations on shallow soils of the northwest were 119 kg/ha, 56 kg/ha, and 50,000 per hectare, respectively. As no separate recommendation for these soils was calculated in 1967, it was decided to recommend 110 kg of nitrogen, 50 kg of P_2O_5, and 50,000 plants per hectare for plantings on shallow soils of the northwest in 1969. Although no experiments

The goal of the agronomic research — to be able to make precise recommendations on the kind and amount of fertilizer application which will give the farmer the greatest return on his investment.

were conducted on the shallow *tepetate* soils in the north central region, the above recommendation was extended to corn plantings on these soils.

The corn yields obtained in the four dates of planting experiments are summarized in Appendix Table XXIII. The results reported for the four locations were averaged for each of the six varieties to determine optimal dates of planting. The loss in yield per day for plantings made before or after the optimal planting period were estimated. Optimal dates of planting and estimated yield losses for early and late plantings are given in Table 2.8. The effect of date of planting on yield is shown graphically in Fig. 2.2 for Colorado Precoz and H-129.

The optimal planting period for Colorado Precoz was the month of April, and both earlier and later plantings yielded less. The other 5 varieties yielded about the same for plantings made in March and early April. Yields declined quite rapidly and in essentially a linear fashion for plantings made after April 15. Although the best planting period for these varieties appears to be March and the first half of April, farmers will not always be able to plant during this period because of insufficient soil moisture.

For early plantings, March 6 to April 15, the best varieties were H-129, Pinto Salvatori, and Blanco Salvatori; H-28 yielded only slightly less. For plantings during the period April 15 to June 20, the same four varieties performed the best. For plantings after June 20 the highest yielding varieties were H-28 and Colorado Precoz.

TABLE 2.8. Optimal planting dates and estimated yield losses for early and late plantings for six corn varieties.

Variety	Optimal dates for planting	Loss in yield (kg/day) for: Early plantings	Late plantings
Colorado precoz	April 1-30	40	51
Amarillo Salvatori	Mar. 6-31	—	48
Pinto Salvatori	Mar. 6-Apr. 15	—	63
Blanco Salvatori	Mar. 6-Apr. 15	—	73
H-28	Mar. 15-Apr. 15	—	63
H-129	Mar. 6-Apr. 15	—	77

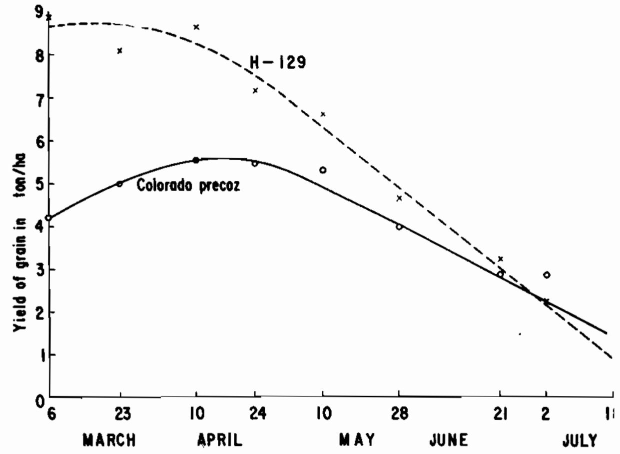


Fig. 2.2. The effect of date of planting on the yield of two corn varieties.

The yield data obtained at two locations where the effect of time of application of nitrogen and phosphorus was studied are given in Appendix Table XXIV. Applications of phosphorus did not significantly affect corn yields at either location, son differences reported in this table were due only to nitrogen. The average effect of time of application of nitrogen on corn yields at the two locations is presented graphically in Fig. 2.3. At the 75 kg/ha rate of fertilization, apparently yields were slightly lower when all of the nitrogen was applied at planting time. When 150 kg/ha of nitrogen was applied, yields were about the same for the four time schedules of application. Additional information is needed on the effect of time of application of fertilizers on yield. Meanwhile, it is recommended that 20 kg of nitrogen plus all the phosphorus be applied in the row at planting time, and the remainder of the nitrogen be added as a sidedressing at the second cultivation.

TABLE 2.9. The effect of deep plowing at the second (last) cultivation on corn yields, expressed in kilograms per hectare of grain containing 12% moisture.

Characteristics of second cultivation: Type of plow	Depth of plowing cm	Age in weeks of corn	San Mateo	San Matías
Wooden	10	8	4930	
Double moldboard	20	6	4620	4900
Double moldboard	20	8	4570	4780
Cultivator				4920
LSD at 5% level			588	404
Error mean square			540690	256530
Coefficient of variation			15.6	10.4

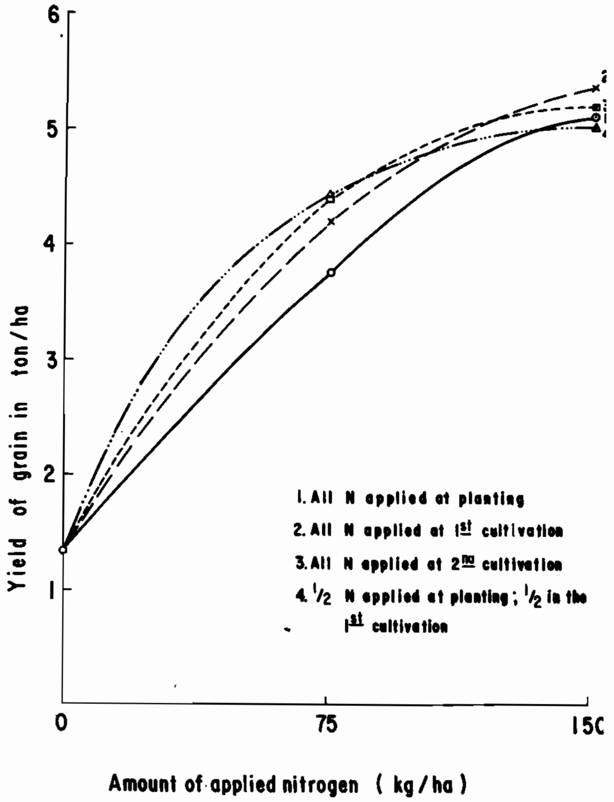


Fig. 2.3. The average effect of time of applying nitrogen on corn yields at two locations.

The corn yields obtained at two locations with three methods of plowing at the last cultivation are given in Table 2.9. Yields were not significantly reduced by deep plowing as late as 8 weeks after planting.

The effect of nitrogen fertilization on the yield of corn planted in the space between rows of fruit trees is shown graphically in Fig. 2.4. Competition by the ten year old trees had no effect on the yield and response to fertilizer of the second and subsequent rows and a very minor effect on the first row. Competition by the twenty-five year old trees reduced corn yields in the first and second rows but had no appreciable effect on corn in rows farther away.

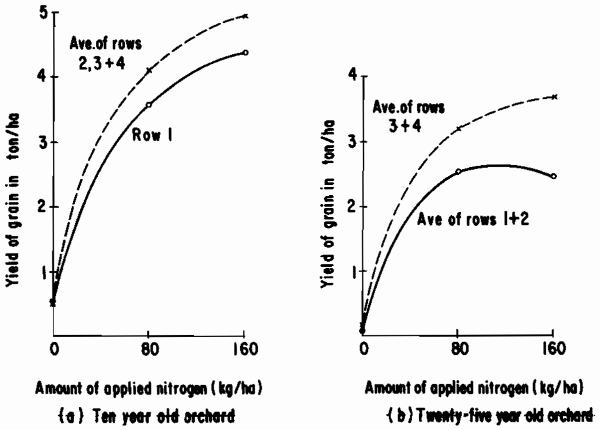


Fig. 2.4. The effect of nitrogen fertilization on the yield of corn from rows at different distances from the line of trees in ten and twenty-five year old orchards. Rows 1, 2, 3, and 4 correspond to the first, second, third, and fourth row from the line of trees, respectively.

These results were used to arrive at the following recommendations for fertilizing corn plantings between fruit trees: (a) In young orchards — up to 10 years old — fertilize every row of corn with the general recommendation (e.g., 130-50-0 for deep, light-textured soils); (b) In old orchards, rows of corn beneath the branches should receive two-thirds of the general nitrogen recommendation (e.g., 87-50-0 for deep light-textured soils); other rows should receive the general recommendation.

AGRONOMIC PROGRAM FOR 1969

The agronomic research program in 1969 was extended to cover the entire project area. The types of studies that are being conducted and the number of experiments in each case are as follows:

Line of research	No. of expts.
Fertilizer rates and plant densities	14
Rates of manure and fertilizers	3
Dates of planting	2
Time of applying fertilizers	5
Preparation and cultivation practices	1
Residual effects of fertilizers	1
Fertilization of corn in orchards	1

Based on the results obtained in 1968, two modifications were introduced into the rates-densities studies. The nitrogen levels in the experiments which are being planted in the deep, light-textured soils will range from 80 to 240 kg/ha, and densities will vary from 30 to 82 thousand plants per hectare. The elimination of very low rates of nitrogen from the experiments carried out on soils that are very low in nitrogen will make it possible to obtain data that can be represented more accurately by a quadratic equation. Higher plant populations are included because a maximum was not reached in 1968 with 70,000 plants per hectare.

The rates of application experiments comprise five rates each of nitrogen, phosphorus and chicken manure. A study of the comparative effects of manure is being made this year because: (a) farmers in parts of the area contend that chicken manure is superior to chemical fertilizers, and (b) visual comparisons of the 1968 field trials with neighboring fields fertilized with chicken manure indicated that the corn in the latter field often developed more vigorously. The effect of applying a magnesium salt to the soil at planting time is also being studied in these experiments. Leaf chlorosis observed in 1968 in young corn plants in different parts of the area suggested that a magnesium deficiency may limit corn yields on certain soils.

The dates of planting studies will retain three of the varieties used in 1968 (H-129, Pinto Salvatori, Rojo Salvatori). In addition, the local variety grown by the cooperating farmer will be included plus a composite of the cryptic double crosses that were most outstanding in the comparisons made in 1968. The land preparation and cultivation practices experiment is being added this year to study: (a) the importance of the current practice of many farmers to plow and smooth the surface of their land as soon after corn harvest as possible, and (b) the effectiveness of minimum tillage that would reduce labor and possibly wind erosion during the winter and early spring.

During November 1968, composite samples consisting of 20 cores each of the surface 15 cm of soil were collected at 58 sites distributed as uniformly as possible over the area east of the city of Puebla (Fig. 1.2). These samples were analyzed for pH and available phosphorus and potassium by the Soil Testing Laboratory, North Carolina State University, Raleigh, North Carolina. Maps were prepared showing the levels of pH, phosphorus, and potassium of the soils in the eastern area. In general, there was a tendency for nutrient levels to vary in accordance with their distance from the volcano La Malinche. This information was useful in selecting the sites where the fertilizer rate studies are being conducted in the eastern area.

GENETIC IMPROVEMENT PROGRAM

PRIOR TO THE INITIATION of the Puebla Project, very little varietal testing or study of the native varieties had been done in the region. It was known that Chalqueño and Conico were the predominant races in the area. And yield tests carried out during the late 1950's and early 1960's indicated that some hybrids and improved varieties for similar altitudes in other parts of Mexico were better than the local varieties in certain years and for certain specific localities. However, as shown by the evaluation data, at the time this project was begun, most farmers were still planting their native varieties. In a few cases they had made selections from a mixture of these varieties and certain introduced varieties or hybrids.

A limited survey of corn plantings in the region during the early fall of 1966 suggested that a first step should be to field test a wide range of germ plasm in a search for lines with greater yield potential. No single disease appeared to present serious limitations, but a variety was needed with greater resistance to lodging and more responsive to fertilizer.

STRATEGY OF GENETIC IMPROVEMENT

It was acknowledged from the outset that the genetic improvement program must take into account the following factors:

1. Farmer preferences. In the Puebla area, two principal types of corn are grown. The majority of the plantings are made in mid-April with a late matur-

ing corn (170 days) utilizing residual moisture for germination and early growth. If farmers must delay their plantings because of insufficient moisture, they prefer to plant a shorter season corn. Such early maturing corns are also used by farmers in areas where they must plant in early March to avoid damage from excess water later in the season. Farmer preference also indicated the desirability of attempting to develop an improved seed which would not have to be replaced with new seed each year.

2. Since the proposed life of the project was only five years, new varieties or hybrids would have to be developed no later than the third year of the project if they were to have a significant effect on average production within this time period. If sufficient seed of an improved corn variety or hybrid was to be available for widespread plantings during the 5th year, the 4th year would be utilized principally in increasing the seed. It was apparent that conventional hybrid corn breeding methods would take too much time.

Two methods were chosen for attaining the desired genetic improvement: mass selection and development of cryptic double-cross hybrids.

The genetic work within the Project calls for exceptional speed in order to obtain a variety or hybrid with greater yield potential by the end of the third year. Two crops per year are obtained by planting in the winter at lower altitude.

Mass selection was chosen on the basis of past experience that when done properly one may expect immediate and long term increases in yield varying between 4 and 10% per year. In addition, since the selection would be done with farmer cooperation, they would have improved seed available immediately and could continue to attain better yielding corns through their own efforts after the project itself was terminated. This method involves the selection of desirable plants at representative experimental sites in the area. The desired plants would be high yielding, prolific, healthy, low-eared and non-lodged. They would be selected in carefully controlled plantings having complete and uniform competition between plants. Equal quantities of seed from each ear selected at each location are mixed to form one overall composite which is then used to make plantings for the succeeding cycle of selection. Continuation of this system should over a period of time result in a high-yielding population with a rather broad area of adaptation.

The decision to develop cryptic double cross ($S_1 \times S_1$) hybrids and $S_1 \times$ double cross hybrids was based on experience in other areas showing that it should be possible to have a hybrid which would outyield the parental varieties by 25 to 30% by the third year of a program. This time table is dependent on growing two crops per year, which has been possible through winter plantings at lower altitude at the Progreso, Morelos station of the National Institute for Agricultural Research (INIA) and at the Tepalcingo, Morelos station of the National Seed Production Agency (PRONASE). The method involves the crossing of two individual prolific plants while at the same time self pollinating second ears on the same two plants. The crosses are then evaluated in yield trials. The selfs of parents of the best crosses (cryptic double crosses) are planted in the winter season so that any superior cross can then be produced in quantity the following year. Because of the relatively high yield of the introduced hybrid H-28 in the 1967 trials, a number of topcrosses between S_1 lines of the best local varieties and H-28 were produced. The objective of these crosses was to combine the high yield of the hybrid with better resistance to ear rots.

1967 PROGRAM AND RESULTS

Taking these factors into account, the genetic improvement program set out to determine in 1967 which corns, native or introduced, could be recommended immediately and which germ plasms could best be utilized in the genetic improvement program

Fig. 3.1. The procedure in use for developing a cryptic double cross hybrid. Two individual prolific plants are crossed while at the same time self pollinating second ears on the same two plants.

Uniform trials

Eight local varieties, four double cross hybrids recommended for similar altitudes (2,100-2,600 meters) in other regions of Mexico, and two populations emanating from CIMMYT's program at Chapingo were studied in replicated yield trials at six locations. These trials were conducted at 45,000 plants per hectare with fertilizer applications ranging from 120 to 160 kgs. of N plus 80 kgs. of P_2O_5 per hectare. Average data obtained from these trials are summarized in Tables 3.1 and 3.2.

Average yields ranged from a high of 6.9 tons/ha at Santa Ana to a low of 3.3 tons/ha at Cerritos Mextla and Chautenco. The analysis of variance for yield indicated there was a highly significant variety × location interaction. On the average, the varieties Colorado and Pinto and the four commercial hybrids did not differ significantly in yield. At only one location, Santa Ana, did one of the commercial hybrids significantly outyield the best local variety included in the trial.

TABLE 3.1. Average yields in ton/ha of dry ears of 8 local varieties (L), 4 commercial hybrids (H), and 2 improved varieties grown at 6 sites within the area of the Puebla Project in 1967.

Variety or Hybrid	AVERAGE YIELDS IN TONS/HECTARE AT: Santa Ana	Cuanalá	San Buena	Cholula	Cerritos Mextla	Chautenco	Means
Colorado (L)	8.0	6.6	5.1	4.9	4.0	3.9	5.4
H-28 (H)	9.4	6.9	5.1	3.3	3.7	3.4	5.3
H-127 (H)	8.2	6.2	4.9	3.9	3.8	4.2	5.2
Pinto (L)	8.4	6.2	4.6	4.5	3.5	3.8	5.1
H-125 (H)	7.9	6.0	4.7	3.7	3.9	4.5	5.1
H-129 (H)	7.7	6.1	5.0	3.2	3.4	4.0	4.9
Blanco (L)	7.5	5.5	4.3	3.8	3.6	2.9	4.6
Amarillo (L)	6.2	5.8	4.0	4.5	3.3	3.3	4.5
Comp. CH-61 MC-IV	7.0	5.6	4.6	3.1	3.4	3.2	4.5
Mex-Gpo. 10 MC-IV	6.6	5.4	4.2	2.9	3.0	3.3	4.2
Blanco Sanchez (L)	5.4	5.8	3.8	3.7	2.8	2.9	4.1
Blanco Rubin (L)	5.8	5.7	3.2	3.2	3.1	2.2	3.9
Amarillo Rubin (L)	4.6	5.0	3.6	3.4	2.7	2.7	3.7
Cacahuacintle (L)	4.2	4.9	3.3	2.3	2.5	1.8	3.2
Locality Means	6.9	5.8	4.3	3.6	3.3	3.3	4.5

TABLE 3.2. Data on yield in ton/ha of dry ears and six other agronomic traits of 8 local varieties (L), 4 commercial hybrids (H), and 2 improved varieties. Average of six locations in the Puebla Area 1967.

Variety or Hybrid	Yield	Days to Flower	Ear Height cm.	Lodging Score [1]	% Barren Plants	% Diseased Ears	% Fallen Ears
Colorado (L)	5.4	91	144	2.6	2	5	6
H-28 (H)	5.3	93	140	1.5	3	20	2
H-127 (H)	5.2	92	146	1.8	2	15	2
Pinto (L)	5.1	96	165	3.3	3	10	10
H-125 (H)	5.1	100	151	1.3	3	11	1
H-129 (H)	4.9	103	160	1.8	4	15	1
Blanco (L)	4.6	105	174	3.4	4	12	12
Amarillo (L)	4.5	94	166	2.9	3	6	7
Comp. CH-61 MC-IV	4.5	100	167	3.1	4	17	8
Mex. Gpo. 10 MC-IV	4.2	101	157	2.7	6	17	7
Blanco Sánchez (L)	4.1	89	147	2.7	5	15	7
Blanco Rubin (L)	3.9	87	147	3.2	6	35	9
Amarillo Rubin (L)	3.7	86	130	2.5	4	35	9
Cacahuacintle (L)	3.2	89	144	2.9	8	48	11

[1] Scale of 1.0 = no lodging to 5.0 = 100% lodging.

The agronomic data in Table 3.2 indicate:

1. Both local and introduced material ranged from 86 to 105 days to flower.
2. Ear height ranged from 130 to 174 cm —all too tall.
3. Lodging: local varieties generally susceptible and the introduced hybrids, resistant. Colorado with a lodging score of 2.6 had an average of nearly 40% plants lodged.
4. Barren plants. The best local varieties and the introduced hybrids did not differ significantly in this respect. Percentages were low in both cases.
5. Percentage of diseased ears. Two local varieties —Colorado and Amarillo— were better than the other local varieties and better than the introduced hybrids. H-28 was poor in this regard.
6. Percentage of fallen ears. The local varieties were approximately equal and not as good in this respect as the introduced hybrids.

Germ plasm survey

Observation nurseries of a broad spectrum of germ plasm were planted at two locations in the area —Santa Ana and Cerritos Mextla— to determine which materials should be included in the genetic

The local variety Pinto was chosen as germ plasm for initiating the cryptic double cross breeding program. In 1967, reciprocal crosses were made in 500 selected plants of the local variety Pinto. Wherever possible second ears were self pollinated obtaining in this way 94 complete sets.

TABLE 3.3. Yield in kilograms per plot and six other agronomic traits of materials selected from the observation nurseries for inclusion in the genetic improvement program. Averages of two replications at each of two locations in the area, 1967.

Entry	Yield	Days to Flower	No. of Ears Per Plant	Ear Height Cm.	Lodging Score [1]	% Barren Plants	% Diseased Ears
Early Composite [2]							
Chalqueño x Cónico	10.06	93	1.11	136	2.1	1	20
Chapalote x Cónico	8.98	93	1.26	126	1.4	1	17
Pue. Group 26	8.57	92	1.20	118	1.6	0	22
Pue. Group 30	8.44	93	1.13	139	1.6	1	14
Pue. Group 10	8.31	94	1.10	145	1.6	2	14
H. de Ocho x Cónico	8.27	95	1.44	102	1.5	1	28
Puebla Group 11	8.11	94	1.16	124	2.4	1	19
Late Composite [3]							
Batán E-CIV	10.19	106	1.04	172	1.5	2	8
Puebla Group 44	8.97	98	.98	156	2.4	2	9
Hgo. 8 M-CI	8.92	113	1.20	167	2.2	2	14
Pue. Group 49	8.40	105	.98	170	2.0	2	4
Pue. Group 33	8.10	101	1.00	148	2.2	0	7
Hybrid Checks							
H-28	11.03	96	1.11	139	0.4	1	21
H-127	10.67	97	1.18	151	1.1	2	13
H-129	10.05	112	1.11	160	1.1	2	11

[1] Scale of 1.0 = no lodging to 5.0 = 100% lodging.
[2, 3] The breeding materials listed under these two headings were selected for inclusion in an early and a late breeding composite.

improvement program. The following items were studied: 41 composites from the corn germ plasm bank involving all the collections which had been obtained from the area in earlier years, 15 intervarietal or interracial crosses from CIMMYT's program, and the hybrids H-28, H-127 and H-129. Data on the entries selected to form the basis of the genetic improvement program are summarized in Table 3.3.

Development of cryptic double cross hybrids

Because of the desire to have a variety with substantially higher yield potential within less than 5 years, a well thought of local variety, Pinto, was chosen as germ plasm for beginning this breeding program in 1967. Following the method described earlier, 500 crosses of selected plants were made, attempting at the same time to self-pollinate second ears of each of the 1000 parental plants. Due to the problems involved in obtaining sufficient good quality seed of the cross as well as of the self-pollinations, which involved second ears or ears on tillers, the program realized only 94 complete sets.

1967-68 WINTER PROGRAM

To gain a complete cycle in the breeding program, 1967-68 winter plantings were made in a frost-free climate on land of the PRONASE near Tepalcingo, Morelos. The winter plantings involved the following:

1. Production of the early and late composites for beginning the mass selection program. This consisted of: A) Intercrossing the "early" entries listed in

Uniform yield trials were the first step to find out if there was in existence genetic material which would yield significantly more than the local varieties. Several materials looked promising but were not consistently better in all plantings.

Table 3.3 with H-28 and Colorado, which were the most promising early entries in the uniform trials (see Tables 3.1 and 3.2); and B) Intercrossing the late entries listed in Table 3.3 with Pinto and Blanco which were the most promising "late" entries in the uniform trials (see Tables 3.1 and 3.2).

2. Increase of the number of cryptic hybrids utilizing S_1 lines of Pinto as one parent and plants of the most promising entries in the trials and observation nurseries planted in 1967 as the other parent. Using S_1 lines from Pinto as females, about 30 additional $S_1 \times S_1$ crosses were obtained using plants of Colorado, Puebla Group 26, Puebla Group 44 and the racial cross Chalqueño x Cónico as sources of male plants. As in the case of the cryptic double cross program, the plants used as males were selfed to insure S_1 line seed of both parents.

3. Production of topcrosses between H-28 and S_1 lines of varieties that were outstanding in 1967 plantings. Individual plants of the variety were selfed at the same time they were crossed with 10 to 15 plants of H-28. Approximately 50 complete sets were obtained for testing in 1968.

1968 PROGRAM AND RESULTS

Although rainfall was irregular in 1968 throughout the Puebla area and most locations suffered from drought during some period of the growing season, important progress was made in selecting and breeding more productive materials.

As an average of all locations the local variety Pinto has proven similar in yield to the INIA hybrids H-28 and H-129. All three, plus Composite 1500, are included in the present improvement program.

TABLE 3.4. Yield data in ton/ha of shelled corn at 12% moisture and other agronomic traits of the four best entries in the uniform trials in comparison to the local variety. Averages of six locations in the Puebla area, 1968.

Entry	Yield	% of Local Variety	Days to Flower	Character Ratings [1] Ear	Plant	Ear Diseases
H-129	6.0	115	100	1.5	1.3	1.6
H-28	5.9	113	92	1.9	1.7	2.0
Composite 1500	5.8	112	98	2.0	2.3	1.3
Pinto	5.7	110	95	2.3	2.3	1.4
Local Variety	5.2	100	92	2.5	2.4	1.4

[1] Scale of 1 = very good, 5 = very poor.

Uniform trials

These trials, each with eight replications, were planted at six locations in the area. The entries included the best local varieties from the 1967 trials, the two best hybrids (H-28 and H-29) in the 1967 trials, three new collections from the area and six entries provided by the INIA corn improvement program.

The data for the four highest yielding entries in these trials are presented as an average of all six locations in Table 3.4. As in the 1967 trials, H-28, H-129 and Pinto were similar in yield. On the basis of these results, Composite 1500 was added to the basic populations being utilized in the genetic improvement program. Study of the data at individual locations indicated there was again a highly significant location x entry interaction and that no single variety or hybrid was significantly better than the local variety at all six locations. On the other hand, at any specific location at least two of the four best entries were significantly better than the local variety.

Mass selection

Eight mass selection blocks involving the early and the late composites as described earlier were planted and carried through the first cycle of selection. The three locations involving the early composite were Mayorazgo, Capultitlán and Almecatla. The late composite locations were Mihuacán, Cholula, Zaragoza, Mayorazgo and Capultitlán. The second cycle will be carried out in each composite in 1969 using the composite obtained in 1968.

In 1968 uniform trials were planted at six locations in the area. The entries included the best local varieties and the two best hybrids from the 1967 trials, three new collections from the area and six entries provided by the INIA corn improvement program.

TABLE 3.5. Yield data in kg/ha of dry ear corn and four other agronomic traits of the chosen cryptic double-crosses and top crosses. Averages of five locations, 1968.

Entry	YIELD kg/ha	% of Checks	Days to Flower	% Lodged Plants	Ear Height (m)	% Rotted Ears
CRYPTIC CROSSES IN PINTO						
358	8825	119	100	13	1.70	6
133	8582	116	90	32	1.44	12
275	8563	116	98	22	1.65	10
246	8524	115	94	10	1.42	7
205	8418	114	99	21	1.83	4
88	7649	103	93	7	1.45	6
Mean	8427	114	96	17	1.58	7
Checks						
H-129	7491	101	95	10	1.61	6
Pinto	7447	101	93	19	1.55	8
H-28	7224	98	91	4	1.30	16
TOPCROSSES TO H-28						
309	7964	131	96	23	1.60	10
292	6936	114	88	20	1.33	6
257	6875	113	91	24	1.36	6
276	6793	111	90	21	1.32	3
333 A	6790	111	89	19	1.40	3
Mean	7072	116	91	21	1.40	6
Checks						
Pinto	6257	103	96	21	1.62	8
H-129	6149	101	101	22	1.68	17
H-28	5887	96	90	21	1.36	17

Hybrid development program

The 94 cryptic double crosses from the variety Pinto and 68 topcrosses between S_1 lines of this variety and Colorado, H-28, Puebla Groups 26 and 44 and the racial cross Chalqueño x Cónico, were yield tested at four locations in the Puebla area and one location near Chapingo, Mexico. A simple lattice experimental design with two replications was used in an effort to evaluate the materials at more locations even though it meant a sacrifice of precision at any one location.

Eleven of the 94 cryptic double crosses and eight of the topcrosses to H-28 yielded significantly more than the best commercial bybrids included in the trials as checks. Six of the cryptic double crosses and five of the top crosses to H-28 were chosen on the basis of yield and agronomic characteristics. The crosses and their parental S_1 lines will be used as germ plasm for continuing this part of the genetic improvement program. Data for these two groups of crosses and the check entries are summarized in Table 3.5.

The parental S_1 lines of the 94 cryptic double cross hybrids were planted at El Batán in the Valley of Mexico for sib increase so that adequate seed of the best crosses would be available for further production of these crosses after the yield trials had been completed.

1968-69 WINTER PROGRAM

To gain a generation all the S_1 parents of the five best cryptic hybrids (See Table 3.5) were planted for increase and to obtain more seed of the crosses at the PRONASE station near Tepalcingo, Morelos.

The S_1 line parents of the selected cryptic double crosses were arbitrarily divided into two groups to form two composites (A and B). Two detasseling blocks were planted to produce as much seed of the cross as possible from semi-commercial testing in the Puebla area in 1969. In one block Composite A was used as the female while in the other the parentage was reversed. This procedure was followed for the purpose of using the male rows as an increase of the composites.

At Matamoros, Puebla, one detasseling block was planted using H-28 as the female and a composite of the S_1 line parents of the best topcrosses noted in Table 3.5 as the male.

THE 1969 SUMMER PLANTINGS

The uniform trials are being continued with the following entries: the commercial hybrids H-28 and H-129, Composite 1500, Pinto, the best cryptic double crosses and topcrosses listed in Table 3.5, the cross of Composite A x B and the local variety. The research design is a randomized block with four replications.

A new aspect of the mass selection program was the addition to each composite of a mechanical mixture of converted Opaque-2 high lysine seed stock of Chalqueño and Cónico.

Using composite A and B as basic stocks the second production cycle of cryptic double crosses is underway. This aspect of the program is considered a training activity as the planned duration of the Puebla Project does not allow sufficient time for new crosses to be used within the project.

From the seed increase of composites A and B, harvested in the 1968-69 winter plantings, a seed increase program and production of the cross of composites A x B is in progress.

From the bulk male seed harvested in Matamoros, Puebla, one detasseling block has been planted using H-28 as the female. About 200 good plants are being selfed in the male and each will be crossed with 10 to 15 plants of H-28 to develop a new series of topcrosses for testing in 1970. This program was initiated as a training activity since the planned duration of the Puebla Project does not allow sufficient time for new crosses to be used within the project.

Insofar as seed stocks of the composite cross, A x B, and the detasseling block in Matamoros, Puebla permitted, this seed was used to plant the high yield plots in the Puebla Project area. For the remaining plots the local variety was employed.

COMMUNICATION OF INFORMATION

WHAT IS THE ROLE OF EXTENSION in this program and how is it different from that of any other extension program?

The main difference is that here extension is an integral part of the entire program. Every effort has been made to avoid a research-extension compartmentalization where certain persons would work on producing knowledge and others would later have the responsibility for disseminating it. In this case the whole region is the experiment station, and farmers' fields are the experimental plots. Because of this, experimental results can be immediately interpreted in terms of specific recommendations for farmers without going through an intermediate step of adaptation trials in the region. All research is focused on producing knowledge of value in raising yields in the Project area and extension activity may include all kinds of measures to facilitate farmer adoption of more productive practices.

OBJECTIVES

The main objective of the extension advisory work is to provide technical assistance to farmers in the area. In addition the advisors work with the coordinator to keep the other participating institutions well informed on progress of the project. The urban population in the area is also kept informed in order to maintain a favorable general environment.

The research parcels planted at numerous sites throughout the area in 1967 also served an extension function in demonstrating possible results to a small number of key individuals and neighboring farmers. In addition, the results were photographically documented in order to have evidence on hand for future use. At the end of 1967 the photographic evidence of plant response to fertilizer was presented along with the statistical data at a first annual meeting of all state institutions interested in the project.

RECOMMENDATIONS FOR INCREASING YIELDS

Based on research data obtained in 1967 and on rainfall records from three stations in the area over a period of years it was possible to elaborate specific recommendations for increasing corn yields in 1968. These recommendations differed from the traditional practices as shown in the table below.

Basically, two changes were involved: an increased investment in fertilizer and a change in farm management and farming techniques. In the case of fertilizer use, this consisted of a better understanding of fertilizer elements, learning to mix the fertilizer elements for oneself, a higher level of fertilization, and a greater investment of time for the application. In the case of plant population, it meant leaving the same separation between rows but closing up the distance between hills. The better weed control was obtained by traditional cultivation and hand labor, but through convincing farmers that their higher fertilizer investment required more care in eliminating all weeds. Complete weed control runs contrary to the common practice of leaving the weeds which develop around the plants after the second cultivation to be cut for animal feed during the growing season.

THE PROGRAM FOR 1968

Location of the high-yield plots

With the research results at hand, a demonstration program was planned for 1968 so that farmers should see with their own eyes the advantages of these new practices. Plans were made to locate high-yield plots throughout the region. The term "high-yield plot" was chosen in preference to "demonstration" as the plots were to be more than a simple demonstration of the advantages of certain practices. Nevertheless, the initial plans at the end of 1967 followed largely the usual system for planning and locating demonstrations — choosing highly accessible points on good soils where the largest possible number of farmers could see the plots. This approach implied that the fields should be located first and the owners then convinced to participate with demonstrations on these particular fields. However, the experience obtained by the evaluation team in January and February of

Comparison of traditional and recommended practices.

Practices	Traditional	New Recommendations
Fertilization (N, P, K)		
Quantity (kg/ha)	50-25-10 *	130-40-00
Form of purchase	Mixture	Elements
Form of application	By hand, around the hill	By hand, along the row
Distribution at planting	None	All of the P_2O_5 and 20% of the N
at first cultivation	All	None
at second cultivation	None	The rest of the N
Population (plants/ha)		
Rainfed plantings	15,000-25,000	50,000
Irrigated plantings	25,000 30,000	60,000
Weed control	Incomplete	Complete and timely
Insect control	None	Control of rose chafer at flowering when necessary

* Average applications of the 70% of the farmers who fertilized in 1967.

1968 suggested a change of strategy. The negative attitude, and in some cases hostility of many farmers suggested that it would be best to work through the existing power structure in each community. This meant identifying, first of all, the people of authority and then working through them. For this reason, the first step in locating the high-yield plots was not the selection of the geographic site but rather the selection of the farmers to participate in the demonstration program. These farmers were selected carefully, as they would provide the nuclei for expanding the project in future years. This selection was accomplished in two steps through meetings first with local authorities and then with farmers in each village.

Meetings with local authorities

The decision was made to meet with local authorities in as many communities as possible, obtaining in this way a better understanding of the local power structure. The political administrative unit in this area is the municipio, each of which has a principal village and usually several ancillary population units. The municipios are irregularly shaped, as can be seen in the maps showing the project area. The head village is known as the "cabecera municipal" where the municipal president and other local authorities reside. Each community within the municipio has auxiliary authorities responsible to the municipal president.

In each case, project staff contacted municipal presidents first, explaining the project and its goals. The president was then asked to arrange a general meeting with all of the municipal authorities in order to provide complete information about the project and the work plans for 1968. In the meantime, he was given additional information. This included a report of the 1967 results prepared originally for the first annual meeting of the project, a map showing all of the points where experiments were carried out during 1967, a list of the cooperating farmers, and a brief description of the project. This basic information was attached to an official letter of presentation signed by the General Agent of the Ministry of Agriculture, the state director of agriculture, and the coordinator of the project. The letter explained the responsibilities of the municipal authorities in organizing the proposed meetings and the important role they had to play in developing the project. It also suggested the social and economic importance that the project might have for farmers in each municipio. This information was delivered personally to each municipal president in January and February, 1968; at the same time, places, dates, and hours were set for meetings with the municipal authorities. Meetings of this kind were carried out in all but one of the municipios in the half of the Puebla area in which extension work was to be initiated in 1968.

In the first meeting with the municipal authorities, a careful explanation was given of what the project might provide and what farmers would be expected to do. At the same time, an effort was made to evaluate the level of interest in the project. At the completion of each meeting, the participants were asked which farmers in the locality would be interested in the project. The authorities usually asked for time to return to their villages to explain the project and find out who might be interested. However, in several cases they were ready to guarantee that the farmers of their village would be interested. And in a few cases the authority himself was ready to be one of the participants and to initiate work in his village with the Puebla Project.

Meetings with farmers in each village

The next step was to program a series of meetings with farmers in the villages which had expressed some interest. Where the authorities did not express interest, it was decided to make no further effort the first year. These villages would be kept in mind for invitations to see the high-yield plots and to participate in field days in neighboring villages.

Through this two-step process it was finally possible to have meetings with the farmers themselves, along with the local officials in many communities of the area. In every case, the authorities were encouraged to invite all members of the community. The advantage of this approach was that the authorities took the initiative in organizing the meetings in each community, and this gave the technicians of the project a chance to evaluate the level of influence of these authorities and the level of community organization.

A total of 31 meetings were held to explain the project to farmers and suggest how they might participate in the 1968 program by providing plots for experimental work or by planting high-yield plots. Their responsibilities in either case were summarized in the following manner:

Experiments vs. high-yield plots

In both cases the farmer would be expected to provide his land, his work, his equipment, and his time for giving special care to the plot. There were two main differences. Because of the greater care needed for an experiment and the fact that check plots and low-fertilizer treatments would yield very little, the project provided the fertilizer. In the case of the high-yield plot, the farmer would be expected to purchase the recommended amount of fertilizer and have it on hand well before planting. The other difference was that the technicians of the Puebla project would take full responsibility for the technical direction of the experiment, whereas the farmer would have more responsibility in the case of the high-yield plot.

In the case of the high-yield plots, where the farmer had to obtain his own fertilizer, help was offered in obtaining credit from a private or governmental institution. This did not imply that any certain harvest was guaranteed. The technicians pointed out only that the research experience of the previous year, under the ecological conditions of the area, indicated that the recommended application of fertilizer would make possible a substantial yield increase. This increase would be of a magnitude which would permit paying the cost of production and obtaining an attractive profit on each hectare. Usually after explaining all of this in detail and participating in lengthy discussions, a small select group of farmers gradually came to the fore. These farmers generally had two characteristics: 1) They were responsible workers of their own land with a desire to progress who saw in the project a possibility for improving themselves, and 2) They were persons whose moral character and influence were amply recognized in the community. In future years these farmers should be the most active in diffusing the new ideas in their communities. When the planting season was ready to begin, about 150 farmers had been selected.

In some communities, many farmers wished to participate. In these cases, the final selection was made by visiting the possible sites. In general, no less than 2 and no more than 5 sites were included in each community, but in a few cases there were more than 5. Around one village there were 25 and in another, 8, due principally to the enthusiasm of the farmers and the fact that in some cases the village land extended over a broad area so it was convenient to have one or two lots in each zone of the community. In some cases, after making the initial selection, other farmers became interested and were added on the recommendation of those already included. There were only two cases in which farmers were accepted and later withdrew, and these were due to objections of the wife, principally because the husband was planning to obtain fertilizer on credit which would have to be paid back at harvest.

Credit

A total of 141 high-yield plots were established with the selected farmers. The plot size varied from .25 to 1.0 hectare; the most frequent size was .5 hectare. Each farmer was told what the work would consist of and where special attention would be needed at each step in the growing cycle. He was also told of the availability of credit, the interest rate, and what the role of crop insurance could be in reducing risks from natural causes such as frost, drought, and hail. He was told that he had a responsibility in conducting a high-yield plot to show his neighbors the advantages of the new practices. He should tell his neighbors how he initiated contact with the technicians of the project and the conditions under which he was conducting the plot, the date it was planted, how much it had cost him to establish it, how he obtained financing for fertilizer, what kind of harvest he was looking for, and now he calculated the possible profit in changing from the traditional to the new method.

Sixty percent of the farmers who participated in 1968 were financed by the private supply house, Agronomos Unidos, S. A., 20% of the credit was provided by the Banco Agropecuario, and 20% of the plantings were self-financed by the farmers. One essential condition of the project was that the fertilizer be on hand at the farm at planting time. As explained earlier, the agreement made with Agronomos Unidos made available both the credit and the fertilizers recommended by the project. Credit was provided at an interest rate of 1.5% monthly. This interest, along with the cost of the fertilizer, would be paid at harvest. The credit was given for a period of 9 months, sufficient to cover the long growing season and give the farmer time to harvest and sell enough corn to repay the loan.

One interesting experience is worth noting here. The letter of credit indicated the value of the fertilizer and the rate of interest, but not the calculation of the total amount of the loan plus interest. However, in a few cases the interest corresponding to the nine months was also added to the fertilizer price. In these cases where the interest was calculated in the original loan agreement, and the farmer came back and paid before the nine months were up, he received a cash refund for the additional interest originally calculated. This turned out to be an agreeable surprise with resulting good-will for the distributor who provided the credit. In contrast, there were frequent frictions when the farmer arrived to pay his loan and brought with him only the exact amount indicated in the letter of credit without calculating the interest. In this case, when the interest was calculated he frequently did not have enough money with him. In one case the farmer considered it a fraud. However, even for those who understood that the credit terms were very favorable compared to local lenders and had simply forgotten to calculate the interest, this caused bad feelings. In some cases, the farmers had to make separate trips to pay the remaining interest. As a result of this experience it was decided that in the future the total amount should be included in the letter of credit.

In the important aspect, repayment, both this private distributor and the public Agropecuario Bank obtained excellent results. In both cases, the farmers paid back their credit on time and completely.

The majority of those who decided not to use credit were farmers who lived far from the city of Puebla and decided it would be easier to obtain money locally and pay cash for the fertilizer. Technical assistance was provided equally to all participants without regard to their source of credit.

Crop insurance

After the plantings had been made, the crop insurance agency entered to insure them. This was an experimental operation for the insurance agency, as the usual procedure was to insure only plantings of 5 hectares or more, principally private holdings. Previously, the only exception had been the ejido plantings financed by the official banks, which by law must be insured. The plots financed by Agronomos Unidos varied from .25 to 1.0 hectare and it was difficult at first for the insurance agency to include them. However, the risk aspects of rainfed plantings were of special interest to the project, and the participation of the crop insurance agency was finally arranged. The insurance agency made the necessary inspections of the plantings, and discarded 14 plots which were considered, for various reasons, not acceptable to them. The rest were fully insured. At the end of 1968, according to the yield level obtained, the insurance agency had no indemnizable losses whatsoever due to hail, drought, wind, frost, and other risks covered by the program. There were reductions in yield due to these causes, but none which would result in a payment under the insurance regulations. The coverage is for a value equivalent to 1.1 tons of shelled corn.

Planting and care of the high-yield plots

In deciding on planting dates for the high-yield plots, the farmer himself was considered the best authority. The criteria generally followed by farmers in the area is that the soil should have sufficient moisture to guarantee total germination of the seeds. Before planting, a date was fixed to carry out a demonstration with neighbors present. In some cases, the farmer made the fertilizer mixture several days before planting. In others, the mixing was part of the demonstration. The materials were carried to the field so that the neighbors could learn by participating.

The next step was to show the farmers how and when to apply the mixture so that the fertilizer would be evenly distributed at the bottom of the furrow. A convenient local measure was found for calibrating the fertilizer distribution — a one-liter oil can. When this was filled to about one finger below the top and distributed over 20 meters, the appropriate amount of the mixture was applied. For rapid measuring, a 20-meter wire was prepared. This could be laid out quickly and stakes put at both extremes.

The new plant population was demonstrated in terms of a distance between hills of about ½ step in contrast to one long step in the traditional plantings. The higher population required learning a new rhythm of planting and, in fact, inserting the shovel, opening and covering twice as many holes per hectare. The farmers learned very quickly and then continued alone, sometimes under the guidance of a field assistant of the project. These field assistants were young farmers from the region who had been trained in the project, many of them in the experiments conducted during the previous year. They worked full-time during the growing season.

In general, the farmers learned the methods quickly and did good work. In a few cases, especially where the owners hired help at planting, there was some difficulty in maintaining a constant distance between hills. Several factors — too much distance between hills, attack by rats, and losses from other causes — combined to give populations that were in general slightly under 50,000.

An interesting experience with population is worth recounting. To assure an optimum population it was first decided to teach farmers to overplant and then thin back to the desired 50,000 plants per hectare. In this way, the population could be assured in spite of soil insects, inadequate germination, and other factors. What happened was that the phosphorus and nitrogen put down at planting time helped assure a vigorous growth of the young plants. When told that it was time to thin the plants, the frequent reply of farmers was: "Here I have one of the most

The first step in modernizing corn production is better fertilization and greater plant population. The knowledge accumulated by farmers over the years is respected and taken into account before recommending changes.

One of the applied problems in recommending a new rate of fertilization is how to calibrate the application. The one liter oil can is a convenient local measure.

beautiful plantings of corn that I have ever had, and you want me to pull out some of the plants?" To them, pulling out the superfluous plants was to destroy something very dear. As a result, before the planting season was far underway, it was decided to reduce the planting rate and eliminate the thinning operation.

Frequent contact was kept with the high yield plots throughout the growing season. As the plantings were completed, attention was given to weed control, once again following the farmers' usual cultivation procedure. As the plantings were made at the bottom of a deep furrow, the first plowing made the land almost level, and the second made a deep furrow between the rows, with the soil piled high around the plants. Demonstrations for neighboring farmers were carried out again at the second cultivation when the second fertilizer application was made. The visiting farmers learned which fertilizer and how much to apply as well as how to keep fertilizer out of the bud to avoid damaging plants.

Result demonstrations

The high-yield plots were intended, first of all, to stimulate diffusion of new production practices. Care was taken to make sure that the neighbors were well aware of how the crop had been planted and fertilized. The value of these practices would be seen as the crop neared harvest. A total of 15 local demonstrations and two on a regional basis were carried out.

Local demonstrations

For the local demonstration, neighbors in the same community and in the neighboring communities were invited personally by local sound equipment, by circular letter, and posters to attend the demonstration. The name of the farmer was always included in the invitation. Generally, the farmer on whose land the demonstrations would be held, circulated the invitations. In other cases, the municipal authorities sent circular letters to farmers whom they thought would be interested. The demonstration itself consisted of 3 parts: an explanation by an agronomist of the Puebla Project and its goals, a report by the farmer on his experience with the high-yield plot, and open discussion led by the farmer and the agronomist. An interesting aspect of this was the obviously greater confidence which the visiting farmers felt in raising questions and making comments to the farmer-demonstrator. In spite of the good rapport that the agronomist had developed with the farmers who had the high-yield plots, the neighbors preferred to get their information from the farmer. In some cases, they felt free to correct calculations that the farmer had made on production costs and practices. On the other hand, the presence of the agronomist was helpful as a source of additional information and to add seriousness to the event.

The important fact is that the farmers themselves were able to awaken interest among the visitors. The attendance at these local demostrations ranged from 11 to 75 farmers. Only one demonstration had practically no attendance, and that was because of faulty local promotion. In this community it was found that the farmers considered the demonstration irrelevant because they were generally using manure instead of the chemical fertilizer which the project recommended. In fact, they were convinced that they could obtain much higher yields than with chemical fertilizer. At harvest, however, there was no case in which the current fertilizer practice gave higher yields than the high-yield plot. Of course, the comparison is not complete because the recommendations of the project included not only the type of fertilizer, but also the quantity and time of application, control, and doubling the plant population.

Regional demonstrations

For the two regional demonstrations, somewhat more organization was required. Again, the participating farmers in each locality were asked to take the leadership. In the series of meetings held prior to the event, it was interesting to note two aspects. First, the farmers lacked confidence in their ability to plan and carry out a demonstration. Second, they thought that no one would come. They felt the technicians of the project should decide how things ought to be done. However, the agronomists insisted that the farmers should handle the problem. They agreed that it was difficult, but that it was within the farmers' capabilities.

The approach was finally to organize a committee of the most enthusiastic people with the formal title, Committee for Organizing the Agricultural Field Day. The committee took charge of: 1) inviting the authorities, both of the federal and state governments, 2) inviting the neighbors, 3) organizing the event locally by naming a person to receive each of the groups as they arrived from the different communities, 4) naming commissions to look after the smooth functioning of the demonstration to assure that there would be an environment of hospitality. In each case, the farmers planning the demonstration insisted on preparing a brief description of the locality and its principal characteristics — the date it was

The "high-yield plot" was the basic extension method used in 1968. Farmers in the western half of the area planted 141 of these plots; the Project provided technical advice on an individual basis.

The result demonstrations in the fall included an explanation of how the high yields were obtained. The agronomist usually led off with a description of what had been done and then the host farmer took over to answer a broad variety of questions.

Two regional field days were held at experimental plantings. Here the farmers learn something of research techniques and results up to now in the development of a higher yielding variety.

founded, the date the ejido was formed, the land area belonging to the village, and data on the local economy. The significance of the Indian name of the village was also included. The committee wanted to be sure that everyone who attended the demonstration knew the most important facts of the village.

The other important concern in planning the event was how to handle food and refreshments. Many of the visitors would come from distant points to visit the plots from 10 a.m. to 1 p.m. It was finally decided to provide each person with a refreshment and to invite persons from the organizing villages to prepare food which would not be a gift, but would be sold at a modest price at the end of the demonstration.

Promotion

The technical personnel of the project took the responsibility for inviting farmers from the entire region. In addition to personal contact, they used a poster and circular letter, and sent personal invitations to all of the farmers with high-yield plots. The result was a good attendance of farmers at both events, although limited somewhat by the fact that the invitations went out only a few days before the event.

For the farmers who organized the events, these were experiences of lasting value in that they realized they could carry out demonstrations of this type. The attendance was greater than they had imagined could be possible, including farmers from the more distant villages. Both of the regional demonstrations were held at locations where farmers could see both a high-yield plot and an experiment. As it turned out, the demonstrations were especially effective in interesting farmers from distant points where high-yield plots were not planted in 1968. Many of the farmers who planted high-yield plots in these villages in 1969 were precisely those who had heard of or seen the regional demonstrations.

Other demonstrations were conducted throughout the growing season for representatives of various state and national institutions, both private and public. These included the Secretary of Agriculture, state directors of agriculture, the governor of the state, directors of the official banks, and many other professionals interested in the project. There were also numerous visitors from other countries of Latin America, Europe, and the United States.

Printed matter and audio-visual methods

In meetings with the farmers it was always impressive to see that even those who were barely literate took notes on the recommendations on scraps of paper. To assure that there would be no error and that the recommendations would be presented as completely as possible, mimeographed and printed materials were prepared.

Both the plant breeder and the soil scientist took part in the field days, explaining the goals of their research and what they had learned. The farmers attending were in many cases the ones who later took the lead in forming groups of cooperators in 1969.

At the end of 1968 a pamphlet was published with specific recommendations for increasing corn yields with the title "Would You Like to Increase Your Corn Yields?". The text was kept to a minimum, and the essential data were presented in illustrations. In this way, farmers attending a meeting could first hear the recommendations and then take home a folder which functioned in this case as a more accurate form of note-taking.

The idea was not to prepare material for mass distribution, but rather to provide a type of visual aid that farmers could take home and show to their neighbors. Consistent with this idea, the folder was used by agronomists during the meetings as a kind of text or outline. In this way, farmers also saw how they could use it in their local meetings. The same folder was used during visits to the demonstration plots. In contrast to areas where printed matter is more available, no one discarded the bulletin and many asked for extra copies to take back to neighbors in their home communities.

During the 1968 growing season, a 16 mm film in color was produced with farmers in the region. The title of the film is "Would You Like to Increase Your Harvest?" This film was used extensively in early 1969 to organize groups of cooperating farmers to participate in the high-yield program.

Only half of the farmers in the area have more than two years of schooling, but a simple leaflet worked well in providing specific recommendations.

One of the ideas in developing printed and mimeographed materials was to have in each community a permanent center of information with bulletins, posters, and one or more persons who could provide farmers with accurate and timely information without necessarily having to consult the technical personnel of the project.

THE PROGRAM FOR 1969

After the social milieu of the farming community had been penetrated successfully in 1968, the year 1969 was contemplated with much more optimism. There was one more year of research results, finances had been obtained to expand the technical team of the project, and the banks and fertilizer distributors were ready to expand credit in order to make fertilizer more readily available. Taking this into account, the project team decided to attempt to extend the area under improved technology to 10,000 hectares operated by approximately 5,000 farmers. This goal implied that each agronomist should work with about 1,250 farmers — 18 times more than the number with which he worked in 1969. Although this was a difficult goal, it was considered necessary if the Puebla Project was to serve as a realistic model for other areas.

The harvest of an experimental plot provides convincing evidence. Besides listening to group explanations, farmers were able to study the treatments and draw conclusions of their own.

To achieve this, certain important changes were made. Instead of working with individuals in each community, the unit of work for the farm advisors became the group. Once the groups were formed, they named representatives to work closely with the farm advisors on all phases of the work from the planting and arrangements for credit on through the harvest.

Greater use was made of "mass media" — the pamphlet already produced, mimeographed maps showing in detail the different zones and the corresponding recommendations, radio, and the 16 mm film. This film occupied a key position in bringing together groups of farmers, demonstrating exactly how increased yields could be obtained. It also lent credibility to the recommendations by careful documentation with local names and places where successes had been obtained in the previous year. Each agronomist had a copy of the film and this was used intensively in meetings previous to planting.

Organizing groups

It should be mentioned that in spite of increasing the number of farm advisors from 2 to 4 and the high level of morale of all of the project personnel, the formation of groups is not easy in an area where little social organization exists among farmers. In spite of this, 64 groups were organized directly by personnel of the project. In addition, other groups are operating as recipients of credit from two official banks. The groups of project cooperators were generally organized by farmers who had participated the previous year, or through efforts of project personnel who arranged with local authorities to project the movie and discuss with farmers the convenience of forming a group of cooperators in 1969.

A typical meeting began with an explanation of the project and presentation of results obtained by farmers who had high-yield plots the previous year.

This was a key point in raising the level of interest. Then the colored film, "Would You Like to Increase Your Corn Harvest?" was projected. This was especially effective in communities where none of the farmers had seen the high-yield plots in 1968. After seeing the film, they often felt that they knew enough about the project and decided to participate. In this way the film both motivated the farmers to participate and provided specific information on how to obtain higher corn yields. About halfway through, the projection was stopped to provide an opportunity for questions and answers. During this intermission, a mimeographed map of the region giving recommendations for each community was distributed. In this way, each farmer could identify his own location and then on the back of the sheet find the specific fertilizer recommendation. The discussion at this point also covered how to calculate the correct fertilizer mixture and how to determine the amount to apply at planting and at the second cultivation.

Complementary role of the mass media

Clearly there is nothing basically new in the informational methods and materials employed. The unusual, perhaps, is that these materials and methods are being used in an integrated way with the other activities of the project, so that they play a crucial complementary role. The film, for example, was made

In some plantings, gophers were a serious problem. Here an extension advisor demonstrates how to control them with poison baits.

specifically for organizing groups in the project area. Starting in 1969, radio is also being used in this way.

A radio program was initiated in March, 1969, on a local radio station which covers the project area. This program is aired Sunday mornings from 7:30 to 8:00 — one of the most convenient hours for farmers, according to data collected by the evaluation team. The initiation of the radio program was also due in part to data collected in evaluation which showed that 60% of the farmers have radios. The program was not initiated until the project personnel felt they had sufficient research and demonstration experience in different parts of the area to be able to initiate a sound area-wide program. The intent, once again, was not to use radio as a mass medium in itself, but rather in close integration with the over-all program. Individuals and groups were advised of the program through a flyer which included the topics, the radio station, the hour, and the date, and these farmers were invited to tell their neighbors of the program.

As to content, the radio program includes recommendations and news notes about what is happening at the moment. For example, that fertilizer has now arrived at such and such a place; that farmers who have their land ready should now mix their fertilizers to be ready for planting; that they should mix simple superphosphate and the ammonium sulfate in certain proportions and take such and such precautions to preserve it. In other words, the program attempts to provide specific technical information on situations certain farmers have experienced that are of extreme interest to those with similar problems in other places within the area. In addition, popular local music is included.

The radio program has been useful for alerting farmers to specific actions in relation to the crop recommendations and has stimulated the participation of a growing number of farmers in the project. The program receives financial support from the fertilizer distributor, Agronomos Unidos, and other commercial firms which distribute agricultural inputs in the city of Puebla. The program is considered a source of credible information, as it is operated by a member of the technical team of the project whom the farmers know and identify as a friend.

Changes in the credit program

In planning the 1969 program, it was obvious that one of the limitations on extending fertilizer use was going to be the lack of the right fertilizers and adequate credit at the local level. The problem was solved in large part by the previously-mentioned fertilizer distributor who took the initiative to establish subdistributors at the local level throughout the region. The project personnel worked closely with these subdistributors in providing technical assitance to the farmers and in assuring that the materials available were precisely the recommended ones.

Functioning of the groups

Working with groups greatly facilitated the selection of participants in 1969, as the farmers themselves, not the technicians, decided who would participate. The groups, in turn, nominated their representatives in a democratic manner. These representatives were the link for requests for both credit and technical assistance. Project personnel worked either through the representative or with the entire group when the representative preferred to call together all of the members.

The goal of the work in 1968 was to begin to arouse interest in the possibilities of increasing yields; the goal of the work in 1969 was to blanket the area with high yielding fields. The idea was to not wait for a trickle-down effect, but to attempt to cover the area as quickly as humanly possible. The result of having 20 or 25 high-yield plots distributed around the village should be that even those who might not want to see the plots could hardly avoid them in 1969. On their way to their fields and home again, they would see the development of the plantings throughout the growing season. In early plantings made in some communities, the neighbors could see the difference as soon as the plants were 20 to 30 days old. The vigor, height, color and density of population all gave a much more attractive presentation than the traditional plantings.

In fact, more farmers are participating in the project now than signed up at the beginning of the year. Part of the reason is the one already given, and part is the fact that the nonparticipants began to see that the fertilizer for the participating farmers did arrive in the various communities. Many had doubted that it really would.

In this way the number of participants originally included in the list for 1969 continued to grow in nearly all of the communities, in some cases even doubling or tripling. The outlook appears optimistic. When the farmers have watched their plants develop through the entire growing season up to the harvest, and when they have had time for long discussions in the villages on the effects of fertilization and following the new practices, the number who want to participate next year should increase sharply.

A radio program was begun in March 1969 to keep close contact with participating farmers and reach others. Here students of the Chapingo Graduate College gain experience in making field recordings in the Project area.

Fertilizer knowledge

The level of knowledge about fertilizer elements and methods for preparing mixtures has grown rapidly. The fertilizer discussions were previously in terms of which brand was best. There was a common belief among the farmers that most of the fertilizer was adulterated and for this reason did not give the results that were expected. They have become more confident as they have made their own mixtures of ammonium sulfate and superphosphate and applied them sucessfully. They have begun to understand something of the elements involved.

Nature of the groups

In view of the fact that practically no organizations existed in the area when the project began, it is particularly interesting that it was possible to crystallize the interest of so many people, so rapidly, in a particular project, and to organize local groups.

The groups were formed basically for two reasons: as recipients for technical information from outside, and to bring together requests for credit and fertilizer. It appears that farmers are willing to work together for a well-defined objective and that in most cases they are making plans already for next year. In some cases, where the original group was large, it has divided into several groups by communities. No attempt has been made to give a general name to the groups such as "society" or "cooperative". Rather, this has been left to develop over time as the farmers begin to identify the functions which they wish their groups to perform.

In 1968, it was estimated that a maximum of 5% of the farmers of the area had any contact with the project. In 1969, it is hoped to reach at least 25 to 30% of the farmers with some information about the project. At this rate, it seems reasonable to expect that nearly all of the farmers of the area should know how to produce better yields of corn within the next two or three years. If a variety can be developed with a substantially greater yield potential than the native varieties, this will give an important added impulse to the rapid adoption of improved production practices. If it yields 20% more, an enormous additional production would result at practically no cost to the farmer.

In the meantime, it is already clear that it will be possible to rapidly increase yields based on a combination of better fertilizer use, more adequate population, and adequate weed control.

EVALUATION

THE PUEBLA PROJECT has been conceived of from the beginning as a test of a methodology for obtaining rapid yield increases among small holders. For this reason, it is essential to know precisely what happens as a result of the project and to the extent possible, WHY. To carry out this task, evaluation is included as an integral part of the project.

STRATEGY

The manner of including evaluation was arrived at after considerable discussion among project members and advisors. One point of view was that an independent outside agency should make the evaluation. There were two principal arguments in favor of this approach: 1) complete objectivity could be expected, as those involved in evaluation would have no direct personal interest in the success or failure of the project, and consequently 2) the results should carry more weight with policy makers, especially outside of Mexico.

In spite of these two potential advantages, the decision was ultimately made to include evaluation as an integral part of the project in order to obtain not only before-and-after measurements but also a more or less continuous feedback to those in charge of the action program. It was felt that this was crucial in this project where an ambitious goal had been set to double yield within a period of five years. The coordinator was especially interested in having rapid and easy access to evaluation of different problems, key limiting factors and potential solutions; such information would be of value to him in constantly assessing and redefining strategy.

In regard to the question of objectivity, it is felt that the essential conditions here, as in any kind of research, are: 1) objective criteria and 2) adequate methodology.

After the harvest of the 1967 fertilizer experiments, it became evident that the project would be ready to carry out demonstration plantings in 1968. Consequently, it was imperative to: 1) immediately establish bench marks on yield, technology employed, level of living, etc., for future comparisons, 2) obtain information about the farmers and their present level of technology for use in planning the action program, and 3) obtain information on the infra-structure of the region — fertilizer distribution, agricultural credit crop insurance and price support programs.

COLLECTION OF EXISTING INFORMATION

The first step was to collect existing information about the region. Unpublished data for 1960 covering the municipios in the study area were obtained from the Census bureau. This gave a tentative idea of the total area and number of farm families involved, the total area planted to corn and amount produced, and an idea of the size of holdings.

Yearly data by municipio from the Dirección General de Economía Agrícola provided additional data on area, production and yield. The methods of data collection and yield estimation employed by this latter agency were studied to determine whether such data would provide an adequate estimation of yield changes. It was decided that in this case it would be convenient to obtain a more precise measure of yield in order to be certain to detect minor year-to-year changes.

To obtain the kinds of estimates desired, of both yield and characteristics of the farming population, it was decided to use a probability sample.

This sample would be used first for a personal interview survey and later for objective yield measurements of the kind now being used successfully in various crops and various parts of the world.

PERSONAL INTERVIEW SURVEY

The population of interest in this case was the farm operators and their families. In previous studies in other parts of Mexico, the Census lists by municipios have been used as a sampling frame. However, in view of problems encountered in these studies and the fact that eight years had passed since the lists were drawn for the 1960 Census, it seemed prudent to use another basis.

An area sampling technique turned out to be feasible because of the availability, at a moderate price, of aerial photos taken just six months earlier.

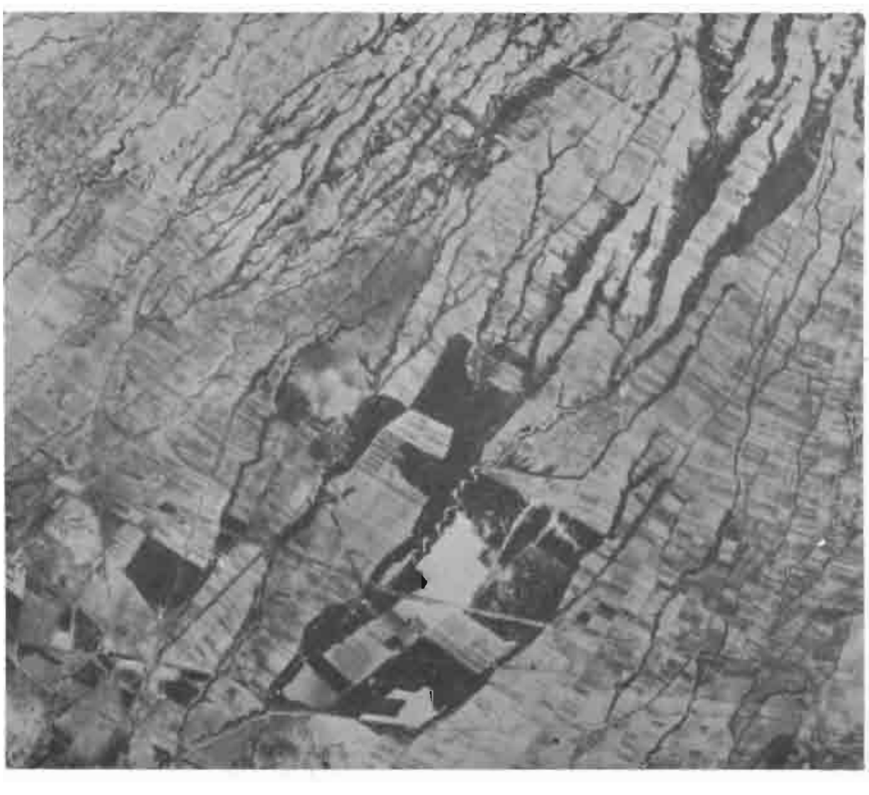
In order to keep costs at a reasonable level, a two-stage sample was drawn. The sample was selected in the following manner. Using a map of the region provided by the Mexican Defense Department, the project area was first delineated. Then 25 points were identified by locating coordinates with a list of random numbers (Figure 4.1). These points were then transferred to the aerial photos and a 5 cm x 5 cm square was drawn with the point as the center. This 25 cm^2 area was equal to 100 hectares. These squares were then photographed and enlarged to a size which simplified identification of individual parcels and in a proportion which permitted more precise measurement and easy calculation of area. For example, an area 5 cm by 2 cm was equal to 1.0 hectare.

The first stage of the field work consisted of locating the segments and finding reference points — trees, cross-roads, gulleys — that would help to identify the parcels in the segment photo. Once the segment boundaries were established, the next step was to obtain the names of those who had operated each piece of land in 1967. Anyone who operated any land within the segment, even though most of his land was outside of the segment, therefore became part of the sampling frame. The plots were numbered chronologically on the map as identified and the names of operators corresponding to the numbers were listed on a separate sheet. This list of names served as the sampling frame for the second stage. The number of segments to be included in the sample and the number of farmers needed in each segment were estimated from the variability in two sets of data: 1) yield data from the fertilizer trials planted throughout the area in 1967, and 2) yields measured on a sampling of farmers' fields in two municipios of the area in the fall of 1967.

Based on these data, a 12% sample was drawn in each segment in order to finally obtain 10% of the farm operators in the segment. A total of 251 farm operators were interviewed in the 25 segments.

The inquiry was conducted with an interview schedule, prepared in advance and pretested in December 1967. After the pretest, the interview form

The availability of aerial photos taken six months earlier made it possible to use an area sampling procedure for the interview survey and later for objective yield measurements. The gulleys are the result of water erosion on sloping land. Most of the small strips are 1/4 to 1 hectare.



Locating the segments and establishing the boundaries required the help of local farmers and officials.

was revised. Students, principally from the National School of Agriculture at Chapingo, conducted the bulk of the interviews during a six-week period from January 2 to February 15, 1968.

Important impressions from the information obtained in this survey were passed on to the coordinator as the study progressed. Survey data describing the area, its agriculture and its people have been included in earlier sections of the present report. There are also plans to publish a complete report of this bench mark study in order to make all of the data readily available for future comparison.

STUDIES OF INFRASTRUCTURE

The data collected on infra-structure through interviews with farmers were supplemented with raw data obtained directly from the agencies involved in credit and crop insurance. This information is summarized in Appendix Tables XI through XVIII. Price support data were also collected and are referred to in the section on corn marketing. The fertilizer distribution network was identified by compiling a list of all persons who buy and sell fertilizer in the

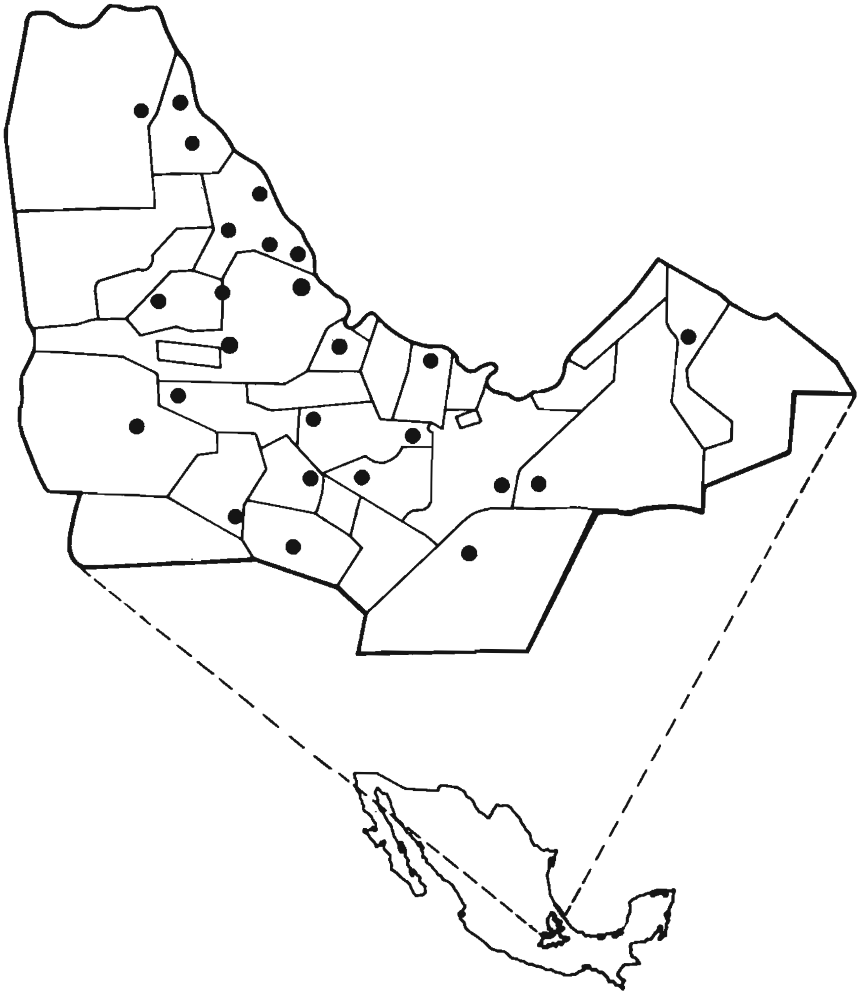
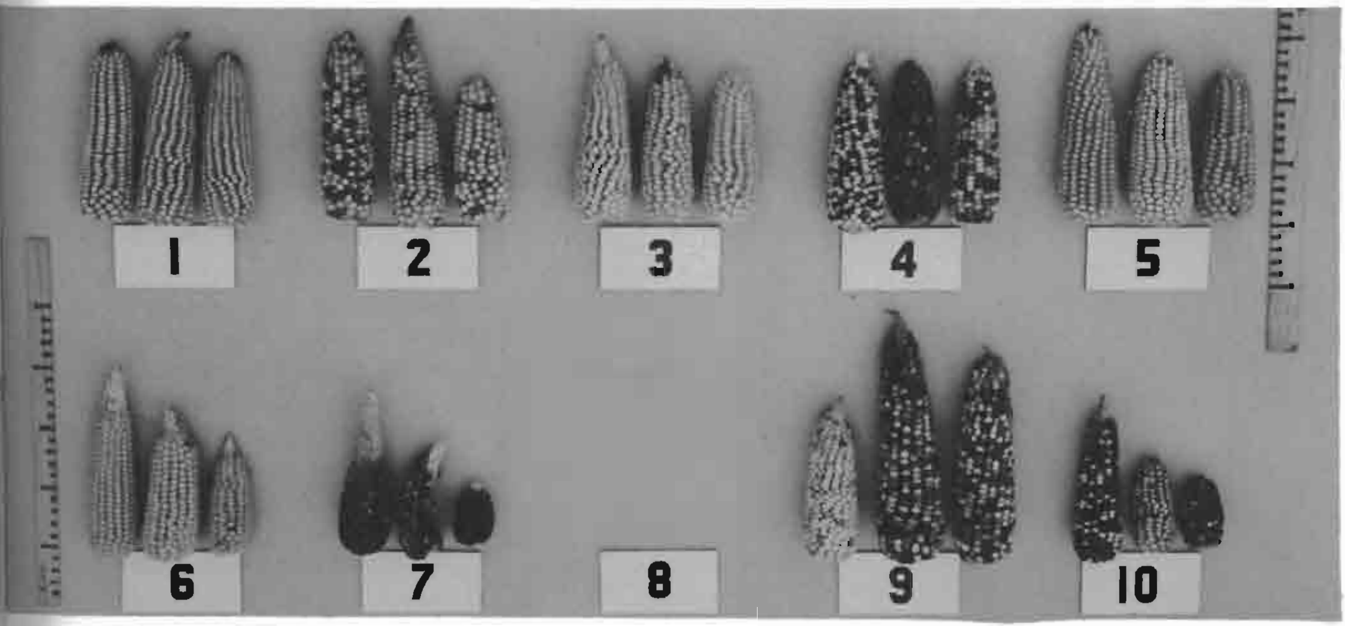


Fig. 4.1. This map shows the distribution of the 25 segments selected through the use of random coordinates. All farmers with any land within the 100-hectare segments were identified and then a 12% sample drawn.



The 10 parcels sampled within a 100-hectare segment often revealed substantial variability in ear size and varietal characteristics. There were also large differences in yields among neighboring parcels.

villages of the area. In the time available, it was not possible to obtain data on the quantity sold by each, but the farm survey data provide a good estimate of the amount used by farmers in the area.

OBJECTIVE YIELD MEASUREMENT OF THE 1968 HARVEST

As the number one goal of the Puebla Project was, and is, to increase production per unit area of corn, it was imperative to have an accurate and continuing measure of what happens to corn yields. This problem is made more difficult under natural rainfall production where yield increases due to the introduction of better practices may be covered up, or exaggerated, by yearly differences in climate. Several methods were considered for extracting the part of the yield change due to climate. A method commonly used by statisticians is to compare four-year averages. However, because of the rapid change in yields sought in this case, it was necessary to measure year to year differences. A second method considered was to measure each year the total rainfall and distribution at a rather large number of locations throughout the region and then based on previous studies by the soils department, calculate the probable rainfall effects. Because of the unknown variation in moisture retention properties of the various soil types, this method also had serious potential limitations. The procedure which appears to have promise is one of comparing yields of unirrigated plantings at various locations where the same varieties, same populations, same fertilization and same care have been applied, in such a way that any differences in yield from year

Measurements taken at most of the high yield plots, showed that yields were approximately double the average for the Project area.

to year can reasonably be expected to be due to various aspects of climate, principally rainfall.

To obtain the necessary data, it is planned to use a selection of the best cared for demonstration parcels spread throughout the region. In 1968 there were 141 from which the selection could be made.

Yields would be measured each year on a probability sample of farm plantings. The data might then be used as in the following hypothetical case.

	Estimate of average farm yield	Estimate of sample of best high yield plots
1968	1,100 kg/ha	4,000 kg/ha
1969	1,300 kg/ha	4,400 kg/ha
Difference	+200	+400

The estimated increase in yield in the area as a whole was $\frac{200}{1,100}$ or 18.2%.

The increase in yield on the demonstration parcels (attributed to climatic factors) was $\frac{400}{4,000}$ or 10.0%.

It is thought that the difference, 8.2 percentage points, can be credited principally to the introduction of a combination of better practices. Obviously, there are several important assumptions behind any comparison of percentages at different yield levels, and it may be possible to make further improvements on this procedure. The 1968 experience with this kind of an adjustment is presented in the next section.

Sampling

A yield estimate for the entire region was obtained in the fall of 1968 by measuring corn yields on a sample of fields. The same 25 segments of 100 hectares each were used and the same list of parcels. To this list was now added the size of each parcel and a cumulative total in order to sample with a list of random numbers among the parcels within each of the segments. The necessary size of sample in the second stage was determined with yield data from the personal interview study. Because of the high level of variability within segments, 10 parcels were included from each. The selection was made in a random systematic form with probability proportional to size, that is a four-hectare parcel had four times as much probability of appearing in the sample as a one-hectare parcel. Because of great variability within parcels observed during the growing season, the size of sample determined for each parcel was five locations of ten lineal meters each, distributed as shown in Figure 4.2.

Ear diameters were measured with husks on (right). The next man husked the corn and passed it to the man at the balance for weighing. Both single ear weights and plot yield weights were obtained.

Once the parcels were selected, the field was sampled as follows. First a coin was flipped to determine from which end the field should be entered. Then the number of rows were counted from left to right. Next with a table of random numbers the starting row was selected. In this row, 10 meters were harvestd out of the first 20 as shown in Figure 4.2. Then the sampling was moved five rows to the right, and so on, until a total of 50 meters had been harvested. If this brought the sampling to the edge of the field, as shown in the illustration, then a jump was made to the opposite edge and the counting of rows was continued toward the right.

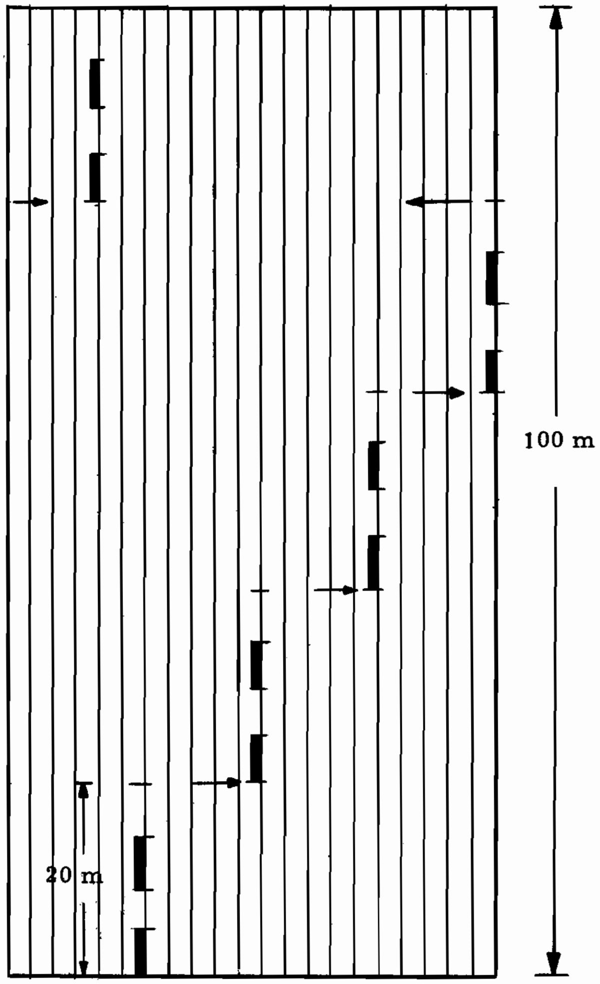


Fig. 4.2. This drawing shows the manner in which a total of 50 meters of corn row was sampled in each field. In each 20 meters as shown two 5 meter sections were included.

Field measurements

To make sure that there would be no problems in carrying out the measurements in the short period between the time that the corn reached maturity and the time that farmers began to harvest, help was requested in advance from municipio and ejido officers and from the farmers included in the sample. In one segment it was not possible to obtain the necessary cooperation; consequently the sample in this case includes only 24 segments. In each segment, measurements were made in the farmers' fields and all of the ears were harvested at the sample locations in order to weigh them. Samples for making moisture determinations were collected at all locations and the rest of the harvested corn was turned over to the owner.

1967 and 1968 yields compared

In this way, an average yield for the entire region was estimated at 2091 kg/ha for 1968 (See Appendix Table XXV for yield data and XXVI for plants per hectare). This was compared to a figure of 1310 kg/ha for 1967, based on the interview data obtained in January and February of 1968. The difference was 781 kg, an increase of 59% from one year to the next. What was the explanation? There was no reason to believe that the first demonstrations, planted in 1968, should have greatly affected fertilizer use during that same year. Nor was there reason to question the validity of the interview data which had been carefully recorded in the yield measures commonly used by farmers and then converted to kilos per hectare of shelled corn at 12% moisture. True there had been less drought in 1968, but the difference had not appeared to be great. What was the explanation?

The problem was not a deficiency in the objective yield measures. These had been checked on 50 high-yield plots. Yields were first estimated by the procedure already described and then the entire plots were harvested and weighed. (See Appendix Table XXVII for comparative data on the 50 plots; Tables XXVIII and XXIX provide additional data on a total of 123 high yield plots). In the 50 plots compared, most estimations were within 5 or 6% of the actual harvest with a maximum error of 13% The error for the 50 farmers as a group was only .74 of 1%.

Must it be, then, that the 1967 yields had been underestimated in the farmer interviews? A partial answer was found by using yield trial data collected by the soils program under similar ecological condi tions during both years. Sites were chosen from those distributed in the centrai part of the area — eight in 1967 and five in 1968 — for the comparison. By using the production functions obtained during each growing season, it was possible to estimate the yield for a given fertilizer application and a given plant population.

Comparisons were made at four levels of fertilization including the one recommended for the area (130-40-0) and the average level used by farmers according to the interview survey, which was 34-17-0. The results of the comparison are striking in at least two aspects: 1) the percentage increase from 1967 to 1968 was similar at various yield levels, and 2) the increase attributable to climate at the level of fertilization used by farmers in 1967 explained all but about 5% of the yield increase from 1967 to 1968. See the following table.

Item	kg/ha
200-50-50M *	
1967 average from 8 locations	4,375.0
1968 average from 5 comparable locations	6,484.0
Increase attributable to climate	2,109.0
Per cent increase attributable to climate	48.2%
130-40-50M	
1967 average from 8 locations	3,618.8
1968 average from 5 comparable locations	5,596.0
Increase attributable to climate	1,977.2
Per cent increase attributable to climate	55.0%
100-50-50M	
1967 average from 8 locations	3,147.5
1968 average from 5 comparable locations	4,968.4
Increase attributable to climate	1,820.9
Per cent increase attributable to climate	57.9%
34-17-50M	
1967 average from 8 locations	1,540.3
1968 average from 5 comparable locations	2,388.4
Increase attributable to climate	848.1
Per cent increase attributable to climate	55.1%

ESTIMATES

Estimate of 1967 yields based on verbal response of farmers interviewed	1,310.0
Estimate of 1968 yields based on objective measurements in the field	2,090.0
Increase from 1967 to 1968	780.0
Per cent increase	59.5%

* Respectively units of elemental nitrogen, P_2O_5 and thousands of plants per hectare.

DESIGNING AN EFFICIENT METHOD FOR ESTIMATING YIELDS

In planning the yield measurements for the fall of 1968, it was realized that the procedure would take considerable time in a very busy period. The method used in 1968 required locating the fields, locating the farmers — who usually lived some distance away in a neighboring village —, obtaining permission to harvest the necessary sample area, harvesting in the presence of the farmer, and finally delivering the corn to him. All of the sample segments had to be harvested within a brief period between the time when the earliest plantings reached maturity and the time when the farmers began to harvest. This period also coincided with the time that experimental and demonstration plots were being harvested.

To overcome part of this problem in future years, a new yield measurement procedure was tested in 1968 and the results were correlated with those obtained by harvesting mature corn. In essence the goal was to estimate yield based on the following data from a statistical sample of corn plantings in the area: number of ears in a given area, average length of ear filled with grain and average diameter of ear at the base. The method was tested on the same plantings included in the statistical sampling of the area. In this way it included all of the important varieties in the area, a wide range of soil fertility and various grain moisture levels.

The ears, later harvested to estimate the 1968 yields, were first counted and measured. A prediction equation was then developed, by relating these measurements to the harvest data through the use of regression analysis. This prediction equation was, in turn, used to develop a table with lengths listed down the side and diameters across the top. Estimated yields of shelled corn at 12% moisture can be read from the body of the table at the juncture of the two points. The data on which this table was based covered yields ranging from 100 to 6,000 kg/ha and the relationships of the measurements with yield showed very little distortion at either end of the scale. This then gives a rapid and fairly accurate means to estimate yields at the plot level.

A more precise estimate of yields will be obtained by machine analysis of the measurements for individual ears. Forms have been prepared for rapid processing of this data on the 1620 computer of the Statistics Center of the Chapingo Graduate College. A detailed description of the statistical procedures involved is included in a paper prepared for journal publication.* In brief, 92% of the variation in grain weight of individual ears ranging in size from 10 grams to 600 was explained with length and diameter and their quadratic effects. Based on this finding, the 1969 yield estimates will be made before harvest following this new design.

Because of climatic variation in the Project area, additional segments are being added, bringing the total to 35, and the number of locations per segment is being reduced.

A COMMENT ON THE GOAL OF DOUBLING CORN YIELDS OVER AN ENTIRE REGION

There are several problems involved in obtaining a general increase of yields throughout a region which are not always completely understood. To bring this into clear perspective, it is worthwhile summarizing what is involved. Obviously, there must be a "technically possible" level of yields which is above the level currently being obtained by farmers. Second, there must be an "economically feasible" level, also above farmers' present yields, but which is usually below the technically possible. Having accepted this, however, there is still a temptation to use single averages to represent the technically possible, the economically feasible, and farmers' yields in order to speak in terms of possible increases. In the field, we find that this can be highly misleading as is illustrated in Figure 4.3. The rather sharp slope of each line, not only the farmers' yields, but also the technically possible, suggests caution in speaking of tripling or quadrupling yields in an entire area of largely rainfed production.

The space between the upper two curves and the two representing farmers' yields indicates the possibilities for increases from all present yield levels. However, it also shows that with given soils and rainfall, not every farmer can think in terms of seven tons per hectare every year. In fact, in 1967, with the best of technology, some could not have reached more than 2.6 tons. For this reason, every effort must be made to raise the level, and if possible, reduce the slope of the curve which represents the "highest technically possible", at the same time that the extension advisory program focuses on bringing the curve of farmers' yields closer to the level of economic optimum.

The prospects for achieving this rest heavily on the genetic improvement work to develop a higher

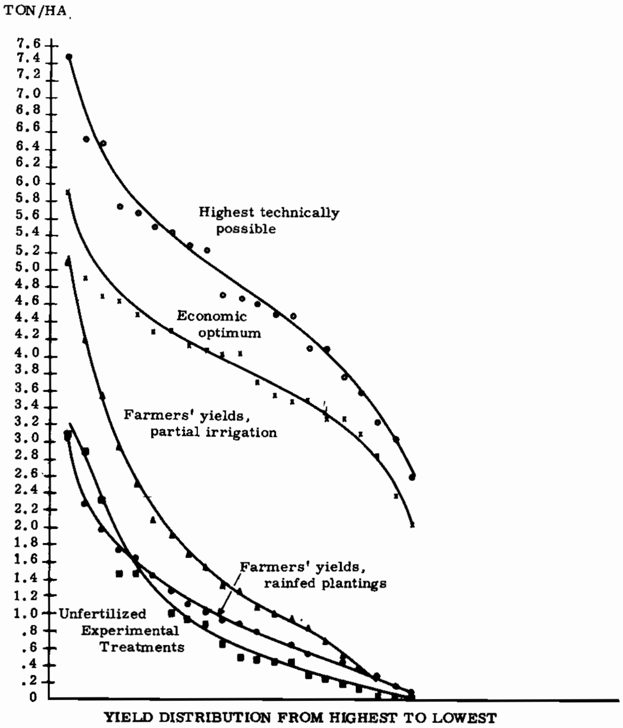


Fig. 4.3. Comparison of 21 yield levels in 1967.
○ Yields of the best treatment in each of 21 fertilizer experiments located throughout the area in 1967, in rank order by yield.
× Data from the same trials obtained with the application of 120-50-0 and 50,000 plants per hectare, also in rank order by yield.
△ Survey data for the 1967 harvest from 95 farmers who had at least one parcel on which at least one irrigation was applied. Data were rank ordered and then averaged by groups of five.
● Data for the 1967 harvest from the 202 farmers in the survey who had rainfed plantings. Data were rank ordered and then averaged by groups of ten.
□ Yields of the 0-0-0 treatments with 50,000 plants in 21 fertilizer experiments located in the area in 1967, in rank order by yield.

yielding variety capable of responding to higher levels of fertilization and broadly adapted throughout the region. The sharp slope of the curve is due in part to yearly fluctuations in rainfall distribution. In part, it also appears to be due to special soil conditions which limit response to nitrogen and phosphorus. The continuing soils research may provide answers to help solve these problems.

Figure 4.4, based on 1968 data, shows similar relationships to those obtained in 1967. In this case, data from irrigated and rainfed plantings are combined, but an additional curve is included, one based

* Heliodoro Diaz C., Delbert T. Myren and Richard E. Lund. "Estimating Corn Yields in the Puebla Area with a Regression Model Based on Ear Length and Diameter".

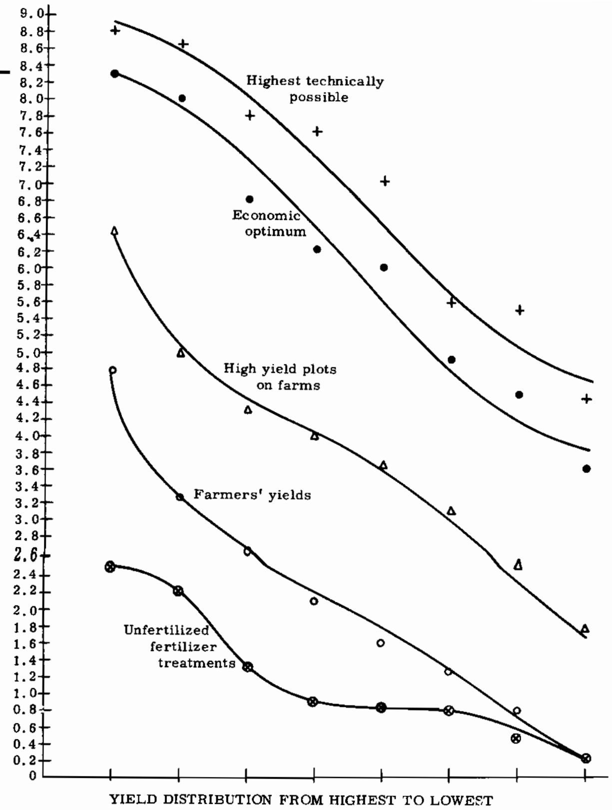


Fig. 4.4. Comparison of eight yield levels in 1968. Sources of data were:

- **+ Yields of the best treatment in each of 8 fertilizer experiments strategically located throughout the area in 1968, in rank order by yield. In 7 cases, the N application was 200 kg/ha in the other it was 150. In 6 cases, the phosphorus application was 100 kg/ha, in the others 0 and 75. In 7 cases the optimum population was 70,000, in the other, 50,000.**
- **● Yields of the economically optimum treatment in each of the 8 fertilizer experiments, in rank order by yield. The N applications varied from 102 to 200 kg/ha; the phosphorus from 0 to 95; plant population from 42,000 to 70,000.**
- **△ The data from farmers' high yield plots include 123 fields that were measured by the evaluation team in 1968. Data were rank ordered and then averaged by groups of 15.**
- **○ Data from an objective sampling of 184 farmers fields in a two-stage probability sample of the Project area. Data were rank ordered and then averaged by groups of 23.**
- **⊗ Yields of the 0-0-0 treatments with 30,000 plants in 8 fertilizer experiments in 1968, in rank order by yield.**

on yields of 123 high-yield plots grown by farmers who participated in the Puebla Project. The item of additional interest here is the still substantial gap between yields of these plots and yields from the economic optimum determined from soils research data. Part of this difference is due to the fact that the recommendation followed in the high-yield plots is purposely conservative and partly because weed control and other care were not optimum in all cases.

TRADITIONAL CORN PRODUCTION AND THE ECONOMICS OF RECOMMENDED CHANGES

In order to obtain a clear picture of the use of capital and labor in traditional corn production compared with the recommended practices, small groups of farmers were interviewed in five different corn producing situations. Table 4.1 shows average data from the five.

Note the following: 1) cultivation practices are distributed over the entire year, from plowing under the stubble in mid-November to harvesting the crop the following November; 2) the total amount of labor used, 40.6 days per hectare; 3) the total cost, even at the low labor rate of just over one dollar per day for a man and $ 2.00 per day for a man with team. The labor costs alone add up to 935.40 pesos, about US $ 75 per hectare.

An additional point which does not stand out in the table is the precision of timing required for certain operations. Some may be spread over two or three weeks, such as the initial land preparation and the planting period may be extended by using different varieties for different planting dates, which also helps spread the labor needs for the first and second cultivations. However, the timing of the cultivations is critical. As soon as the corn reaches a certain height, as mentioned earlier, the farmer waits for a rain to moisten the soil well, and then immediately cultivates. If the soil dries out again before the cultivation is completed, the corn may suffer a serious set-back.

In this way the work on corn is spread throughout the entire year. At certain times there is work that must be done at the moment if yields are not to be reduced, and at other periods there is free time which could be, and frequently is, employed in other work. The heavy labor demand at certain peak periods, especially harvest, is solved in part by participation of all members of the family.

The recommended changes for high yield production have been described earlier in this report. Essentially, these changes imply a slight additional cost for seed to obtain the higher plant population, a heavy additional investment in fertilizer plus interest on the loan for the additional fertilizer, and additional labor for planting at a higher density, applying the fertilizer, and harvesting the additional crop.

The data in Table 4.2 are from the same farmers who provided the data for the previous table. There

TABLE 4.1. Animal and human labor used per hectare in traditional corn plantings.

Item	Days	Day Rate *	Total *
Plowing under the stubble. Nov. 15			
Team and man	3.4	25.00	85.00
First plowing (Primer barbecho). Dec. 1-15			
Team and man for plowing	3.2	25.00	80.00
Team and man for dragging	.4	25.00	10.50
Second plowing (Segundo barbecho). Jan. 1-31			
Team and man for plowing	1.8	25.00	45.00
Team and man for dragging	.3	25.00	8.00
Planting. March 15-May 15			
Team and man to row out	1.7	25.00	42.50
Planters	2.6	12.30	32.00
Meal for workers			2.50
First cultivation. April 15-June 30			
Team and man	1.7	25.00	42.50
Field hands, fertilizer application **	.8	10.75	8.60
Field hand to uncover plants	2.1	13.04	27.40
Meals for workers			2.50
Second cultivation. May 15-July 15			
Team and man	1.8	25.00	45.00
Field hands, fertilizer application **	.4	15.00	6.00
Hand weeding	1.8	12.22	22.00
Meal for workers			2.50
Harvest. October 1-December 31			
Hand-harvest of tops of plants	2.0	13.80	27.60
Shocking the corn	1.6	13.00	20.80
Picking the corn	8.6	13.40	115.20
Transporting ear corn from the field			57.40
Drying and turning the ear corn			41.00
Meals for workers			20.00
Transporting fodder from the field			60.00
Husking the ears			45.00
Shelling the corn	6.4	13.50	86.40
		TOTAL	935.40

* Values are in Mexican pesos. One peso = US $ 0.08 The unrounded numbers are the result of averaging figures from five separate areas.
** Some apply fertilizer in the first cultivation and others in the second.

is no attempt here to exaggerate differences. These particular individuals were using some fertilizer — close to the average application for the region — so the fertilizer is included in the traditional practice. By following the recommended practices, these men averaged 3,870 kgs/ha (60 bushels per acre) just under the average of all high yield plots. The result was an additional net per hectare of 1,232.70 pesos (US $ 100.99) per hectare. As far as the region is concerned, more than half of the additional cost — that for labor — also remained in the area.

It is easy to see that if on the average this much increase can be obtained on all of the corn acreage in the area, the additional net per year would be over 8 million dollars, paying many times over the cost of the project. This is one important aspect that will be measured carefully as the Project progresses.

TABLE 4.2. Costs and returns per hectare under traditional and recommended production practices. *

Item	Mex. pesos	Mex pesos
Costs under usual production methods		
Animal and human labor (Table 4.1)	935.40	
Fertilizer and transport, 320 kg of 10-8-4. 742 pesos/ton	261.00	
Seed	7.80	
		1,204.20
Returns under usual production methods		
1,500 kg grain. 900 pesos/ton	1,350.00	
Fodder	196.00	
		1,546.00
NET UNDER TRADITIONAL METHODS		**341.80**
Costs under recommended practices		
Animal and human labor	1,475.70	
Seed	16.80	
Fertilizer and transport, 650 kg of ammonium sulfate at 844 pesos/ton and 200 kg of simple superphosphate at 560 pesos/ton	704.00	
Interest on fertilizer loan at 1.5% for 8 months	82.00	
		2,278.50
Returns under recommended practices		
3,870 kg of shelled corn at 12% moisture. 900 pesos/ton	3,483.00	
Fodder	370.00	
		3,853.00
NET UNDER RECOMMENDED PRACTICES		**1,574.50**
ADDITIONAL NET		**1,232.70**

* Data provided by cooperating farmers at five localities in the Puebla Area. Land rent is not included.

Farmers who followed project recommendations averaged about 4 tons per hectare. Neighbors who did not, averaged about 2 tons on similar fields.

Going home with the harvest.

appendix tables

TABLE I. Average monthly temperatures in degrees centigrade for the period May-October at five locations.

Location	May	June	July	Aug.	Sept.	Oct.
San Martin Texmelucan	19.7	19.7	18.8	19.3	19.0	17.7
Puebla	19.3	18.3	17.4	17.8	17.2	16.6
Huejotzingo	18.6	18.3	17.3	17.2	16.7	15.1
Acajete	17.0	16.5	15.5	16.2	15.5	15.2
Tepeaca	17.4	17.2	16.1	16.4	16.1	15.0

TABLE II. Average frequencies of frosts and hail for each month at five locations.

Location	January	February	March	April	May	June	July	August	September	October	November	December
A					Average number of days with frost							
San Martin Texmelucan	3.5	2.2	0.1	0	0	0	0	0	0	0.4	2.0	3.4
Puebla	2.1	1.2	0.3	0	0	0	0	0.4	0	0.3	0.8	2.4
Huejotzingo	10.2	6.8	1.8	0.7	0.3	0.1	0	0	0	1.8	5.0	8.7
Acajete	11.2	6.6	1.9	0.6	0.06	0	0	0	0	2.4	6.4	13.0
Tepeaca	17.8	11.1	3.3	0.6	0.1	0	0	0	0.04	1.7	7.9	14.4
B					Percentage of years with one or more days with frost							
San Martin Texmelucan	69	41	4	0	0	0	0	0	0	16	54	67
Puebla	50	44	17	0	0	0	0	4	0	12	29	42
Huejotzingo	92	88	54	33	17	5	0	0	0	42	75	88
Acajete	96	87	55	21	6	0	0	0	0	53	92	92
Tepeaca	100	100	86	39	7	0	0	0	4	61	96	100
C					Average number of hails							
San Martin Texmelucan	.00	.09	.04	.48	.96	.61	.83	.92	.24	.68	.25	.08
Puebla	.31	.04	.08	.48	1.00	.88	.88	1.96	.80	.37	.29	.12
Huejotzingo	.12	.08	.04	.43	.67	.54	.96	1.04	.46	.23	.08	.00
Acajete	.00	.04	.09	.21	.56	.35	.11	.07	.19	.00	.15	.00
Tepeaca	.21	.07	.29	1.04	1.96	.54	.64	1.04	.54	.68	.21	.18

TABLE III. Monthly precipitation in millimeters during the period April-October at Puebla, Pue.

Year	April	May	June	July	Aug.	Sept.	Oct.	Total
1941	44.9	37.8	159.3	104.8	93.0	148.0	117.2	705.0
1942	4.7	28.6	256.6	144.7	209.5	150.8	43.2	838.1
1943	17.7	106.5	111.5	53.5	222.5	208.4	102.0	822.1
1944	2.8	75.4	197.7	157.0	235.6	159.0	6.8	834.3
1945	3.1	88.2	124.0	143.8	176.5	126.6	51.4	713.6
1946	81.9	73.6	230.7	59.6	87.6	71.1	57.6	662.1
1947	35.8	152.0	136.3	54.8	240.3	193.4	97.5	910.2
1948	47.4	66.5	118.4	200.5	140.2	168.0	28.4	769.4
1949	0.6	54.2	119.7	187.3	57.7	88.3	26.9	534.7
1950	7.7	75.7	86.4	134.9	67.1	171.6	61.4	604.8
1951	1.4	59.9	173.1	173.2	103.5	147.5	14.5	673.1
1952	39.6	113.8	162.1	126.4	141.6	216.7	18.1	818.3
1953	3.8	4.2	148.9	105.8	96.0	159.7	149.6	668.0
1954	30.1	117.5	250.6	167.5	153.8	154.9	126.0	1000.4
1955	8.2	91.2	152.5	221.1	281.2	301.2	75.5	1130.8
1956	69.9	127.9	209.4	129.9	152.7	138.3	41.0	869.1
1957	59.7	22.8	141.1	93.9	78.9	163.1	57.7	617.2
1958	8.3	32.2	111.6	124.1	172.3	266.9	144.2	860.6
1959	74.2	58.6	250.9	133.1	233.7	61.6	124.5	936.6
1960	15.5	35.3	86.4	207.5	162.2	182.2	86.9	776.0
1961	13.4	33.9	119.5	147.0	71.9	154.0	54.8	594.5
1962	55.4	92.5	121.6	55.4	107.3	128.7	92.5	653.4
1963	7.0	76.3	133.6	203.0	191.0	95.2	117.6	823.7
1964	23.4	138.8	203.7	107.9	163.3	194.2	13.7	845.0
Average	27.4	73.5	158.6	134.9	151.6	160.4	71.2	777.5

TABLE IV. Monthly precipitation in millimeters during the period April-October at Huejotzingo, Pue.

Year	April	May	June	July	Aug.	Sept.	Oct.	Total
1943	26.6	69.1	175.0	139.6	240.6	364.2	24.1	1039.2
1944	7.5	39.1	177.2	215.6	194.2	187.3	37.8	858.7
1946	55.9	105.8	136.5	106.9	106.8	115.1	72.5	699.5
1947	30.6	108.7	65.1	80.6	188.8	121.9	103.5	699.2
1948	34.4	47.9	130.8	215.2	157.0	143.1	41.3	769.7
1949	5.4	65.6	146.1	136.0	45.0	115.4	41.6	555.1
1950	15.9	67.9	99.3	216.0	106.9	72.2	19.0	597.2
1951	28.1	83.0	115.5	323.0	149.0	97.5	42.8	838.9
1954	35.5	97.5	258.8	186.4	146.5	170.5	178.0	1073.2
1955	0.0	11.0	98.0	344.5	214.0	277.5	81.0	1026.0
1956	39.5	139.0	205.5	182.5	235.0	162.0	33.0	996.5
1957	58.0	59.5	136.0	105.5	186.5	120.0	59.0	724.5
1958	20.0	35.0	128.5	199.0	163.0	216.0	168.0	929.5
1959	38.0	76.5	119.0	169.5	128.5	98.0	151.0	780.5
1960	0.0	79.5	88.0	296.5	180.5	131.5	100.0	876.0
1961	11.5	31.5	232.5	195.0	174.5	159.0	40.5	844.5
1962	48.5	42.0	146.5	97.5	197.0	256.5	69.5	857.5
1963	2.0	78.0	167.0	188.0	175.5	240.0	163.0	1013.5
1964	17.0	158.5	194.0	162.0	139.0	106.0	19.0	795.5
1965	32.0	98.0	86.5	186.0	270.5	227.5	140.0	1041.5
1966	36.0	32.0	69.0	197.0	231.0	113.5	21.0	699.5
1967	36.5	43.0	117.5	88.5	136.5	160.5	25.0	607.5
1968	86.9	44.0	197.0	92.5	115.0	129.5	48.0	712.9
Average	28.9	72.6	141.7	187.7	172.8	166.4	76.5	827.7

TABLE V. Monthly precipitation in millimeters during the period April-October at San Martin Texmelucan, Pue.

Year	April	May	June	July	Aug.	Sept.	Oct.	Total
1943	52.2	66.3	153.0	118.0	224.4	229.5	97.6	941.0
1944	9.0	34.7	109.0	150.0	193.5	139.0	22.5	657.7
1948	8.5	66.5	182.0	237.0	245.5	154.0	69.5	963.0
1949	16.0	71.5	83.0	78.5	67.5	159.0	38.0	513.5
1950	21.0	54.5	117.0	165.5	82.5	160.0	8.0	608.5
1951	20.6	58.7	67.7	259.0	120.0	100.9	20.9	647.8
1952	49.7	144.8	197.4	141.6	197.9	109.3	4.5	845.0
1953	10.3	7.2	243.5	87.6	143.5	69.8	176.3	738.2
1954	42.7	107.2	179.6	162.0	184.1	118.3	75.9	869.8
1955	0.0	47.3	146.4	242.4	227.7	261.3	75.1	1000.2
1956	35.9	127.7	257.6	204.1	104.4	128.2	16.3	874.2
1957	35.9	90.8	111.6	170.8	145.5	150.0	79.2	783.7
1958	15.9	104.7	155.8	191.2	291.0	176.6	99.5	1034.8
1959	67.1	105.4	175.5	149.0	140.4	79.9	191.3	908.6
1960	43.4	104.2	90.7	208.0	94.7	155.0	199.5	895.5
1961	28.7	55.1	223.0	160.0	119.2	150.4	59.8	796.4
1962	53.3	47.2	160.1	35.6	87.2	103.5	85.0	571.9
1963	10.4	132.3	136.7	203.5	136.8	132.3	115.3	867.3
1964	11.2	221.3	147.4	137.5	119.1	161.3	45.7	843.5
1965	45.2	51.4	62.4	165.5	142.8	105.9	101.5	674.7
1966	36.3	22.1	93.8	218.4	100.9	53.2	36.5	561.2
1967	29.0	83.4	144.2	55.5	171.9	159.6	56.6	700.2
1968	0.0	100.8	184.3	122.3	67.9	72.7	45.2	593.2
Average	27.9	81.9	147.3	166.0	150.9	138.0	77.0	777.8

TABLE VI. Monthly precipitation in millimeters during the period April-October at Acajete, Pue.

Year	April	May	June	July	Aug.	Sept.	Oct.	Total
1943	49.0	283.3	203.2	95.1	196.2	203.8	28.6	1014.2
1944	23.0	41.7	218.7	165.9	261.3	190.0	26.2	927.7
1945	12.0	34.2	73.7	177.4	101.5	84.0	67.0	549.8
1949	17.5	141.6	163.0	112.5	114.5	175.1	90.0	814.2
1952	53.3	146.8	252.5	221.3	110.5	143.3	0	927.7
1953	31.0	7.0	179.5	83.0	112.5	149.5	138.3	700.8
1954	65.5	223.0	268.5	127.0	147.5	181.0	65.0	1077.5
1955	12.5	85.0	91.5	256.5	264.0	362.0	89.0	1160.5
1956	103.5	205.5	269.8	175.0	112.5	135.0	22.0	1023.0
1957	76.0	108.5	70.0	96.5	41.0	113.0	74.0	579.0
1962	42.0	62.5	77.0	71.0	129.5	291.5	48 5	722.0
Average	44.1	117.6	169.7	143.7	144.6	184.5	59.0	863.3

TABLE VII. Monthly precipitation in millimeters during the period April-October at Tepeaca, Pue.

Year	April	May	June	July	Aug.	Sept.	Oct.	Total
1941	68.1	81.0	195.6	118.4	42.3	167.8	135.4	808.6
1942	39.7	82.9	260.7	94.6	163.9	190.9	55.2	887.9
1943	46.6	178.2	93.2	61.9	154.3	138.3	7.5	680.0
1944	4.0	49.3	196.7	120.7	163.1	202.2	35.7	771.6
1945	25.0	63.4	94.2	147.5	150.9	98.5	65.2	654.7
1946	44.8	138.3	125.3	22.7	138.5	92.5	75.6	637.7
1947	73.8	248.8	140.7	69.3	203.8	158.1	79.4	973.9
1948	34.3	96.7	128.7	197.2	98.6	138.4	55.3	749.2
1949	18.6	109.5	115.4	66.9	36.6	135.5	44.6	527.1
1950	37.9	164.1	73.0	48.6	99.0	136.8	19.1	578.5
1951	5.6	155.9	236.7	123.4	84.0	156.6	35.4	797.6
1952	108.4	213.3	155.6	74.6	93.8	132.0	3.4	781.1
1953	13.3	8.9	246.6	65.4	79.3	128.4	84.5	626.4
1954	53.2	159.6	158.8	91.1	139.2	148.3	133.4	883.6
1955	8.4	38.8	89.6	184.6	172.1	298.2	49.7	841.4
1956	44.7	187.8	164.2	133.6	65.8	124.1	50.4	770.6
1957	79.1	39.2	104.8	66.1	28.5	89.9	20.7	428.3
1958	16.0	120.3	133.9	100.4	120.6	338.2	169.2	998.6
1959	71.3	55.7	295.2	71.8	64.3	94.1	135.9	788.3
1960	25.1	115.7	73.5	106.3	125.0	157.0	55.0	657.6
1961	19.8	57.6	107.5	128.9	64.9	153.4	15.4	547.5
1952	32.8	67.9	113.1	53.4	189.3	118.9	20.8	596.2
1963	34.6	178.5	158.3	131.5	137.2	91.5	123.4	855.0
1964	32.7	87.7	122.6	68.5	98.1	84.2	141.3	635.1
1965	31.7	120.8	205.4	51.9	141.9	79.0	110.4	741.1
1966	110.4	119.7	124.7	236.7	166.1	146.4	108.3	1012.3
1967	42.7	73.1	172.7	18.0	107.7	168.5	119.4	702.1
1968	92.5	137.0	258.7	66.1	38.1	12.5	40.2	645.1
Average	43.4	112.8	151.6	96.0	114.2	146.1	68.9	734.9

TABLE VIII. Description of soil profiles *

I. Guadalupe Zaragoza

Position: A broad, relatively flat interfluve of dissected alluvial fan.

Parent material: Volcanic outwash.

Ap1	0-18 cm Very dark grayish brown fine sandy loam; weak, subangular blocky and granular; slightly hard, very friable; pH 6.5.
Ap2	18-40 Very dark grayish brown fine sandy loam; massive; very hard, friable.
B21t	40-62 Very dark grayish brown to dark brown light clay; moderate prismatic and moderately strong subangular blocky; very hard, friable to very friable.
B22tx	62-92 Dark brown light clay; moderate weak subangular blocky; very hard, friable to firm; pH 7.0.
B3	92-120 Brown to dark brown loam; weak subangular blocky; slightly hard to hard, friable; pH 7.5.
C	120^{+} Dark grayish brown loam; massive; soft, very friable; pH 7.5.

II. San Rafael Ixtapalucan

Position: High, dissected alluvial fan.

Parent material: Volcanic outwash.

Ap	0-23 cm Very dark grayish brown sandy loam; weak subangular blocky; very friable; pH 6.5.
B1	23-36 Brown to dark brown sandy loam to loam; weak subangular blocky; friable.
B21tx	36-53 Brown to dark brown light clay loam; very weak subangular blocky; firm; pH 8.0.
B22t	53-94 Dark yellowish brown heavy clay loam to light clay; moderately weak subangular blocky; very friable; pH 7.5.
B3	94-140 Dark yellowish clay loam; moderate subangular blocky; friable.
C	140^{+} Brown to dark brown light clay loam; weak granular; friable; pH 7.0; soft Fe-Mn segregations.

III. San Miguel Tianguistengo

Position: Medium high dissected alluvial fan.

Parent material: Volcanic outwash.

Ap	0-15 cm Brown loam; mixed weak granular and weak subangular blocky; very friable; pH 6.5.
B2t	15-32 Dark brown clay loam; moderate subangular blocky; friable, very hard (dry); pH 7.5.
B31x	32-80 Pale brown loam; weak subangular blocky; friable to firm, hard (dry); pH 7.5.
B2′t	120-140 Mixed dark brown and dark yellowish brown loam; mixed weak subangular blocky and massive; mixed friable and firm, mixed very hard and soft (dry).
C	140^{+} Brown loam; massive; friable; pH 7.5.

IV. San Andres Calpan

Position: Gently sloping interfluve of strongly dissected alluvial fan.

Parent material: Mostly volcanic outwash. Upper 75 cm may be unsorted volcanic ejecta.

Ap	0-18 cm Dark grayish brown sand; weak granular to single grain; very friable to loose; pH 7.0.
A1	18-31 Dark grayish brown sand; weak granular to single grain; very friable to loose; pH 7.0.
IIB1	31-51 Very dark grayish brown loam; weak granular and weak subangular blocky; very friable; pH 6.5.
IIB2	51-94 Grayish brown heavy loam or light clay loam; moderately weak subangular blocky; firm; pH 7.0.
IIIB3	94-112 Grayish brown loam; weak subangular blocky and weak granular; firm except for Fe-Mn segregations which are very firm.
IIIC	112^{+} Light brownish gray loam; weak subangular blocky and weak granular; very friable; pH 7.5.

V. San Mateo Capultitlan

Position: Middle constructional alluvial fan. Sloping topography.

Parent material: Recent alluvium composed of volcanic debris.

Ap 0-18 cm Very dark grayish brown sand; single grain and weak granular; loose to very friable; pH 6.7.

C1 18-89 Varicolored sand particles; interstratified thin layers of variable-sized sands and silt; sandy strata compose by far the greater percentage of the horizon; single grain; loose; pH 7.2.

C2 89⁺ Very dark grayish brown sandy loam; massive; friable; pH 7.5.

VI. San Pedro Tlaltenango (Xometitla)

Position: Undissected, very gently sloping lower part of alluvial fan.

Parent material: Water-reworked, fine textured volcanic ejecta.

Ap1 0-13 cm Dark grayish brown loamy sand; weak granular; very friable.

Ap2 13-36 Very dark grayish brown loamy sand; weak granular; very friable.

B21 (t?) 36-64 Dark grayish brown light clay loam; mixed subangular blocky and granular; friable.

B22 (t?) 64-94 Dark grayish brown light clay loam; mixed subangular blocky and granular; hard, friable.

B3 94-122 Very dark grayish brown to dark brown mixture of B22t and C materials.

C 122⁺ Pale brown, weak granular; soft, very friable.

VII. San Lorenzo Almecatla

Position: Gently sloping upland unrelated to alluvial fan development. Possibly low terrace.

Parent material: Partially consolidated ash (*tepetate*).

Ap 0-20 cm Grayish brown loamy sand; weak subangular blocky and granular; loose to very friable; pH 6.0.

A1 20-38 Grayish brown loamy sand; massive; friable; pH 6.5; few coarse mottles.

A11b 38-62 Dark gray sandy clay loam; moderately weak prismatic; very friable; pH 8.2; common Fe-Mn concretions.

A12b 62-80 Dark gray sandy clay loam; weak prismatic; friable; pH 8.2; few Fe-Mn concretions.

Cmb 80⁺ light gray; structureless; pH 8.2; moderately cemented.

VIII. San Jeronimo Tecuanipan

Position: Undulating upland unrelated to present alluvial fan. Lower part of profile (IIB2 and IIB3) may be outwash material.

Parent material: Volcanic ejecta.

Ap1 0-27 cm Very dark grayish brown gravelly sand; single grain; loose; pH 6.5.

A1 27-60 Brown dark brown gravelly sand; single grain; loose.

B1 60-75 Dark yellowish brown gravelly sand; single grain; loose; pH 7.5.

IIB2 75-118 Light brownish gray heavy loam; weak subangular blocky; friable; pH 7.5.

IIB3 118⁺ Yellowish brown gravelly loam; massive, very firm (brittle); pH 7.5.

* Soil horizon designations are in accordance with the 7th Approximation, A Comprehensive System of Soil Classification, Soil Conservation Service, U.S.D.A. Washington, D.C. For each horizon is given in order the color of the dry soil and its texture, structure, consistence, and sometimes pH or other observation.

TABLE IX. Properties * of soil samples taken from several horizons at sites where fertilizer experiments were conducted in 1967.

No. of exper.	Soil depth cm	pH	Ammon-ifiable N kg/ha	Avail-able P kg/ha	Avail-able K kg/ha	Available moisture %	Textural class
	0-42	7.6	76	21	244	7.6	Sandy loam
01	42-67	8.7	18	11	265	12.7	Sandy loam
	69-85	8.3	2	10	170	5.5	Sandy loam
	91-156	7.6	11	17	203	8.5	Sandy loam
02	0-30	6.7	28	16	298	7.1	Loamy sand
	30-75	7.2	10	9	361	10.6	Sandy clay loam
	75-200	7.3	2	8	421	10.3	——
	0-32	6.3	81	86	226	22.1	Silt loam
03	32-66	6.3	15	72	122	6.5	Sandy loam
	66-92	6.7	2	46	76	3.5	Sand
	92-127	6.7	7	60	258	10.0	Silt loam
	0-28	6.7	15	12	169	7.3	Loamy sand
04	28-73	7.2	7	10	337	14.8	Sandy loam
	73-200	7.0	15	7	450	14.2	——
05	0-27	7.4	7	8	352	10.1	Sand
	27-200	6.7	17	16	414	9.8	Silt loam
06	0-40	6.9	4	12	282	7.3	Sand
	40-185	6.8	5	8	386	12.7	Sandy loam
	0-27	6.2	21	13	286	9.0	Sand
07	27-83	6.8	4	10	288	14.9	Sandy loam
	83-200	6.9	8	7	447	11.3	Silt loam
	0-30	6.6	16	12	221	5.2	Sand
08	30-52	6.9	9	7	310	4.6	Sand
	73-94	6.9	8	5	483	11.7	Silty clay loam
	111-156	6.9	5	5	477	8.8	Silt loam
	0-42	7.0	35	34	127	5.3	Sand
09	42-62	7.3	10	11	193	7.7	Sand
	88-132	7.2	8	5	296	13.0	Silty clay loam
10	0-25	7.0	52	8	353	14.3	Sandy clay
	25-148	7.4	8	5	493	20.3	Silty clay loam
	0-18	6.7	18	11	272	4.0	Loamy sand
11	18-55	6.9	8	7	348	4.9	Sandy loam
	55-200	7.4	5	5	333	2.4	Sandy loam
	0-26	6.8	11	10	273	3.9	Sand
12	26-62	6.9	15	8	562	7.4	Sandy loam
	62-118	7.0	12	8	522	4.5	Silt loam
	0-36	7.0	64	22	429	9.7	Sandy loam
13	36-82	7.5	22	21	427	7.3	Sandy loam
	82-114	7.9	21	27	545	10.2	Sandy loam

Continued

TABLE IX. Continued

No. of exper.	Soil depth cm	pH	Ammon-ifiable N kg/ha	Avail-able P kg/ha	Avail-able K kg/ha	Available moisture %	Textural class
14	0-25	7.0	26	13	214	12.2	Sandy clay loam
	25-99	7.3	9	5	279	10.1	Clay
	0-28	6.0	42	63	441	7.2	Sandy loam
15	28-58	6.7	3	12	523	11.4	Silty clay loam
	58-200	7.0	4	5	529	7.5	Silt loam
	0-30	7.0	26	53	299	4.5	Sand
16	30-49	7.3	15	52	412	4.6	Sand
	68-156	7.5	3	21	444	7.8	Sandy loam
17	0-37	8.0	52	104	663	4.7	Sand
	37-200	7.5	4	9	463*	7.0	Sandy loam
18	0-33	6.5	47	10	504	15.8	Silt loam
	33-115	7.0	38	292	752	21.1	Silt loam
19	0-92	7.0	8	12	157	11.8	Sand
	92-180	7.0	7	8	388	23.7	Silt loam
20	0-31	6.5	9	16	204	2.2	Sand
	31-200	6.9	3	11	416	9.4	Sandy loam
	0-22	6.6	36	45	356	7.2	Sandy loam
21	22-49	7.2	0	37	858	14.1	Clay loam
	67-200	7.0	9	67	484	12.6	Silt loam
	0-26	6.5	8	16	159	3.6	Sand
22	26-66	7.0	13	7	230	20.7	Silty clay
	66-146	6.8	4	5	600	20.0	Clay
23	0-22	6.5	1	18	231	8.6	Sand
	22-86	6.9	5	7	429	21.8	Clay
	0-27	6.9	73	72	304	11.2	Sandy loam
24	27-53	7.3	9	40	424	14.0	Silt loam
	82-128	7.5	4	22	412	15.6	Sandy loam
	0-26	7.3	10	23	195	7.7	Sand
25	26-80	7.4	2	7	585	17.6	Sandy loam
	80-200	6.9	3	5	570	15.0	Silt loam
	0-22	8.1	95	46	806	20.6	Silt loam
26	22-57	8.2	8	23	663	20.2	Silty clay loam
	57-82	8.1	8	15	492	21.5	Silt loam
	82-101	7.9	3	15	464	15.6	Sandy loam
	0-20	7.7	49	21	428	7.5	Sandy loam
27	20-50	7.8	5	9	458	15.3	Silt loam
	50-125	7.9	8	11	520	11.1	Sandy loam

* The chemical analyses and the determination of the available moisture percentages were made by the Soil Testing Laboratory, Iowa State University, Ames, Iowa. The pH values were determined in a 2:1 water-soil suspensión. Ammonifiable nitrogen was the amount of nitrogen mineralized after one week of anaerobic incubation at 40°C. Available phosphorus was extracted with a 0.025 *N* HCl plus 0.03 *N* NH_4F solution (Bray No. 1 Extractant). Available potassium was extracted with a 1*N* ammonium acetate solution. The available moisture percentage was calculated as the difference between the moisture retained by the soil against suctions of 0.3 and 15 bars. The natural class was estimated in the field by rubbing a moist sample of soil between the fingers.

TABLE X. The urban-rural classification compared with the farming population in the 32 municipios of the Puebla Project.

Municipio	Farm population by occupation [1] Private operators and family: More than 5 ha	5 ha or less	Share crop-pers	Farm laborers	Ejidatarios and families	Total	Population by place of residence [2] Urban	Rural	Total
1. Acajete	147	3,994	78	236	13,240	17,695	6,009	12,132	18,141
2. Amozoc	250	2,826	—	290	5,510	8,876	7,019	7,172	14,191
3. S. A. Calpan	9	6,224	—	3	2,071	8,307	6,104	2,309	8,413
4. Coronango	—	11,382	—	—	3,482	14,864	6,009	2,753	8,762
5. Cuautlancingo	18	7,811	—	38	3,136	11,003	7,026	5,018	12,044
6. Chiautzingo	57	3,040	—	54	5,316	8,467	2,773	5,126	7,899
7. Domingo Arenas	2	773	—	6	1,472	2,253	—	2,431	2,431
8. Huejotzingo	69	5,059	—	73	6,205	11,406	12,015	5,291	17,306
9. Juan C. Bonilla	5	5,248	—	3	1,036	6,292	—	5,135	5,135
10. S. B. Nealtican	—	3,114	—	—	—	3,114	2,819	235	3,054
11. Ocoyucan	—	4,871	—	—	3,397	8,268	—	7,938	7,938
12. Puebla	196	2,293	—	314	3,263	6,066	289,049	8,208	297,257
13. Resurreccion	30	1,536	—	66	2,834	4,466	2,647	312	2,959
14. San Andres Cholula	45	15,826	—	64	2,617	18,552	5,910	8,162	14,072
15. S. Felipe Hueyotlipan	49	1,015	—	67	1,958	3,089	2,731	2,630	5,361
16. S. Felipe Teotlalcingo	—	1,606	—	—	3,217	4,823	—	4,014	4,014
17. S. G. Atzompa	12	3,144	—	5	—	3,161	—	2,918	2,918
18. S. Jeronimo Calera	15	1,179	—	23	1,410	2,627	2,689	2,193	4,882
19. S. Jeronimo Tecuanipan	15	3,920	9	10	1,671	5,625	—	2,552	2,552
20. S. Martin Texmelucan	107	4,477	3	108	11,663	16,358	25,296	12,503	37,799
21. S. M. Tlalancaleca	—	734	—	—	5,426	6,160	4,344	2,246	6,590
22. S. M. Canoa	—	3,715	—	—	2,874	6,589	5,051	—	5,051
23. S. M. Xoxtla	—	2,054	—	—	1,066	3,120	—	1,903	1,903
24. S. Nicolas de los Ranchos	—	1,816	—	—	3,190	5,006	3,137	3,314	6,451
25. S. Pedro Cholula	82	13,014	2	87	437	13,622	12,833	13,792	26,625
26. S. Salvador el Verde	19	2,202	—	28	6,398	8,647	2,617	4,815	7,432
27. Sta. Isabel Cholula	20	4,842	—	15	1,908	6,785	—	3,334	3,334
28. Tepatlaxco de Hidalgo	123	2,711	—	105	3,065	6,004	6,624	32	6,656
29. Sta. Rita Tlahuapan	240	1,342	119	213	11,174	13,088	—	11,203	11,203
30. S. Pedro Tlaltenango	—	2,157	—	—	1,229	3,386	—	2,478	2,478
31. S. Francisco Totimehuacan	210	2,699	5	339	8,111	11,364	7,439	9,872	17,311
32. S. Juan Tianguismanalco	9	3,049	—	2	2,168	5,228	2,970	3,787	6,757
TOTAL	1,729	129,673	216	2,149	120,544	254,311	423,111	155,808	578,919

[1] IV Censo Agrícola, Ganadero y Ejidal. 1960.
[2] VIII Censo General de Población. 1960

TABLE XI. Credit provided for corn production by two official banks in 1966 and 1967, and by three official banks in 1968.

	No. of farmers	Hectares	Av. ha per farmer	Total pesos fertilizer	Total pesos in cash	Total pesos crop ins.	Total credit
1966	2,676	3,603	1.34	1,412,638	366,616	225,327	2,004,581
1967	1,013	3,187	3.15	1,281,312	294,876	207,486	1,783,674
1968	1,280	4,201	3.14	2,011,392	483,842	262,475	2,757,709

TABLE XII. Percentages of farmers, area and total credit for corn provided by each of the official agricultural banks for each year, 1966-68.

Bank	Year	% of farmers receiving credit	% of the hectares receiving credit	% of the total credit for corn
Ejidal	1966	96.11	81.27	72.48
	1967	91.31	78.50	69.22
	1968	93.20	75.20	53.15
Agricola	1966	3.89	18.73	27.52
	1967	8.69	21.50	30.78
	1968	3.75	12.93	16.95
Agropecuario	1968	3.05	11.84	29.89

TABLE XIII. The ejido bank. Farmers and area covered by credit for corn each year, 1966 to 1968.

	No. of soci-eties	No. of ejida-tarios	No. of hec-tares	Ha per ejida-tario	Total pesos fert.	Pesos per ha fert.	Total pesos in cash	Pesos per ha in cash	Premium crop insurance	Premium per ha	Total credit per ha
1966	33	2,572	2,298	1.14	1,178,165	512.69	104,346	45.40	170,575	74.23	632.32
1967	28	925	2,502	2.70	1,047,042	418.48	38,931	15.56	148,587	59.38	493.42
1968	37	1,193	3,025	2.54	1,244,265	411.33	43,697	14.45	177,978	58.84	484.60

TABLE XIV. Percentages of the ejido bank loans provided for fertilizer, for crop insurance and in the form of cash, 1966-68.

	% of loan for fert.	% of loan in cash	% of loan for crop ins.
1966	81.08	7.18	11.74
1967	84.81	3.15	12.04
1968	84.87	2.98	12.15

TABLE XV. The national agricultural bank. Farmers and area covered by credit for corn each year, 1966-68.

	No. of farmers	No. of ha	Ha per farmer	Total pesos fert.	Pesos per ha fert.	Total pesos cash	Pesos per ha cash	Premium crop insurance	Premium per ha	Total credit per ha.
1966	104	675	6.49	234,473	347.37	262,270	388.55	54,752	81.11	817.03
1967	88	685	7.78	234,270	342.00	255,945	373.64	58,899	85.98	801.64
1968	48	520	10.82	243,126	467.55	177,669	341.67	46,755	89.91	899.13

TABLE XVI. Percentages of the agricultural bank loans provided for fertilizer, for crop insurance and in the form of cash, 1966-68.

	% of loan for fert.	% of loan in cash	% of loan for crop ins.
1966	42.00	48.00	10.00
1967	42.66	46.62	10.72
1968	52.00	38.00	10.00

TABLE XVII. Farmer participation in crop insurance for corn by those who received credit from the public agricultural banks each year, 1966-68 *

Year	Farmers receiving credit	Farmers insured	% of farmers insured	Hectares receiving credit	Hectares insured	% of hectares insured	Farmers with losses	% of those insured	Hectares with losses	% of area insured
1966	2,676	1,169	43.7	3,603	3,079	85.5	155	13.26	311	10.10
1967	1,013	940	89.9	3,187	2,944	82.4	457	48.62	1,195	40.59
1968	1,280	934	73.0	4,021	2,830	70.4	215	23.02	646	22.83

* Data provided by crop insurance agency in Puebla.

TABLE XVIII. Premiums paid for crop insurance on corn by farmers and by the federal government, 1966-68 *

Year	% Prem. paid by farmer	% Prem. paid by Fed. Govt.	Premium paid by farmer $	Premium paid by Fed. Govt. $	Indemnification paid $	Indemnity as % of farmers premium	Coverage per hectare $
1966	7.33	22.2	190,086	433,019	75,640	39.79	1,000.00
1967	6.60	21.2	183,711	437,802	291,595	158.72	1,000.00
1968	6.35	21.4	149,298	400,616	115,909	77.64	1,000.00

* Data provided by crop insurance agency in Puebla.

TABLE XIX. Corn yields obtained with the different fertilizer treatments in the experiments carried out in 1967. Yields are reported in kilograms per hectare of grain containing 12% moisture.

Fertilizer treatment *	Number of Experiment 01	02	03	04	05	06	07	08	09	10	11	12	13	14
0-0-0	6770	10	3240	150	30	510	250	510	1010	410	30	200	2890	630
360-0-0	5830	4560	3570	3930	4080	3590	2860	3100	3120	400	1590	2600	2680	2020
60-25-0	6810	2040	4980	2450	2280	1750	2300	2610	2780	1170	1980	2260	2460	2500
180-25-0	6730	4650	3630	4690	4780	3890	3760	5100	3010	1840	3280	3580	2260	2600
300-25-0	5990	5360	4750	4470	4510	3680	3740	5390	3440	2270	3510	2830	1700	1770
120-50-0	6660	4610	3960	4540	4670	3480	4320	4160	3260	2810	4050	3450	2330	2370
240-50-0	6260	5850	5180	5030	4870	3360	4000	5740	3450	2390	3910	3210	2140	1840
60-75-0	7060	1950	4670	2220	2400	2020	2240	3050	2870	1790	2170	2190	2780	1710
180-75-0	6310	5270	4190	5280	4630	3970	4680	6210	3610	2930	5080	3360	2270	2380
300-75-0	6390	6070	6060	5030	5070	3850	4580	6320	3540	1180	4470	3680	2420	2360
120-100-0	6870	4590	3510	4770	4650	3660	4290	5080	3590	2120	4650	3660	2120	2090
240-100-0	6380	6050	3550	4700	4930	4170	4860	6360	3890	2390	5370	3260	2280	2250
60-125-0	6520	1590	4150	2320	2440	1910	2450	3210	3070	1430	2170	2000	2730	2030
180-125-0	6720	5810	4930	5750	5290	4620	5520	6130	4100	3210	5110	3550	2600	1950
300-125-0	6590	5620	4520	5710	4830	4120	5300	7020	3320	2870	5210	3780	1850	2520
0-150-0	7220	60	2830	180	160	440	150	360	1240	100	70	230	2130	400
360-150-0	6770	6470	5070	4960	5150	3760	5480	7500	3890	2940	5660	3790	2090	2050
180-75-60		4400		5460		4220		6120		2550		3460	2540	1710
180-75-0 + Zn	7040		4350		5070		4700		3570		4640			
LSD at 5% level **	NSD	860	2250	820	720	450	650	600	740	1290	800	490	730	870
Error mean square $\times 10^{-5}$	1.968	2.644	18.371	2.394	1.824	0.737	1.573	1.286	1.229	6.042	2.294	0.842	1.919	2.705
Coefficient of variation	7.37	12.72	31.59	12.50	11.09	8.63	10.90	7.75	11.48	40.89	13.91	10.05	18.41	26.28

Continued

TABLE XIX. Continued

Fertilizer treatment *	Number of Experiment 15	16	17	18	19	20	21	22	23	24	25	26	27
0-0-0	2880	1490	1990	3540	480	830	2290	1490	970	3130	320	1420	1400
360-0-0	3380	6510	1360	2910	2870	3620	4090	4480	4090	4360	4450	1590	2470
60-25-0	3720	4660	1800	3500	2610	2500	3920	3030	3000	4480	2750	1610	1770
180-25-0	.3540	5780	1100	3140	3340	4080	4550	3600	4450	4750	4580	1710	2480
300-25-0	32-70	6300	930	3040	3300	3750	4060	3570	4260	4720	3550	1750	2310
120-50-0	4100	5870	1170	3860	3580	3680	4330	3120	3240	4920	4030	1610	2050
240-50-0	3500	6030	1490	3960	3260	3960	4200	3540	3970	4820	4830	1650	2360
60-75-0	3850	4990	1870	4080	2150	2310	3330	3090	2870	4890	2750	1770	1540
180-75-0	3730	6100	2210	3630	3120	4370	4480	3510	3910	5020	4470	1750	2290
300-75-0	3830	6030	1830	2800	2860	3990	4600	3740	3610	5110	3810	1900	3020
120-100-0	3660	5780	1210	4150	3150	3920	4090	3250	3890	5320	4250	1680	2140
240-100-0	3860	6040	1490	3700	2880	4500	4350	3750	3900	5110	4530	1540	2280
60-125-0	3860	4720	1400	3730	1950	2300	3380	2280	2360	4200	2460	1550	2030
180-125-0	3780	6350	2620	4660	3190	4640	4480	3980	3390	4910	3520	1620	2310
300-125-0	3500	6230	2710	4060	2830	4430	4050	3600	3830	4280	4610	1530	2230
0-150-0	1980	2400	890	3160	310	380	2670	1170	1200	2970	570	960	1340
360-150-0	3520	6080	1110	2880	2870	4290	3670	3710	3990	5430	5050	1560	2340
180-75-60	3640		1910		3570	4290		4130				1460	
180-75-0 + Zn		6550		3460			4320		4340	5210	4430		2790
LSD at 5% level **	550	940	1130	920	840	540	700	990	800	1270	780	530	810
Error mean square $\times 10^{-5}$	1.076	3.186	4.577	3.022	2.514	1.016	1.764	3.498	2.309	5.817	2.180	1.016	3.347
Coefficient of variation	9.26	10.41	42.11	15.29	18.94	9.03	10.72	18.31	14.29	16.45	13.17	19.92	22.64

* The three numbers represent respectively the kg/ha of nitrogen, P_2O_5, and K_2O applied.
** These values are used for testing the significance of differences due to the application of potassium and zinc. The significance of the effects of nitrogen and phosphorus are determined from the results of the regression analysis (Table XX).

TABLE XX. The regression equations calculated from the yield data expressed in kilograms per hectare of grain containing 12% moisture for the experiments carried out in 1967.[1, 2]

No. of Experiment	Yield without fert.	Linear effect of N	Linear effect of P	Quadratic effect of N	Quadratic effect of P	N x P interaction	Av. No. of Plants per ha[3]	Error mean square x 10^{-5}	Coeffic. of determination
01	5986.6421	0	0	0	0	0	47855	1.9675	0
02	55.5142	+42.8149[a]	− 2.4162[e]	−0.0828[a]	+0.0053[e]	+0.0354[b]	50478	2.6456	0.930
03	4281.8606	0	0	0	0	0	53033	2.6072	0
04	240.6377	+44.7805[a]	−10.0484[d]	−0.0985[a]	+0.0675[d]	+0.0235[b]	52812	2.3941	0.912
05	253.2540	+40.5902[a]	− 3.2565[e]	−0.0855[a]	+0.0267[e]	+0.0153[c]	50433	1.8241	0.894
06	441.1399	+34.5773[a]	−13.2765[b]	−0.0746[a]	+0.0959[b]	+0.0063[d]	46215	0.7372	0.880
07	399.7633	+34.6514[a]	− 4.1946[e]	−0.0802[a]	+0.0287[e]	+0.0525[a]	47406	1.5732	0.921
08	496.1167	+35.6858[a]	+10.4881[c]	−0.0775[a]	−0.0720[c]	+0.0759[a]	48496	1.2855	0.963
09	1276.0520	+16.2113[a]	+10.5212[b]	−0.0332[c]	−0.0483[d]	+0.0054[d]	44964	1.2990	0.648
10	528.2405	+21.7044[b]	−11.6394[d]	−0.0613[b]	+0.0630[d]	+0.0468[b]	46242	6.0415	0.559
11	34.4798	+30.8220[a]	+12.9325[c]	−0.0749[a]	−0.0810[c]	+0.0732[a]	52719	2.2938	0.915
12	640.9124	+22.8726[a]	+ 4.8415[d]	−0.0508[a]	−0.0409[d]	+0.0255[a]	47610	0.8423	0.858
13	2336.5939	0	0	0	0	0	48144	1.9191	0
14	161.5121	+10.1375[b]	+ 3.4029[e]	−0.0241[b]	−0.0409[d]	+0.0135[c]	46629	2.7052	0.388
15	3086.2490	+ 2.6718[d]	+13.9239[b]	−0.0082[d]	−0.1163[b]	+0.0176[b]	46039	1.0761	0.464
16	2146.4780	+29.0204[a]	+15.8336[c]	−0.0510[b]	−0.0673[d]	−0.0209[c]	55094	3.1855	0.806
17	1674.0902	+ 0.0843[e]	+ 0.5107[e]	−0.0059[e]	−0.0287[e]	+0.0275[b]	46966	4.5765	0.078
18	3335.5938	+ 7.7143[c]	− 2.6313[e]	−0.0277[b]	+0.0239[e]	+0.0095[d]	49278	3.0217	0.321
19	1016.7980	+23.3378[a]	− 3.5752[e]	−0.0520[a]	+0.0030[e]	+0.0037[e]	51347	2.5140	0.690
20	945.4062	+32.2494[a]	−12.3693[a]	−0.0721[c]	+0.0676[c]	+0.0238[b]	50093	1.0158	0.914
21	2546.1474	+17.7312[a]	+ 0.9664[e]	−0.0384[a]	−0.0031[e]	−0.0079[d]	45071	1.7639	0.697
22	1796.5065	+15.65[c]	− 1.1395[e]	−0.02682[c]	−0.005603[e]	−0.001568[e]	48045	3.4930	0.656
23	1470.3841	+22.88[a]	− 3.856[e]	−0.04413[a]	+0.01805[e]	−0.004722[e]	47133	2.3089	0.772
24	4611.8687	0	0	0	0	0	48925	5.8167	0
25	953.1212	+27.8700[a]	+ 0.01080[e]	−0.05499[a]	−0.008499[e]	+0.01354[c]	48604	2.1800	0.793
26	1915.3940	0	0	0	0	0	51378	1.0158	0
27	1345.4100	+ 6.992[c]	+ 2.593[e]	−0.01066[d]	−0.01544[e]	−0.003267[e]	48702	2.3467	0.416

[1] The yield without fertilizer is the value predicted from the regression equation when no fertilizer is applied. The linear effect of applied nitrogen is the slope of the yield function at the origin (zero level of applied nitrogen and phosphorus), measured in the plane of the nitrogen axis. It is the predicted increase in yield per kilogram of applied nitrogen at that point. The quadratic effect of applied nitrogen is a measure of the tendency of the yield function to deviate from a straight line in the plane of the nitrogen axis. Negative values mean that the function curves downward. The larger the absolute value of this coefficient, the greater the curvature away from the straight line. The linear and quadratic effects of applied phosphorus represent values comparable to the linear and quadratic effects of nitrogen, except they are measured in the plane of the phosphorus axis. The N x P interaction is a measure of the extent to which the increase in yield from applied nitrogen or phosphorus differs when applied alone or in combination with the other. A positive interaction coefficient means that the increase in yield due to a given increment of either of the elements becomes progressively larger as the level of the other element is increased. The magnitude of the interaction coefficient is a measure of how much the response to one element is affected by the amount of the other element present in the soil.

[2] The superscripts a, b, c, d, and e indicate the level of significance of the regression coefficients: a = $<$ .01; b = .01 − .05; c = .051 − .20; d = .201 − .50; e = $>$ .50.

[3] The equations were estimated from data adjusted by covariance to the average plant density for the experiment.

TABLE XXI. Corn yields obtained with the different fertilizer treatments in the rate studies carried out in 1968. Yields are reported in kilograms per hectare of grain containing 12% moisture.

Fertilizer treatment *	Number of experiment 06	07	08	09	10	11	12	13
50-25-40	1740	3000	4650	3460	2190	2930	4230	1740
50-25-60	1120	2340	4380	3440	1730	2650	4870	2100
50-75-40	1370	3190	5140	3890	2120	3810	3980	2520
50-75-60	1140	2150	4420	3720	2030	3580	3780	2470
150-25-40	4520	6540	5060	6870	2810	3650	4930	2680
150-25-60	5000	6450	5720	6490	2830	5060	5580	3150
150-75-40	5600	6410	6070	6220	3670	4020	4490	4500
150-75-60	5900	7180	6600	6430	3530	6060	5430	5000
100-50-50	3760	5520	6130	5320	3770	5120	4930	4680
0-50-50	70	410	2640	680	420	30	2630	450
200-50-50	6180	6640	6760	7960	3960	5400	3700	3920
100-0-50	3440	4870	4550	4960	1970	3930	4060	1860
100-100-50	4310	5450	6260	5850	3750	5260	5140	4950
100-50-30	4710	6010	4630	6030	3260	4060	4070	3080
100-50-70	355	4740	6540	6550	3240	5330	4350	2980
0-0-30	210	810	2200	1280	870	850	2510	640
0-0-70	70	280	1180	200	560	250	2290	500
0-100-30	210	380	2840	930	1200	680	3140	830
0-100-70	20	370	1070	220	330	90	1580	490
200-0-30	3670	5640	4410	5490	1410	2840	3800	2850
200-0-70	4380	7110	5790	5260	1190	3610	5600	2180
200-100-30	6020	6470	5470	6960	3330	4020	3730	4330
200-100-70	7610	8790	7770	8630	4500	7040	4450	4910
150-75-50	5650	7070	6520	7070	4000	4850	4710	5510
150-75-50 + K	5780	6370	6740	6870	4090	5800	4510	4700
150-75-50 + K + Zn	5590	7270	6080	6650	4210	5500	5220	5070
LSD at 5% level	614	1356	1351	1739	1040	1296	1314	607
Error mean square x 10^{-5}	0.891	4.296	4.302	7.849	2.552	3.955	4.075	0.865
Coefficient of variation	2.53	8.89	8.63	18.06	19.46	10.70	15.40	8.28

* The three numbers represent respectively the kg/ha of nitrogen and P_2O_5 applied and the thousands of plants per hectare.

TABLE XXII. The regression equations calculated from the yield data expressed in kilograms per hectare of grain containing 12% moisture for the experiments carried out in 1968.[1]

Estimated effects[2]	Number of experiment 06	07	08	09	10	11	12	13
Yield at the zero level of N, P, and population	+1724.5927	+2943.3180	+1714.7183	+3473.9052	+1353.2569	+1730.4293	+1647.5719	+1304.2840
Linear effect of N	+31.1922[b]	+47.4970[a]	+18.6226[b]	+46.0117[a]	+18.1518[b]	+39.8089[a]	+23.2210[b]	+25.1709[a]
Linear effect of P	− 0.4436[e]	−11.1493[d]	+19.6692[d]	+ 6.9329[e]	+11.8954[d]	− 4.8337[e]	+10.8529[d]	+12.2217[d]
Linear effect of population	−58.7718[d]	−82.5031[d]	+42.2458[e]	−89.1977[d]	− 9.4280[e]	−33.3949[e]	+49.6130[e]	—
Quadratic effect of N	− 0.0916[b]	− 0.1627[a]	− 0.1111[a]	− 0.1532[a]	− 0.1061[a]	− 0.2264[a]	− 0.1382[a]	− 0.1269[a]
Quadratic effect of P	− 0.0665[e]	− 0.0001[e]	− 0.1597[c]	− 0.2176[c]	− 6.01615[c]	− 0.0821[e]	+ 0.0452[e]	− 0.2274[b]
Quadratic effect of population	+ 0.3999[e]	+ 0.5439[e]	− 0.7349[d]	+ 0.5689[d]	− 0.2131[e]	+ 0.0490[e]	− 0.6198[d]	− 0.3677[b]
Effect of N x P	+ 0.1454[a]	+ 0.0729[b]	+ 0.0591[c]	+ 0.1016[b]	+ 0.1280[a]	+ 0.1211[b]	− 0.0275[d]	+ 0.1826[a]
Effect of N x population	+ 0.1952[c]	+ 0.3279[b]	+ 0.3999[a]	+ 0.2043[b]	+ 0.1824[b]	+ 0.4266[b]	+ 0.3242[b]	+ 0.1350[c]
Effect of P x population	+ 0.0991[e]	+ 0.1848[d]	+ 0.0259[e]	+ 0.2863[c]	+ 0.1154[e]	+ 0.3112[d]	− 0.3252[c]	+ 0.1692[d]
Residual mean square x 10^{-5}	6.3086	5.6667	5.4192	7.3625	2.9914	6.3883	4.5744	2.4195
Coefficient of determination	0.911	0.937	0.872	0.911	0.857	0.877	0.729	0.924

[1] The superscripts a, b, c, d, and e indicate the level of significance of the regression coefficients: a = < .01; b = .01 − .05; c = .051 − .20; d = .201 − .50; e = > .50.

[2] See the explanation of these effects given in Table XX.

TABLE XXIII. Yields of six corn varieties planted on six dates at four locations in 1968. Yields are expressed as kilograms per hectare of grain with 12% moisture.

Variety	Date of planting						Average
	Mar. 5	Mar. 23	Apr.10	Apr. 23	May 8	May 28	
			01 Xalmimilulco				
Colorado precoz	4096	4926	6051	3443	3764	3389	4278
Amarillo S. *	8330	6825	6630	3059	3901	3185	5322
Pinto S.	9388	8957	9332	5444	6011	4129	7210
Blanco S.	9876	8234	8580	7283	6688	4395	7493
H-28	10396	9473	8994	6287	6541	4065	7627
H-129	9800	8874	9118	8641	6353	3822	7768
Average	8648	7882	8117	5694	5543	3814	
			02 Tlaltenango				
	Mar. 8	Mar. 23	Apr. 10	Apr. 23	May 8	May 28	
Colorado precoz	4319	5061	5051	5999	5853	4999	5214
Amarillo S.	5963	6624	5931	5454	5496	3813	5547
Pinto S.	7034	7468	8551	6897	5716	4074	6623
Blanco S.	7363	8474	8128	6434	5187	4283	6645
H-28	4608	7002	7435	6857	4646	4980	5921
H-129	7914	7294	8111	7787	7701	5230	7339
Average	6200	6987	7201	6571	5766	4563	
			03 Xometitla				
	Apr. 18	May 3	May 12	May 29	June 21	July 3	
Colorado precoz	6221	5448	6008	3820	2510	2138	4357
Amarillo S.	5979	5019	5317	4355	2426	1816	4152
Pinto S.	6501	5613	5901	4746	2584	2058	4567
Blanco S.	5860	4945	5572	5126	2462	1841	4301
H-28	6487	5533	5757	4803	2543	2045	4528
H-129	6544	6026	6675	5138	2834	1832	4842
Average	6265	5431	5872	4665	2560	1955	
			04 Coyotzingo				
	Apr. 26	May 12	May 29	June 21	July 2	July 18	
Colorado precoz	7421	6336	4175	3194	3544	1331	
Amarillo S.	6513	5530	4339	3205	3088	1463	
Pinto S.	6831	6388	5086	3180	2793	1140	
Blanco S.	6543	6142	4425	3588	2756	729	
H-28	6942	6383	5089	3624	3869	1334	
H-129	6710	6512	5013	3593	2631	727	
Average	6827	6215	4688	3397	3113	1121	

	Experiment 01	02	03	04
Least significant differences (.05)				
Between 2 dates of planting	2670	1040	570	400
Between 2 varieties	670	520	220	210
Between 2 varieties for the same date of planting	1640	1260	450	510
Between 2 dates of planting for the same variety	2800	1480	720	580
Coefficient of variation (%):	24.0	14.0	9.0	8.2

* The letter S. signifies that the seed was obtained from Felix Salvatori.

TABLE XXIV. Effect of time of application of nitrogen and phosphorus on corn yields, expressed in kilograms per hectare of grain containing 12% moisture.

Fertilizer treatment			Yield in kg/ha	
At planting	First cultivation	Second cultivation	Mextla	San Buenaventura
0-60 *	0-0 *	0-0 *	2305	370
75-60	0-0	0-0	5020	2474
150-60	0-0	0-0	5878	4500
0-60	75-0	0-0	4672	3733
0-60	0-0	75-0	4950	3860
0-60	150-0	0-0	5747	5450
0-60	0-0	150-0	5140	5093
37.5-60	37.5-0	0-0	5756	3135
75-60	75-0	0-0	5026	5025
50-60	50-0	50-0	4917	5223
150-0	0-0	0-0	5095	4478
150-30	0-0	0-0	5496	4424
150-0	0-30	0-0	5177	4953
150-0	0-0	0-30	5887	4695
0-0	150-30	0-0	6019	5289
0-0	0-0	150-30	6561	4661
150-0	0-60	0-0	5850	5073
150-0	0-0	0-60	5146	4850
0-0	150-60	0-0	4880	4922
0-0	0-0	150-60	4976	4846
150-90	0-0	0-0	5890	4657
LSD at 5% level			1561	941
Error mean square			596630	216890
Coefficient of variation			14.77	10.75

* These numbers indicate respectively the kg/ha of nitrogen and P_2O_5 applied.

TABLE XXV. Yield estimates based of field measurements in 24 segments chosen at random in the project area. Kg/ha of shelled corn at 12% moisture, 1968.

Segment no.	Location: Village or municipio	Av.	Lowest	Highest
	CENTRAL AREA			
13	S.L. Coyotzingo	1609	779	1798
14	S.J. Pancoac	653	0	1357
11	S.P. Tlaltenango	1508	630	2881
9	Sta. Maria Moyotzingo	2126	207	5311
4	Sn. Cristobal Tepatlaxco	2948	870	5201
15	S.A. Calpan	1957	416	3134
26	S.P. Yancuitlalpan	2338	1233	3404
25	S.M. Tlamapa	2432	1053	3666
27	S.J. Tianguismanalco	1823	472	2881
29	Chachapa	1464	18	3516
30	Amozoc de Mota	2593	988	4297
31	Tepatlaxco de Hidalgo	1833	1223	2327
20	Momoxpan	3034	2490	4004
	AREA WITH HIGH WATER TABLE			
5	Sn. Martin Texmelucan	3851	1317	5977
6	Sn. Baltazar Temaxcalac	3276	198	6686
10	Sta. Ana Xalmimilulco	3875	2427	5530
19	Sn. Matias Cocoyotla	3034	2490	4004
23	Sta. Maria Tonanzintla	3447	2819	4338
	PERIPHERAL AREA			
1	Sn. Francisco Tlaloc	1058	139	1958
3	Juarez Coronaco	2332	0	5530
2	Sn. Matias Tlalancaleca	1629	351	2774
12	Sn. Agustin Atzompa	1158	77	2107
18	Sn. Lorenzo Almecatla	1290	335	2513
28	Sn. Francisco Totimehuacan	1312	176	2997

Average of 184 sites sampled = 2091.0 kg/ha
Average of the averages for 24 segments = 2190.8 kg/ha
Average of 150 sites sampled in the 20 segments located in the general area where high yield plots were planted in 1968 = 2,143.8 kg/ha
Average of the averages for 20 segments = 2268.9 kg/ha

TABLE XXVI. Plants per hectare based on field counts in 24 segments chosen at random in the project area, 1968.

Segment no.	Location: Village or municipio	Av.	Lowest	Highest
	CENTRAL AREA			
13	S.L. Coyotzingo	31,524	19,123	43,898
14	S.J. Pancoac	17,838	13,517	24,661
11	S.P. Tlaltenango	24,726	14,307	39,968
9	Sta. Maria Moyotzingo	37,789	27,784	49,635
4	Sn. Cristobal Tepatlaxco	35,524	29,830	46,233
15	S.A. Calpan	22,930	15,661	35,382
26	S.P. Yancuitlalpan	23,571	17,207	30,749
25	S.M. Tlamapa	27,466	22,266	35,031
27	S.J. Tianguismanalco	22,529	13,000	30,000
29	Chachapa	27,861	18,233	36,562
30	Amozoc de Mota	24,885	16,804	27,702
31	Tepatlaxco de Hidalgo	27,191	15,361	58,766
20	Momoxpan	35,592	23,236	51,534
	AREA WITH HIGH WATER TABLE			
5	Sn. Martin Texmelucan	35,111	32,399	37,841
6	Sn. Baltazar Temaxcalac	51,632	34,954	63,750
10	Sta. Ana Xalmimilulco	37,883	30,014	43,123
19	Sn. Matias Cocoyotla	36,304	29,978	46,656
23	Sta. Maria Tonanzintla	52,249	44,472	58,825
	PERIPHERAL AREA			
1	Sn. Francisco Tlaloc	28,166	20,285	39,169
3	Juarez Coronaco	39,918	26,856	67,333
2	Sn. Matias Tlalancaleca	28,906	19,176	37,202
12	Sn. Agustin Atzompa	33,341	25,500	38,101
18	Sn. Lorenzo Almecatla	29,749	24,853	39,288
28	Sn. Francisco Totimehuacan	36,561	21,680	83,286

Average of 184 sites sampled = 31,000 plants/ha
Average of the averages for 24 segments = 32,051
Average of 150 sites sampled in the 20 segments located in the general area where high yield plots were planted in 1968 = 32,637
Average of the averages for 20 segments = 32,369

TABLE XXVII. Comparison of estimated yields with yields obtained by weighing the entire harvest of 50 high yield plots located in various parts of the area. Kg/ha of shelled corn at 12% moisture, 1968 harvest.

Location	Name	Yield estimate	Yield at harvest
Coyotzingo	Concepción Pérez (Teop)	7312	7450
	Epifanio Sánchez (Huerta)	3895	4000
	Pablo Ramírez (Esteban)	3376	3550
	Pablo Ramírez (Tepepa)	2002	1820
	Ignacio Ramírez (Esteban)	4744	4450
Atzompa	Amador González	3212	3220
S. A. Tlatenco	Vicente Rosales	3909	3930
	Lorenzo Ortiz	1524	1800
	Daniel Hernández	1616	1640
	Francisco Botello	2450	2200
	Genaro Aguilar	6051	6140
Huejotzingo	Gabriel Paz	1000	945
Mextla	Angel Rojano	4353	4340
	Carlos Calderón	4840	5080
	Irineo Corona	4223	4600
	Serafín Pérez	3897	4170
	Fausto Rojano	4329	4040
	Andrés Gorzo	4473	4450
	Pedro Damián	3582	3270
	Federico Morales	4376	3900
	Juan Ramírez	2837	2700
G. Zaragoza	Pascacio Madrid	1894	1770
	Salvador B. Díaz	2830	2770
	Justino Rodríguez	1876	2060
	Abel Díaz	3297	2900
	Jesús Saturnino	4227	4460
Tlaltenango	Hilario Barrientos	6417	6000
	León Pérez	3985	3940
	Miguel Munive	2490	2660
	Cosme Aguilar	3649	3870
	José Aguilar	4471	4480
S. Lorenzo	Tomás Mendoza	2272	1950
Almecatla	Pascual Vázquez	2158	2120
	Alejandro Zamora	1435	1510
S. M. Tlamapa	Francisco Núñez	3824	3480
S. J. Pancoac	Lorenzo Pérez	4634	4370
	Lorenzo Méndez	4534	4360

Continued

TABLE XXVII. Continued

Location	Name	Yield estimate	Yield at harvest
S. M. Tlalancaleca	Rafael Anguiano	3311	3200
	Antonio Hernández	3042	3380
	Domingo Hernández	4225	4480
S. Buenaventura	Rafael Morales	3335	3500
	Guadalupe García	3414	3380
J. C. Bonilla	Higinio Coyotl	4041	4230
	Rosendo Tehuitzil	4344	4300
S. Gregorio A.	Paz Méndez	4777	4700
	Federico Huitzil	4167	3740
	Adolfo Huitzil	5560	5490
Tonanzintla	Guillermo Guevara	3116	3380
Cholula	Gumersindo Tepanecatl	2940	2640
S. Rafael Ixtapalucan	Salvador Osorio	3963	4180
	GRAND TOTAL	180506	179185
	DIFFERENCE	1321	

Error = 1321/179,185 = 0.0074

TABLE XXVIII. Objective yield estimate in kg/ha of shelled corn at 12% moisture. High-yield plots, 1968.

Location: village or municipio	Av.	Lowest	Highest	No. of. plots
		CENTRAL AREA		
Huejotzingo	4,265	2,240	6,415	15
S. L. Coyotzingo *	4,272	1,859	9,108	26
S. J. Pancoac	4,458	2,240	6,415	6
S. P. Tlaltenango **	4,634	2,490	8,117	9
Juan C. Bonilla	4,520	3,609	6,088	4
S. Buenaventura Tecalcingo	3,746	3,060	4,784	5
S. J. Tecuanipan	4,722	3,824	5,384	5
S. Gregorio Atzompa	5,199	4,167	6,293	4
Cholula	3,221	2,940	3,606	3
S. A. Calpan	4,104	3,882	4,478	3
				80
		PERIPHERAL AREA		
Guadalupe Zaragoza	2,796	1,828	4,716	9
S. M. Tlalancaleca	3,488	3,042	4,225	5
Ixtapalucan y El Verde	4,560	3,867	5,851	3
S. Lorenzo Almecatla	3,055	1,724	4,251	9
S. A. Tlatenco	2,784	1,393	3,500	16
S. F. Teotlalcingo	2,554			1
				43

Average of 123 sites of 16 locations = 3,883.1 kg/ha
Average of the average yields by location 3,898.6 kg/ha
* Includes 6 plots which received one or more irrigations.
** Includes 1 plot planted on a soil with a high water table.

TABLE XXIX. Estimated number of plants per hectare in high-yield plots, 1968.

Location: village or municipio	Av.	Lowest	Highest	No. of. plots
	CENTRAL AREA			
Huejotzingo	43,975	36,848	48,782	15
S. L. Coyotzingo	50,535	38,888	67,000	26
S. J. Pancoac	44,213	33,892	52,348	6
S. P. Tlatenango	46,498	39,416	52,421	9
Juan C. Bonilla	49,204	44,270	55,538	4
S. Buenaventura Tecalcingo	36,901	34,047	39,882	5
S. J. Tecuanipan	43,664	40,555	46,333	5
S. Gregorio Atzompa	45,785	39,099	52,888	4
Cholula	49,123	45,125	54,570	3
S. A. Calpan	43,519	39,422	49,099	3
				80
	PERIPHERAL AREA			
Guadalupe Zaragoza	43,750	35,270	54,436	9
S. M. Tlalancaleca	46,064	37,407	46,780	5
Ixtapalucan y El Verde	46,167	38,249	58,799	3
S. Lorenzo Almecatla	45,905	30,949	59,231	9
S. A. Tlatenco	45,906	35,300	61,439	16
S. F. Teotlalcingo	47,894			1
				43

Average based on 123 high yield plots: 46,025
Average of the averages by location: 45,570