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FIELD TECHNIQUE FOR FERTILIZER EXPERIMENTS

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As farmers make the transition from traditional to modern agriculture their total operation changes. One of the important decisions they have to make during this period is which fertilizer to apply and how much. An important function of adaptive research is to assist farmers in making this kind of decision so that they will realize maximum returns from a given investment.

Useful data for determining optimal fertilization practice are derived primarily from field experiments. Data obtained in these experiments are also used for calibrating soil and plant testing procedures, which, subsequently, are useful in making recommendations on fertilizer use for specific farming conditions.

The modern approach to fertilizer use experimentation assumes that variability in fertilizer response among sites in an area of study arises mainly from measurable differences in the soil, plant, climate, and management factors. Experiments are located to sample the major differences in soil and climate; plant and management factors are controlled at near-optimal levels; observations are made during the course of the experiments to characterize the productivity factors; and the results are expressed in the form of a general yield equation.

Through field experiments conducted in this manner it is possible to determine a quantitative relationship among crop yield, applied fertilizers and the productivity conditions for a given region. This general relationship serves as a basis for making fertilizer recommendations for specific farming conditions. However, certain principles must be carefully observed in locating the experiments, selecting the treatment design, defining the rates of fertilization, conducting the experiments, and analyzing and interpreting the results. This manual treats in detail only one part of the general methodology, the technique of carrying out the field experiments. Fertilizer trials conducted in farmer's field are frequently lost or fail to produce useful information due to an oversight or failure to perform some function properly at the correct time. Careful attention to the principles and details described here should greatly reduce the frequency of such loss and increase the usefulness of data obtained in the harvested trials.

This manual has been prepared as a guide for agronomists who are initiating adaptive research on fertilizer needs of crops. A study of the fertilization of unirrigated maize in an important agricultural region of Central Mexico is described. This manner of presentation permits a detailed examination of the several activities involved in fertilizer use studies with maize and, in addition, shows how these activities are organized chronologically. The details described here will vary somewhat for plantings of maize under other conditions and may be greatly different for other crops. However, the principles apply equally well to maize and to other crops.

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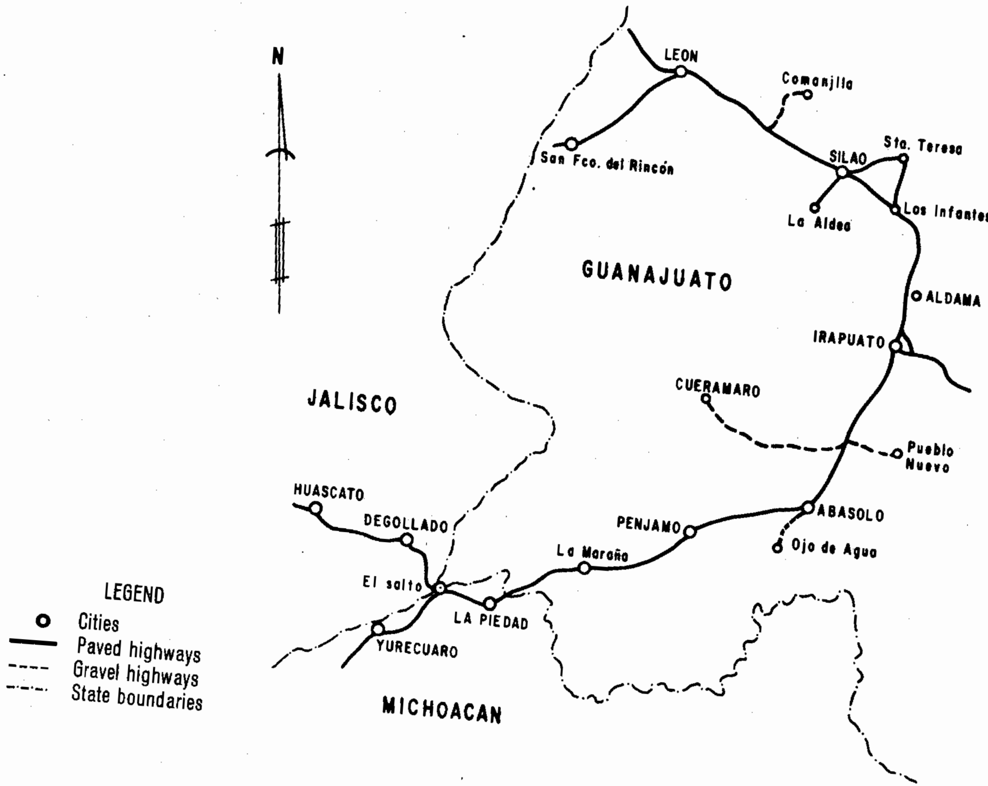
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LEON
Comanjilla
San Fco. del Rincón
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Sta. Teresa
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Los Infantes
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CUERAMARO
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Ojo de Agua
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El salto
LA PIEDAD
YURECUARO
MICHOACAN
LEGEND
Cities
Paved highways
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State boundaries

Region of study and the experimental plan

The area of study consists of the accessible land within 20 kilometers of the highway extending for a distance of 170 kilometers from Leon, Guanajuato to Degollado, Jalisco, as shown in the adjoining figure. This region has a plains-type climate with 90% of the precipitation coming in the summer period from June to October. The average annual rainfall varies from slightly less than 600 millimeters in the Leon-Silao area to nearly 900 millimeters in the southernmost part. The average temperature for the June-October period is around 22°C. The altitude above sea level varies from 1700 to 1800 meters.

The major part of the soils in the area southwest of Abasolo are heavy clays that shrink on drying to give rise to wide, deep cracks. These soils have been called Grumusols in the past and are included in the Vertisols of the 7th Approximation of the Soil Conservation Service of the United States.* North of Abasolo the dominant soil has a sandy loam to loam texture and is brownish in color. The correct designation for this soil within the 7th Approximation is not known.

The fertilizer use study planned for this region consists of 20 experiments to be distributed approximately as follows:

a. Three locations on brown light-textured soils between Leon and Silao.
b. Four locations on brown light-textured soils between Silao and Irapuato.
c. Two locations on brown light-textured soils between Irapuato and Abasolo.
d. Three locations on Grumusols between Abasolo and Pénjamo.
e. Five locations on Grumusols between Pénjamo and La Piedad.
f. Three locations on Grumusols between La Piedad and Degollado.

No restrictions are to be placed on other soil properties such as depth and slope. The sites are to be limited to soils that were planted to maize or sorghum during the previous year without the application of barnyard manure. Approximately 1% of the maize plantings in this region receive one or more irrigations during the growing season. These irrigated plantings are not to be included in the study.

All experiments are to be seeded to the hybrid, H-220, which has proven to be superior for unirrigated plantings in the region. A plant density of 40,000 plants per hectare, shown in previous studies to be optimal for H-220, is to be used. The experiments are to be planted just prior to or immediately after the first heavy rains. A soil insecticide is to be applied at planting time to control soil insects, and leaf-eating insects are to be controlled when necessary. A pre-emergence herbicide is to be applied in a band over the seed and other weeds are to be controlled by plowing or hoeing.

Previous information indicates that the soils in this region are deficient in nitrogen and phosphorus and well-supplied with potassium. No infor-

* Soil Classification. A comprehensive System. 7th Approximation. Soil Survey Staff Soil Conservation Service, U.S.D.A. 1960. Washington, D. C.

mation is available on the need for applying zinc. The estimated optimal levels of nitrogen and phosphorus are 130 and 35 kilograms per hectare, respectively. Therefore, its was decided that each experiment consist of 3 replications of 15 treatments using a randomized block design. The 15 treatments are the 13 from a "double-square" treatment design for nitrogen and phosphorus (see Appendix A) plus a treatment with potassium and another with zinc. The nutrient levels to be studied, expressed in kilograms per hectare, are as follows: nitrogen 0, 60, 120, 180, and 240; phosphorus* 0, 15, 30, 45, and 60; potassium* 0 and 60; and zinc 0 and 20. All of the phosphorus, potassium and zinc, plus one-tenth of the nitrogen, are to be applied at planting time. The remainder of the nitrogen is to be applied as a sidedressing.

Each plot is to consist of six rows 8 meters in length, with a two meter alley between plots. Although the row width used by farmers is known to vary slightly, it is expected that the average will be 0.9 meters. Therefore, this width is used in calculating the amounts of fertilizers to apply and the distance between hills in the row. Should row widths vary appreciably from the average, rates of fertilization and plant densities may be adjusted at the time of analyzing the yield data.

It is expected that a major factor contributing to yield differences among experiments will be rainfall variability. Consequently, rain gauges are to be installed as near as possible to all experiments and daily measurements of rainfall are to be recorded.

With this general description of the field experiments the agronomist in charge proceeds to carry out the study. Based on historical rainfall records and conversations with farmers in the area, it is decided that everything should be ready for the initiation of experimental plantings on June 6. Taking into account that the number of days from planting to physiological maturity of H-220 is about 120, field activities should proceed approximately in accordance with the time schedule given in the following pages.

April 10 — May 10: Location of experimental sites

A list of prospective farmer cooperators is prepared from recommendations gathered from extension agents, agricultural credit agencies, farm chemical salesmen, etc. These farmers are visited and their land is appraised as a possible experimental site. Those with land that meets the requirements of the program are advised of the field study that is to be carried out, informed of the nature of cooperation desired, and requested to participate in the undertaking.

Frequently, a list of farmers prepared in this manner will not be sufficient for locating the desired number of experimental sites. Supplementary locations are found by driving through the region until a suitable piece of land is located and then making the necessary arrangements to incorporate the farmer into the program.

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*Levels of phosphoric and potassic fertilization are expressed in terms of the elements, P and K, instead of the oxides, P_2O_5 and K_2O, as has been done in the past.

The farmers who are interested in cooperating are told exactly what will be expected of them. In general the agronomist will supply all special materials and equipment needed in the experiment, half of the labor for planting and harvest, and all of the labor for added operations, while the farmers will prepare the land, supply half of the labor for planting and harvest, and perform the usual weedings and cultivations. When daily rainfall records are needed, the farmer or some member of his family will be expected to keep them. Farmers who agree to cooperate are visited on three or more occasions prior to planting for the purpose of convincing them of the importance of their cooperation and to evaluate accurately their sincerity.

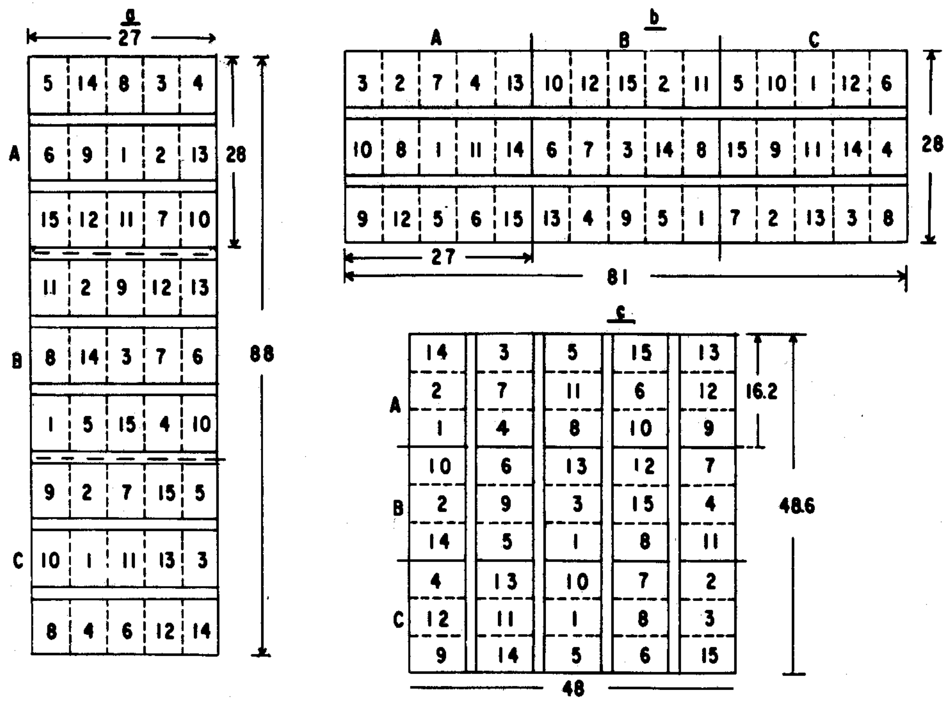
Each tentative site is measured to assure that it will accomodate the experiment. It is examined carefully to make certain that soil properties such as color, texture, and slope are uniform over the area designated for the experiment. Should it be suspected that there is variability in soil depth or other properties which are not readily observable, soil cores should be removed with an auger from different parts of the site and examined.

Land subject to flooding should not be selected for experimental work. Sites should be located at least 10 meters from fences, trees, and ditches, at least 20 meters from roads and 50 meters from houses. Preference should be given to locations where the area around the experiment is to be planted in maize. Sites should be within one kilometer of the point where the rain gauge is to be installed.

A tentative field plan should be prepared for each site. This is accomplished most readily by preparing with anticipation two or more alternate field plans and accomodating one of these plans to the available space. Three possible ways of arranging 3 replications of 15 treatments are shown in the adjoining figure. If there is no reason to suspect that soil variability is greater in one direction than another, the replication should be as nearly square as possible. In parts *a* and *b*, the replication is 27 × 28 meters. The overall dimensions of the experiment are not critical. If there is reason to believe that soil variability is greater in one direction than another, the replication should be rectangular with the long dimension in the direction of minimum variability. This sometimes occurs when the experimental site is steeply sloping and the availability of nutrients and water increases in going from the upper to the lower slope. Part *c* shows how a rectangular-shaped replication 16.2 × 48 meters can be used at a site with these characteristics.

Once a decision is made as to the best way to accomodate the experiment in the available area, the corners of the experiment are marked tentatively with materials such as clods, stones, or stakes.

On completing the location of all experiments, the treatments are assigned at random to each replication of the 20 experiments. This is conveniently done by numbering the 15 treatments and deciding the order of assignment to each replication from a table of random numbers. The numbers of the treatments may also be assigned to the replications by drawing marked beans or marbles from an urn.



Alternate field plans for 3 replications of 15 treatments. Plan *a* is suitable when a small number of long rows are available; plan *b* can be used for a large number of short rows; plan *c* is recommended when there is a soil gradient in the field perpendicular to the long dimension of the replications.

Up to this time the general characteristics of the field study have been defined, and tentative field plans have been made for each experiment. This information should be carefully and systematically recorded in a bound notebook, the field book. As the field work proceeds, all calculations, changes in field plans, observations, etc., should be recorded directly in the field book; they should not be written down first on loose sheets of paper and later copied into the field book.

A second journal should be maintained in the office or home of the agronomist, with a copy of all the information that is in the field book. Entries in the office journal should be made in the evening of the same day that the activity is carried out or as soon thereafter as possible.

May 11 — 13 Preparation of the fertilizer mixtures

In fertilizer experiments it is common to use treatments consisting of two or more fertilizer materials. These materials may be weighed out and applied separately, or they may be blended and the mixture applied to the soil. Generally, the latter proceduce is most convenient and facilitates appreciably the field application of the fertilizer. In some cases, however, it is not feasible to prepare mixtures due to great differences in particle sizes of the materials or to chemical instability of the mixture.

When the fertilizer materials are to be blended, this operation should be performed several weeks before weighing out quantities of the mixture for individual rows. The reason for this is that chemical reactions frequently occur among the blended fertilizer materials and results in the mixtures becoming hard. By preparing the mixtures early, there is time for these reactions to near completion and the mixtures may be recrushed before weighing out quantities for application.

To avoid error, detailed mixing instructions are written out and the calculations are rechecked. An example of mixing instructions is given in Appendix B. If mixtures weigh more than 75 kilograms they should be prepared in two or more batches, as it is difficult to achieve uniform blending of large quantities.

The required amounts of the different fertilizer materials, sieved when necessary to remove coarse aggregates, are weighed out using a scale with a, sensitivity of about 0.1 kilogram. The agronomist should personally supervise these weighings as an error at this point cannot be subsequently rectified or identified. The materials are extended in thin layers one above the other, over a smooth, clean surface. An efficient blending procedure is as follows: two men with shovels take positions facing each other on either side and at one end of the extended layers of materials. Each employs a mixing movement that consists in raising a shovel full of materials and turning it toward the other and away from the layers of fertilizers. This mixing action is continued until all the materials have been moved. The workers then reverse their positions and repeat the blending procedure. This is repeated about six times or until it is impossible to distinguish streaks of individual materials in the mixture. The mixtures are placed in containers and labeled.

Fertilizer materials are sieved when necessary to remove coarse aggregates.

The weighing of fertilizer materials for the preparation of mixtures is personally supervised by the agronomist.

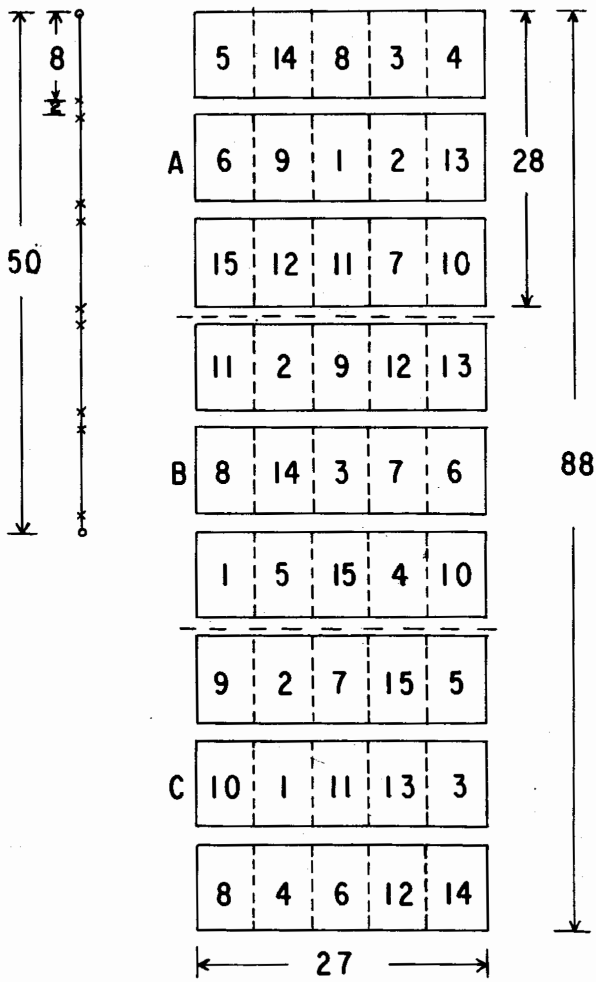
In the preparation of fertilizer mixtures, the different materials are extended in thin layers one above the other, over a smooth, clean surface.

May 14 — 23: Installation of rain gauges

Several types of rain gauges are adequate for collecting rainfall data. The standard, eight inch, non recording gauge used by the U. S. Weather Bureau is very satisfactory. It is simply constructed, easy to use, and accurate. The details of the construction, installation, and use of a slightly modified version are described in Appendix C.

The rain gauge is installed near the home of the person who will collect the rainfall data. It should be located at least 20 meters from roads, at a point inaccessible to large animals, and at a distance equivalent to twice their height from tall objects such as trees or buildings. The distance from the rain gauge to the experiment should not exceed one kilometer.

An alternative device for use in collecting rainfall data is the small economical gauge described by Gamble and Daniels (Agronomy Journal 59:206-207. 1967). This instrument is installed below ground level at the experimental site and readings are taken directly by the agronomist in charge of the experiments. It is particularly appropriate when it is impossible to find a suitable location near the experiment for an eight inch gauge.



A diagram of the field layout for an experiment showing along the left side the location of markers on a measuring wire.

May 24: Preparation of measuring and planting wires

A steel measuring tape may be used to locate the corners of the blocks in the experiments. However, this is done more conveniently and cheaply with a measuring wire. Such a wire is prepared by twisting a small loop in a wire at points corresponding to the corners of the blocks along one side, or a part of one side, of the experiment. The loops are made more visible by marking them with small pieces of red cloth.

An example is given in the adjoining figure of an experiment with plots 8 meters in length and a 2 meter alley between the ends of plots. It would be convenient in this case to prepare a measuring wire that extends slightly more than one-half the length of the experiment. As shown along the left border of the diagram, the wire would have a loop at each end for accomodating steel stakes, and loops with red markers corresponding to the corners of the blocks. The total length of the extended measuring wire is 50 meters. Wire with a diameter of approximately 2 millimeters is adequate for this purpose.

To attain a uniform plant population it is necessary to use a guide for locating the hills along the row. This is conveniently made by twisting into a wire small loops separated by the distance that is desired between hills. The loops are again marked with small pieces of red cloth. An alternate procedure it to twist together two small diameter wires and fix the red markers at the appropriate points by forcing the cloth between the wires and tying.

The overall length of the wire is exactly that of the rows in the experimental plots. The first and last loops in the wire are located at a distance from the ends of the wire equal to one-half the distance between loops.

As an illustration let us assume that rows are 8 meters long and 0.9 meters wide, and that the desire plant density is 40,000 plants per hectare. Moreover, we will asume that the maize is to be thinned to two plants per hill. Forty thousand plants per hectare are equivalent to four plants or two hills per square meter. For rows 0.9 meter in width, a distance $\frac{1}{0.9}$ or 1.111 meters is needed to give an area of one square meter. Therefore, two hills should be planted every 1.111 meters; i. e., the distance between hills along the row should be 0.555 meter. If we divide 8 meters by 0.555 meter we find that 14.4 hills should be planted per row.

However, as we cannot plant a fraction of a hill, a plant density slighty greater than or smaller than 40,000 plants per hectare must be used. Let us assume that its is decided to plant 14 hills per row. The desired plant density then becomes:

$(14 \text{ hills} \times 2 \text{ plants per hill}) \times (10{,}000 \text{ m}^2 \text{ per ha.} \div 7.2 \text{ m}^2 \text{ per row}) = 38{,}889$ plants per hectare

For 14 hills per 8-meter row, the separation between hills is 0.57 meter. Therefore, the first and last loops on the marked wire for planting are located 0.285 meter from each end of the wire.

A composite soil sample is taken, consisting of 5 to 20 individual samples.

May 25 — 28: Collecting soil samples

Soil samples are generally collected from the experimental area prior to applying the fertilizer treatments. The samples are to be analyzed later and the results used for one or more of the following purposes: (1) to determine the available nutrient levels from previously prepared calibration tables, (2) to calibrate analytical methods, (3) to obtain nutrient levels for use as site variables in a multiple regression analysis of variation among sites, (4) to obtain nutrient levels on a plot basis for use as covariants to reduce the magnitude of experimental error, and (5) to make a general characterization of the soil properties of the experiment.

Depending upon the specific objective which the agronomist has in mind, soil samples are collected from the experimental area as a whole, from each replication, or from each individual plot. In all cases, a composite sample is made, consisting of 5 to 20 individual samples. The individual samples may be taken with an auger, tube, shovel or other implement that facilitates the removal of a uniform section of soil to the desired depth. The most useful depth of sampling is the plow depth or about 15 to 20 centimeters. The individual samples are blended thoroughly on a clean, smooth surface and the required amount of sample is placed in a properly labeled container.

The agronomist or a well-trained assistant weighs out the amounts of the fertilizer mixtures needed for individual rows.

May 29 — June 4: Weighing out bags of fertilizer for individual rows

After fertilizer mixtures have been standing for two weeks or so, they are crushed and sieved and the amounts required for individual rows are weighed out. These amounts are calculated and verified prior to initiating field activities. An example is given in Appendix B.

Plastic-lined paper bags or double heavy-weight paper bags are used for packaging the fertilizers. A convenient procedure is for the agronomist to assign an assistant to filling bags with approximately the required amount of fertilizer while he, personally, adjusts the measure to the exact weight using a scale with a sensitivity of one gram. One or more additional assistants label the bags with the treatment identification (before they are filled with fertilizer) and close them with string, stickertape, or rubber bands after they are weighed. All of the bags corresponding to a given treatment are prepared before proceeding to a different mixture. The bags are stored in a dry location in piles no more than 60 centimeters high.

The bags of fertilizer corresponding to an experiment are grouped together, checked, and accomodated in a cloth sack. If the total weight exceeds 20 kilograms, two or more sacks are used. Each sack should contain the bags of fertilizer for an entire experiment, a fixed number of replications, or specified treatments within a replication. The sacking of the individual bags is postponed until 2 or 3 days before the fertilizer are to be applied.

The weighing-out of the other materials needed in the installation of the experiments is done at this time. Commonly needed are an insecticide for application against soil insects and a pre-emergence herbicide.

June 5: Concentration of materials and equipment at a convenient location

A partial list of the experimental materials and equipment which should be assembled at a convenient location is given below:

1. Seed. If an improved variety is to be used, sufficient seed for 20 experiments should be available.
2. Fertilizers. Individual bags for 20 experiments. Bags for two experiments sacked and ready to be transported to the field.
3. Insecticide for soil application for 20 experiments.
4. Herbicide for 20 experiments.
5. Other insecticides that may be needed (e. g. Telodrin for control of budworm, *Spodoptera frugiperda*).
6. Raticide.
7. Two dusters and two face masks for use in applying insecticide.
8. Five sprayers for applying herbicide.
9. Accessories for applying herbicide:
   One 200-liter drum with faucet
   Two 8-liter buckets
   One small cup
   One small strainer
   Two wrenches (for spray nozzles)
10. Small oil can with light weight oil (e. g. 3 in 1).
11. Ten kilograms of heavy string for marking boundaries of plots.
12. Two hundred wooden stakes (about 40 × 5 × 2 cm).
13. Ten metal stakes for extending measuring wires.
14. One hundred copies of field plans showing distribution of plots.
15. Two marked wires for locating boundary stakes.
16. Four marked wires for planting.

These elements will vary somewhat depending upon the exact nature of the study. Equipment such as sprayers and dusters should be checked for serviceability.

June 6 — 30: Installation of the experiments

In areas where rainfall is distributed throughout the year, the time for making unirrigated plantings is controlled by such factors as soil temperature, frost expectancy, diseases, and insects. With a plains or Mediterranean type climate, unirrigated plantings are made just prior to or at the beginning of the rainy season. As mentioned earlier the Leon-Degollado region has a plains-type climate and the earliest date that precipitation sufficient to wet the soil is expected is June 6.

Under these conditions some farmers begin their plantings in dry soil about two to three weeks before they expect the rains to start. This practice is especially prevalent in heavy clay soils that are difficult to work once the rainy season begins. Plantings in dry soil incur a certain risk, however, as sufficient rain may fall to germinate the seeds but not to insure the emergence and establishment of the small plants. For this reason, plantings in dry soil should be limited to the week or ten days period just prior to the time when the rains are expected to begin. Farmers with light-texture soil, especially if it tends to form a surface crust on drying, almost invariably await a heavy rain before initiating their plantings.

As experimental plantings in both heavy clays and light-textured soils are to be made in the present example, a reasonable planting schedule is as follows:

June 6 — 13. Plant at any experimental location where the soil is moist to a depth of at least 20 centimeters. Plant one-half of the experiments on heavy clays even though they are still dry.

June 14 — 20. Plant at locations that are moist to a depth of at least 15 centimeters. Plant the remaining experiments located on heavy clays.

June 21 — 30. Plant the remaining experiments on light-textured soils as soon as they are moist to a depth of 15 centimeters.

This schedule is prepared on the basis of the expectancy that the rains will begin between June 15 and June 20. Obviously, the actual date of initiation of the rainy season may differ greatly from the expected date. Where historical rainfall data are available, however, the starting date for the rainy season should be estimated and the planting schedule prepared accordingly.

Final arrangements for planting are made with the farmer with one or two days of anticipation. The area destined for the experiment is examined and the final field plan is defined. If not previously done, the experimental area is rowed out at this time. The farmer is advised of how the planting will be made and of what he is expected to furnish. Normally, both the agronomist and the farmer supply a couple of workers so that the experiment can be installed within a few hours.

At the appointed time for planting, the agronomist arrives with the necessary materials, equipment and assistants for establishing the experiment. The agronomist walks over the land, confirms the availability of sufficient area, and assures that it is ready for planting. He locates a corner stake in such a way that adequate border is provided for on all sides of the experiment. Normally two rows on either side of the experiment and a 5 meter strip across each end is sufficient border when the area around the experiment is to be planted to maize. When the surrounding area is to be used for another purpose, the size of the border area should be approximately doubled.

Strings are extended to mark the limits of the experimental plots.

Two assistants extend the measuring wire along the first row with one end coinciding exactly with the corner stake. A third man, preferably the agronomist, places a stake at each marker on the wire. The wide dimension of the stake is oriented perpendicular to the direction of the rows. The stakes are driven firmly into the soil to eliminate the possibility of being pulled out at the time of extending the strings. The measuring wire is then moved forward along the row to a position with one end coinciding with the last stake, and the remaining stakes are driven into the soil.

The agronomist then moves to the other side of the experimental area, counting the number of rows as he goes, and locates a new corner stake on the last row at a point which makes an approximate 90° angle with the last stake on the first row. The measuring wire is again extended

The rate of application of the fertilizer is regulated so that the worker passes along the full length of the row at least twice.

along the row, and the stakes along the other boundary of the experiment are driven into the soil at the proper locations.

As soon as one or more stakes have been driven into the soil, strings are attached to them and extended across the rows to the corresponding stakes on the other side. The strings are pulled tight and fastened to the stakes with a knot that may be readily untied.

The sacks containing the fertilizer bags are placed at convenient locations along the side of the experimental area. The bags are removed from the sacks and the several bags corresponding to a given treatment are grouped together. It the surface of the soil is moist, a suitable material such as a sack or newspaper is extended over the ground before removing the bags.

The agronomist, using the field plan for the experiment as his guide, directs his assistants in picking up the fertilizer bags and in locating them

The best adapted hybrid or open pollinated variety is used for planting the experiment.

at the heads of the rows to which they correspond. He then checks the distribution of the bags against the field plant. The agronomist should personally verify the distribution of bags, as an error in this operation cannot subsequently be identified or corrected.

The agronomist then instructs his assistants in the application of the fertilizers in the rows. The bag is opened and the fertilizer is distributed uniformly along the row. The rate of application is regulated so that the worker passes along the full length of the row at least two times. Inexperienced help should gauge the application so that they pass along the full length of the row at least three times. The agronomist supervises the distribution of fertilizer to assure a uniform application in all of the experiment.

The fertilizer should be covered if there is any danger that it may adversely affect the germination of the seed. The strings are moved to one side of the experimental area, and the farmer covers the fertilizer lightly using the same implement employed in rowing-out.

A wire with markers at the location of each hill is extended along the bed between two furrows, and two men plant the rows on either side of the wire.

The relative salt effects of different fertilizer materials are presented in Table 1.

Table 1. Relative salt index per unit of plant nutrients (N, P, or K) of several fertilizer materials. The salt index of one kilogram of nitrogen in the form of ammonium sulphate is taken as unity.

Material	*Relative salt index*
Ammonium sulphate	1.000
Ammonium nitrate	0.919
Urea	0.497
Ordinary superphosphate	0.275
Triple superphosphate	0.149
Potassium chloride (50%)	0.811
Potassium chloride (60%)	0.717
Potassium sulphate	0.316

Rather large amounts of slowly soluble materials like calcium superphosphate may be applied in direct contact with maize seed without appreciably affecting emergence. Small amounts of highly soluble salts like ammonium sulphate and potassium chloride will greatly reduce emergence. In very general terms an amount of fertilizer equivalent in salt effect to 40 kilograms of nitrogen per hectare in the form of ammonium sulphate can safely be applied in contact with the seed when planting maize in light-texture soil with a moisture content near the field capacity. Approximately twice this amount of fertilizer can safely be applied in contact with the seed when planting in heavy clay near the field capacity.

As an illustration let us assume that ammonium sulphate, ordinary superphosphate, and 60% potassium chloride are being used, and we wish to apply 30 kilograms of P plus 25 kilograms of K per hectare. The fertilizers are to be applied in contact with the maize seed. How much nitrogen can also be applied with the seed in moist sandy loam without appreciably reducing emergence? Using the index in Table 1, we can calculate the total salt effect of 30 kilograms of P plus 25 kilograms of K as:

$$(30 \times 0.275) + (25 \times 0.717) = 8.250 + 17.925 = 26.175$$

The permitted salt effect is

$$(40 \times 1.000) \text{ or } 40.00$$

Therefore,

$$40.00 - 26.175 = 13.825$$

is the salt effect that can safely be added in the form of nitrogenous fertilizer and is equivalent to approximately 14 kilograms of nitrogen. Thus, the treatment, 14-30-25, could be applied in contact with the seed without danger of appreciably affecting emergence.

It is frequently necessary to control soil insects that damage maize roots such as the white grub (*Phyllophaga* spp.), wireworm (several species of the family Elateridae) and rootworm (*Diabrotica* spp.). The appropriate insecticide should be applied in the row before planting; a hand duster may be used to apply a powdered form in a 30 centimeter band directly over the center of the row. One assistant is trained to walk and turn the handle of the duster at velocities that results in the correct rate of application (see Appendix D-I). A face mask should be worn to protect the worker against toxic effects of the insecticide.

Granulated insecticides may also be applied to control soil insects. An applicator may be improvised from a bucket by making holes across the bottom for a distance of about 20 centimeters. The size and number of perforations depend upon the size of the granules. The applicator must be calibrated for a given insecticide applied at a fixed velocity. An assistant applies the insecticide by moving along the row at the predetermined speed and agitating the bucket over the center of the furrow.

Where weed control is a problem, a herbicide may be applied in a band over the seed immediately after planting.

Once the fertilizers are covered and the insecticide is applied, the strings are again fixed to the stakes in their original positions. Planting is conveniently done by teams of two men each. The men fill small containers with maize and acquire a planting wire with a metal stake through the loop at each end. The wire is extended along the bed betwen two furrows, and the stakes are forced into the ground at the level of the strings limiting the borders of the plots. The men move in opposite directions each planting one of the rows on either side of the wire. If the maize is to be thinned to two plants per hill, four or five grains are dropped in a hill at the bottom of the furrow opposite each marker. The first and last hills are located in the alley between plots at a distance from the string equal to one-half the distance between hills. On reaching the end of the rows the workers move the wire forward two rows and continue the planting.

The grains are covered to a depth of 6 to 10 centimeters depending upon the soil texture and the moisture content of the soil. The cooperating farmer is a reliable source of information on depth of covering. Uniform covering may be achieved by having each man cover the grains immediately after dropping them in the row by moving soil over them with his shoe. An alternate procedure is to cover the grains by plowing after the entire area has been planted.

On completion of planting the strings are rolled tightly onto stakes and tied securely so that they do not unwind during transit. The four corner stakes are driven well into the ground. The remaining stakes are collected. All materials and equipment are placed in the vehicle.

The installation of the experiment commonly includes a band or broadcast application of a pre-emergence herbicide. This application should be made on terminating the planting or as soon thereafter as possible. A band treatment with an herbicide like Atrazin can be made in the following manner.

Water is brought to the field in a 200-liter drum with a faucet installed near the bottom. A bag of herbicide, sufficient for a fixed portion of the experiment (see Appendix E), is mixed with water in a small cup until lumps have disappeared. The suspension is transferred to a hand sprayer of approximately 12-liter capacity by passing it through a strainer. The sprayer is filled to the marker with water which is passed through one thickness of a cloth sack. The sprayer is closed and the top is carefully locked in position. Each of the sprayers that are needed to cover the experimental area is prepared in this manner.

An assistant is assigned to each of the sprayers. They shoulder the sprayers and move to the edge of the experimental area. The sprayers are placed on the ground and pumped up according to the instructions supplied by the manufacturer. The agronomist then locates one man at the beginning of each row and points out the line along which the seed has been planted. The men are instructed in the manner to hold the nozzles of the sprayers so that a band approximately 30 centimeters wide directly over the seed is covered by the spray. Nozzles with a fan-shaped spray pattern like the Tee Jet 8004 are satisfactory. When everyone is ready, the agronomist gives a signal and the men walk along their rows at a velocity controlled by the agronomist, applying the spray in a band over the seed. On reaching the end of the rows the men stop, change to different rows, and resume application in accordance with the instructions of the agronomist. After a previously determined number of rows have been treated, the sprayers are placed on the ground and pumped again. The procedure is continued until all rows have been sprayed. Any herbicide remaining in the sprayers is applied to border rows and the sprayers are cleaned. Precaution: If the farmer plans to grow another crop as soon as the corn is harvested it may not be advisable to use herbicides like Atrazin and Simazin because of prolonged residual effects.

As soon as the agronomist completes the installation of an experiment and returns to his home or office, he immediately enters a copy of the final field plan in the office journal. Failure to promptly transfer a second copy of field plans to the office journal can result in the loss of experiments.

During the week to ten days after emergence, the experiments should be visited daily to avoid damage by insects, rats or other predators.

Activities during the two weeks following planting

Four to eight days after planting, depending upon soil moisture and temperature, the young maize plants begin to emerge. During the following week or ten days, the experiment should be visited daily. In case the plants are attacked by insects, rats, pocket gophers, etc., recommended control measures should be initiated immediately. The owner of the land should be advised before distributing poisoned bait that could represent a danger for domestic animals.

The farmer is urged to be especially careful in making the first cultivation in the experimental area so as to break or cover a minimum number of plants. The agronomist with assistants should visit the experiment within two days after the cultivation and assure that all plants have been uncovered.

If a hard crust forms on the surface of the soil before the plants emerge, it is removed in the area of the hills with a pointed stick. If

If evidence of damage by rats is found, a poisoned bait should be distributed throughout the experimental area.

emergence is deficient 10 to 15 days after planting (depending upon rapidity of germination), missing hills should be replanted. It is not advisable to replant at a date later than one week after the beginning of emergence. The following criteria may be used as a guide as to when to replant: a) More than 5% missing hills when these are uniformly distributed, or b) Areas with three or more consecutive missing hills.

The experiment is replanted by opening a small hole to depth of 6 to 10 centimeters with a pointed stick, depositing 4 or 5 seeds, and covering. The new planting is made at a point adjacent to the location of the old hill.

At the time of each visit to a experiment an entry is made in the field book indicating the date, deficiences in emergence, damages, and any operations that were performed. The date of the first cultivation is recorded.

Period 15 to 50 days after planting

As soon as the maize plants are well established, and preferably after the first cultivation, the maize should be thinned to the desired plant population. The entire plant including roots is carefully removed without damaging the roots of the remaining plants. Thinning of the maize should

As soon as the corn plants are well established and before they reach a height of 15 centimeters, the experimental planting should be thinned to the desired plant population.

generally be done two to three weeks after planting and before the largest plants reach a height of 15 centimeters.

Although an herbicide is used to control weeds in a 30 centimeter band along the row, it is necessary to eliminate weeds between the rows and those within the row that were not killed by the herbicide. These are usually controlled by the first cultivation. Sometimes, however, due to a deficient first cultivation or the occurrence of continuous rains, it is necessary to weed the maize by hand. In such cases the agronomist may find it necessary to use his assistants to help with the weeding. Maize yields are adversely affected by weed competition mainly during the first month of the growing season. Consequently, any required weeding should be accomplished during the first two to three weeks after planting.

All the phosphorus, potassium and zinc but only a part of the nitrogen were applied at planting time. The remaining portion of the nitrogen should be applied as soon as convenient after controlling the weeds in the experiment. In general this will be about three to five weeks after planting when the maize is 30 to 50 centimeters tall and just prior to the second cultivation.

The second application of nitrogen is carried out in a manner similar to that followed at planting time. Bags containing the required amounts of nitrogenous fertilizer are located at the head of the rows to which they correspond. The locations of the individual bags are checked against the

Most of the nitrogen fertilizer is applied as a sidedressing after weeds have been controlled and just prior to a cultivation. The bags of fertilizer corresponding to the different treatments are grouped together at the edge of the experiment and then distributed to their proper locations under the supervision of the agronomist.

field plan by the agronomist. The contents of the bags are distributed uniformly along one side of the row about half way between the maize plants and the furrow. Care is taken that the fertilizer does not fall on the leaves of the maize plants. The application begins and ends at points mid-way between the last two hills at each end of the row. The fertilizer is covered within a few hours by the second cultivation or, when necessary, by hoe.

During this period each experiment is visited at least once a week. At the time of each visit entries are made in the field book indicating the date, presence or absence of drought magnitude of accumulation of water in the rows, and plant damage due to hail, insects, animals, etc. (see Appendix F). The degree of weed competition at the time of the cultivations or other operations that remove appreciable quantities of weeds is estimated and recorded. Dates of thinning the maize, cultivations, weeding, insecticide applications, and the second application of nitrogen are also recorded.

The sidedressing application of nitrogen is made when the corn plants are about 30 to 40 centimeters tall. The fertilizer is distributed uniformly along one side of the row.

At the time of a visit when the maize is 20 to 30 days old, the vegetative response to the fertilizer treatments should be noted in the field book. Average plant heights, measured from the ground to the highest point on the upper leaf in its normal position, should be indicated. This is the stage of development when vegetative differences due to applications of phosphorus and zinc are most likely to be evident. These early vegetative responses often do not result in differences in grain production, yet they do indicate borderline levels of availability of these elements.

During this period the maize plants are commonly attacked by insects, such as the budworm, that destroy part or all of the plant. The agronomist should know which insects may attack the corn and the degree of damage permissible before instituting control measures. Insecticides should be kept on hand and applied as soon as necessary.

Budworm is controlled by sprinkling the prescribed insecticide in granular form directly in the buds of the plants.

Period 50 to 110 days after planting

During these two months the agronomist is involved in making and recording a series of observations. Many of these observations produce information basic to an adequate interpretation of the experiment. The agronomist must understand the importance of this information and carefully observe the indications with respect to timing given below and those on procedures in Appendix F. *All observations must be made by the agronomist.*

Each experiment is visited once every 5 to 7 days between the hours of 12 noon and 5 p.m. The percentage of plants wilting and the intensity of wilting due to moisture deficiency are recorded for three treatments, selected to represent a high, medium and low level of fertilization. Observations are made on the maize in the center rows of the plots corresponding to the three treatments in each of the replications. The hour of observation, degree of cloudiness, and approximate wind velocity are noted. Under natural rainfall conditions the most common reasons for making frequent visits to the experiments is to record the progress of plant wilting. It is important that the agronomist schedules his meals so that he is free from around 11:30 a.m. to 5:30 p.m. to make these observations.

Several other observations are taken on the plots mentioned above at the time of visits during this part of the growing season. The percentage of the surface of the soil covered by water is recorded. Plant damage due to hail, wind, animals, etc., is described. The degree to which the aerial portion of the plants is attacked by diseases such as *Helminthosporium turcicum* is recorded. During the tasseling period the percentages of plants with tassels showing are noted.

During this two-month period profile descriptions are made of the soil at each experimental site. A pit is dug at a central location along one side of the experiment. Each pit should be one meter wide, two meters long, and sufficiently deep (usually 1 to 1.5 meters) to expose a part of the C horizon. The long dimension of the pit should lie in an east-west direction if it is planned to take pictures of the profile. The soil profile is described according to the 7th Approximation, Soil Conservation Service, United States Department of Agriculture. Soil samples are collected from each major horizon, placed in containers, and labeled with the number of the experiment, name of the farmer and the horizon identification. The samples are forwarded to the laboratory for property characterization. The excavated material is used to refill the pit.

A questionaire is prepared for obtaining information from the farmer about the past history of the experimental site. An example is shown in Appendix G. These questionaires are completed during this period through interviews with the cooperating farmers.

Final 10 to 15 days before physiological maturity

Plant damage due to certain insects and diseases can best be evaluated through observations taken just prior to maturity. Damage by the European stalk borer often occurs late in the season and is described in terms of the number of plants affected in plots corresponding to selected treatments as mentioned earlier. The number of plants in the same plots attacked by diseases such as tassel smut [*Sphacelotheca reiliana* (Kühn) Clinton] and common smut [*Ustilago maydis* (D.C.) Corda] is determined. The date when the grain of 90% of the ears is in the hard-dough stage is recorded.

During this period preparations are made for the harvest. Farmers are advised of the harvesting procedure and impressed with the importance of protecting the experiment until it is harvested by the agronomist. A partial list of the materials and equipment which should be ready for use by the end of this period is given below:

1. Two milk scales — 30 kilogram capacity.
2. Two tripods.

Stalk borers cut or tunnel in the lower part of the stalks and cause the plants to lodge before harvest.

3. Ten baskets for harvesting.
4. Four sickles for cutting plants at the ends of the rows.
5. Ten hand pickers.
6. Fifty copies of field plans showing distribution of plots.
7. One moisture tester with balance or
   a) Drying oven
   b) Balance
   c) Sufficient cans for moisture samples from four experiments
8. Sufficient plastic bags for moisture samples from six experiments.
9. Ten screwdrivers or similar objects for taking grain samples.
10. Labelling tags for moisture samples from all experiments.
11. Paper clips for closing plastic bags used in talking grain samples for moisture determinations.
12. Cloth sacks for transporting moisture samples.

The worker picks all the ears from the rows corresponding to the harvest area of the plot and places them in a pile in the alley at the end of the rows.

Harvest

The maize is harvested as soon as it reaches the hard-dough stage. As the time of harvest approaches a tentative harvest schedule is prepared based on the relative stage of maturity of the grain in the different experiments. The farmers are reminded repeatedly that the maize in the experimental areas must not be touched until the time of harvested by the agronomist.

In many regions farmers are accustomed to cutting and shocking their maize as soon as it reaches the hard-dough stage. *For this and similar reasons it is imperative that the experiments be harvested as soon a possible after the maize reaches maturity. The farmers are visited frequently during this period for the purpose of convincing them to leave the experiments untouched until the arrival of the agronomist.*

On the day prior to the harvest, the farmer is advised of the hour that the agronomist will arrive. He is reminded to have available the men that he is to furnish for the harvest. The agronomist should plant to bring a similar number of helpers.

On arriving at the experiment on the day of the harvest, the agronomist instructs two of his assistants to cut the end hills of the four center rows of each plot. These hills at the ends of the rows and the border row on either side of the plot are not harvested. In fertilizer experiments it

A tripod is located at a central point in the alley between blocks, a milk scale is attached, and the harvested ears from each plot are weighed.

is necessary to discard the plants growing in a strip around the plot as the lateral roots of plants absorb nutrients some distance from the position of the stalk. Also, if the height of plants in adjacent plots is significantly different, the shorter plants may be shaded by the taller ones. In the present example the harvest area of each plot consists of 4 rows 8 meters in length.

While the end hills of the center rows of each plot are being cut and placed to one side, the agronomist locates the farmer and the other assistants with baskets at the beginning of plots. Generally, it is convenient to assign two rows to each man. The men are instructed to harvest all of the ears, large and small, from their assigned rows but not to pick ears from plants of adjacent rows that have fallen across their area. On reaching the alley at the end of the plot the workers empty the ears on the ground and continue the harvest of the same rows in the following block.

The agronomist supervises the cutting of the end hills and is present at the time the harvest of one plot is completed and the harvest of the next plot begins.

A grain sample is taken for moisture determination by removing two rows of grain from 12 to 20 representative ears.

As soon as his two assistants finish cutting the end hills of the entire experiment, they assist the agronomist in counting the number of maize plants and hills in the harvest area of each plot. Usually it is convenient to count hills while moving in one direction and plants on a return trip through the same rows. The agronomist records the number of plants and hills for each plot on the field plan. While these counts are being made, the agronomist observes the progress of the harvest and supervises the change when workers move from one plot to another.

On completing the count of plants and hills, the agronomist locates the assistants at the beginning of plots and instructs them in the harvest procedure. While the harvest is underway, the agronomist continues to assure that no errors occur at the end and beginning of plots; at the same time he checks that harvested rows to assure that no ears were overlooked.

When all plots have been harvested, the tripod is placed at a central point in the alley and the milk scale is attached and adjusted to read zero with the basket in place for weighing. Beginning at one side of the experiment two or three assistants locate themselves successively at the piles of ears harvested from the different plots. Each worker counts the number of ears in his pile and places them in a basket. Then, beginning at the side and advancing in order, each carries his basket to the scale, transfers it to the special basket for weighing, waits while the weight is recorded by the agronomist, empties the ears into his basket, and returns them to the

The piles of harvested ears are inspected and an estimate is made of the pollination percentage and proportion of rotten kernels.

spot from which they were taken. Thus, in order, the ears harvested from each plot are counted, weighed, and returned to their original location. On completing the weighing of the maize in the first alley, the tripod and scale are moved to the other alleys and the process is continued.

As soon as the weighing is underway, the agronomist places on each pile of corn a polyethylene bag with an attached clip and label showing the number of the experiment, replication, and treatment to which it corresponds. It is often convenient to prepare the labels and arrange them in the proper order before arriving in the field. The assistants not occupied in the weighing operation are given a cloth sack and a screwdriver and instructed in the proper procedure for taking grain samples for moisture determinations. Twelve to twenty ears, depending upon size, are selected from the harvest from each plot and placed on the cloth sack. In the selection of the ears it is important to give equitable representation to large and small ears as well as dry and moist ones. Two rows of grain are removed from each ear with a screwdriver. The sample of grain (at least 150 grams) is placed immediately in the polyethylene bag. The label is placed inside the bag so that the identification is clearly visible. The top of the bag, after removal of the air inside, is folded several times and closed with the clip. The samples are placed in a cloth sack and moved to a cool location.

After completing the weighing operation and while the taking of grain samples is in progress, the agronomist estimates the pollination percentage and the percentage of rotten kernels (see Appendix E) in the harvest from the same plots used earlier in making detailed observations on plant wilting, hail damage, etc.

On completion of these operations all materials used in the harvest are carried to the vehicle and checked by the agronomist. The farmer is thanked for his cooperation and informed that within about three months he will receive a brief summary of the results obtained in his field.

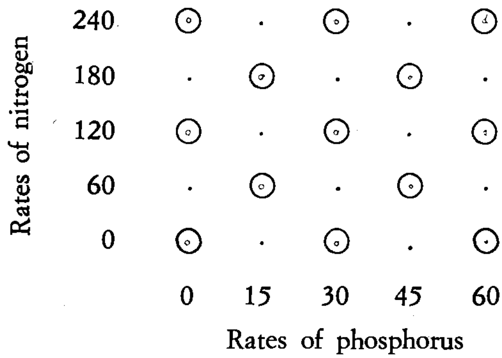
The agronomist then returns to his workroom and determines the moisture content of the grain samples. If the grain is fairly dry, an adequate estimate of moisture content can be made with a moister tester. If the grain is rather moist (more than 30% moisture) the moisture content should be determined gravimetrically. In this procedure the grain samples are placed in drying cans, weighed, brought to constant weight in a drying oven at 105°C, and reweighed.

Post-harvest activities

All equipment and materials are concentrated at a location where they can be adequately protected until needed. Dusters, sprayers, etc., are cleaned and dried before being stored. Rain gauges are removed from their bases, cleaned, and placed in storage. An inventory listing all equipment and supplies is prepared and copies are given to interested parties.

APPENDIX A — Treatment Design

The group of treatment that are selected for a set of experiments depends upon the objectives of the study, the comparisons that are to be made, and the required precision. A suitable treatment design for the study of fertilizer needs in an area where only two elements are expected to be deficient is the "double square." The set of treatments corresponding to this design are the odd-numbered treatments in a 5^2 factorial. This in seen in the following diagram where the 25 treatment of a 5^2 factorial are indicated with dots and the 13 treatments corresponding to the "double square" are shown as circles:



The 13 treatments corresponding to the "double square" are:

1. 0-0-0 *
2. 120-0-0
3. 240-0-0
4. 60-15-0
5. 180-15-0
6. 0-30-0
7. 120-30-0
8. 240-30-0
9. 60-45-0
10. 180-45-0
11. 0-60-0
12. 120-60-0
13. 240-60-0

In defining additional treatments for measuring possible deficiences of other nutrients, a treatment is selected from the above set which has a near optimal level of nitrogen and phosphorus. The added treatments have these same levels of nitrogen and phosphorus plus a reasonable level of the other element. Additional treatments for measuring the effects of potassium and zinc might be:

120-30-50 and 120-30-0 + 20 Zn

APPENDIX B — Calculations for the Preparation of Fertilizers

I. Calculation of Materials Needed in Preparing Fertilizer Mixtures

Area per row = 8 m long × 0.90 m wide = 7.2 m^2.
Number of rows per plot = 6
Number of replications = 3
Number of experiments = 20

* The three numbers in a treatment designation indicate from left to right kilograms per hectare of nitrogen, phosphorus and potassium.

Fertilizer materials:

Ammonium sulphate containing 20.5%N
Calcium superphosphate containing 8.5%P
Potassium chloride containing 50%K

Fertilizer treatment: 120-30-50

Treatment applied at planting time: 12-30-50

Total area per treatment = 7.2 m^2 × 6 rows × 3 replications × 20 experiments = 2592 m^2 = 0.2592 ha.

(12 × 0.2592) ÷ 20.5% = 15.17 kg of ammonium sulphate
(30 × 0.2592) ÷ 8.5% = 91.48 kg of calcium superphosphate
(50 × 0.2592) ÷ 50% = 25.92 kg of potassium chloride

These amounts should be increased by about 5% to permit the preparation of a few extra bags and cover small losses in mixing.

The amounts of materials required:

Ammonium sulphate —	15.93 kg
Calcium superphosphate —	96.05 kg
Potassium chloride —	27.22 kg

The total amount, 139.20 kg, is quite large to be prepared in a single batch. It might be prepared in two equal batches, with the following amounts of materials comprising each batch:

Ammonium sulphate —	7.97 kg
Calcium superphosphate —	48.03 kg
Potassium chloride —	13.61 kg
Total	69.61 kg

In a similar fashion the amounts of materials needed in preparing mixtures corresponding to other treatments are calculated. A few examples are given in the following table:

Fertilizer treatment	Treatment applied at planting	Kilos of materials needed (+ 5%) (1)	(2)	(3)	Total weight kg	No. of batches	Kilos of materials per batch (1)	(2)	(3)
60-30-0	6-30-0	7.97	96.05	0.0	104.02	2	3.99	48.03	0.0
120-30-25	12-30-25	15.93	96.05	13.61	125.59	2	7.97	48.03	6.81
180-45-50	18-45-50	23.90	144.08	27.22	195.20	3	7.97	48.03	9.07
240-45-50	24-45-50	31.87	144.08	27.22	203.17	3	10.62	48.03	9.07
300-60-75	30-60-75	39.84	192.11	40.83	272.78	4	9.96	48.03	10.21

(1) Ammonium sulphate. (2) Calcium superphosphate. (3) Potassium chloride.

II. Calculation of Amounts of Mixtures Needed per Row

The amounts of mixtures were calculated for 6 rows in 3 replications of 20 experiments plus an additional 5%. That is,

$$1.05\ (6 \times 3 \times 20) = 1.05 \times 360 = 378 \text{ rows}$$

The total amount prepared for treatment 12-30-50 was 139.20. Therefore, the amount per row is,

$$139.20 \div 378 = 0.368 \text{ kg}$$

The same value may be arrived at in a different manner. The area per row = 7.2 m^2 = 0.00072 ha. Therefore,

$(12 \times 0.00072) \div 20.5\% = 0.0421$ kg of ammonium sulphate
$(30 \times 0.00072) \div 8.5\% = 0.2541$ kg of calcium superphosphate
$(50 \times 0.00072) \div 50\% = 0.0720$ kg of potassium chloride

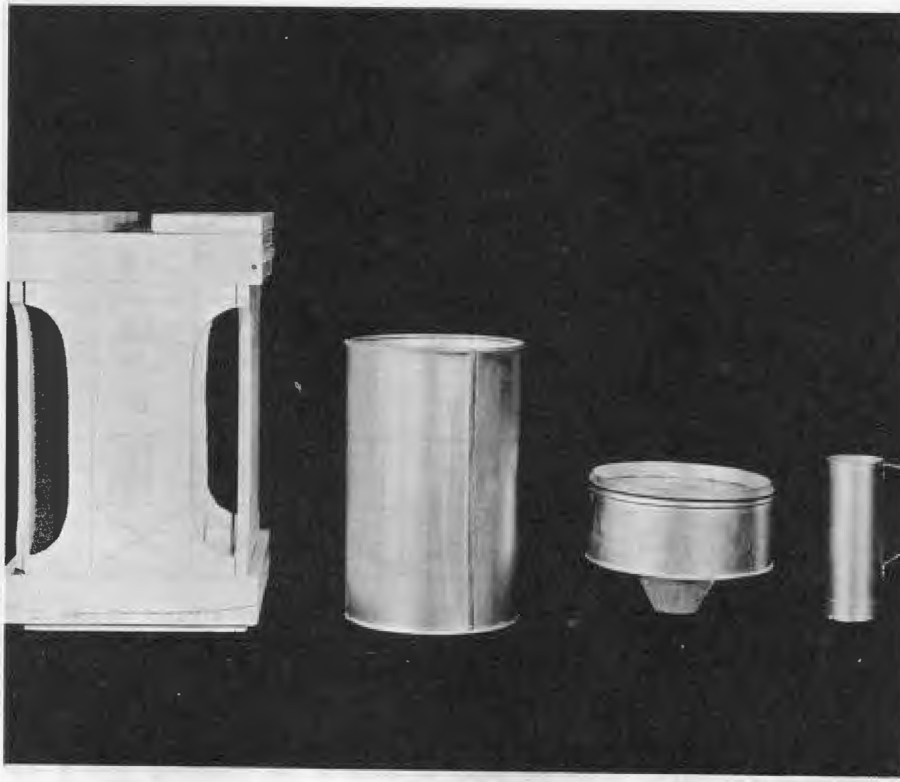
Total 0.3682 kg = amount per row

The amounts of mixtures required per row for the treatments mentioned earlier are:

Total fertilizer treatment	Treatment applied at planting	Amount of mixture per row (gm)
60-30-0	6-30-0	275
120-30-25	12-30-25	332
180-45-50	18-45-50	516
240-45-50	24-45-50	537
300-60-75	30-60-75	722

APPENDIX C — The Eight-Inch Nonrecording Rain Gauge

This is the standard rain gauge for measuring precipitation in many countries. It is described in detail in the eleventh edition of Circular B of the United States Department of Commerce entitled "Instructions for Climatological Observers". This publication may be obtained from the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C., at a cost of $0.55.



The eight inch nonrecording rain gauge. From left to right are shown the support, overflow can, rainfall receiver and measuring tube.

A slight modification of this rain gauge is used in Mexico and described in the Octava Edición of Circular-A, "Instrucción para el uso de las Estaciones Climatológicas", Dirección de Geografía y Meteorología, Secretaría de Agricultura y Ganadería, Tacubaya, D. F., México.

It consists of a support, overflow can, rainfall receiver, measuring tube and measuring stick. The first four of these are shown in the adjoining figure. The support is a wooden box used for shipment of the rain gauge. On unpacking, the two boards at the top, which are slotted at the center to the midpoints of the boards, are removed and placed in a crossed position in the bottom of the box as a base for the overflow can. This can is 34 centimeters tall and 22.6 centimeters in diameter. The rainfall receiver is a funnel fitted with a bronze ring with a beveled edge exactly 22.6 centimeters in diameter. The measuring tube is 20 centimeters tall, 7.1 centimeters in diameter and has a small handle. The measuring stick is a very thin, 30 centimeter wooden ruler.

Experiment: No. 13 Alfredo Jiménez

Month: July

						0
0	0	T	0	17.2	0	3.3
0	0	0	20 13.5 33.5	11.1	5.2	14.7
0	0	3.8	0	0	T	0
9.8	0	0	0	0	0	20 15.1 35.1
15.3	5.9					

Total: 154.9 mm.

A form for registering precipitation at an experimental site. Amount of rainfall is recorded in millimeters. When the depth of water in the measuring tube is less than 0.1 millimeter, it is recorded as a trace using the letter "T".

The rain gauge should be installed with the rainfall receiver in a horizontal position and the support firmly anchored to the ground. A carpenter's level is used to verify the position of the rainfall receiver. The support may be attached to wooden stakes driven firmly into the ground. Where a more secure installation is preferred, the support may be bolted to a metal pipe base which in turn is bolted to a concrete base. The metal pipe base is made by welding a metal cross to both ends of a 50 centimeter length of 5 centimeter pipe. The concrete base is poured using a pyramidal wooden frame approximately 35 cm wide at the top, 45 cm wide at the bottom and 12 cm high. A carpenter's level is used to assure that the top of the form is level. As the concrete begins to harden, bolts for connection to the metal pipe base are positioned in the surface of the concrete. The concrete bases may be prepared at a central location and later transported to the installation site or they may be poured on location. The height of the top of the installed rain gauge should be about one meter above ground level.

A measurement of the amount of rainfall during the previous 24 hours should be made at the same hour each day. The rainfall receiver is removed from the overflow can, and the level of water in the measuring tube is noted. If the tube is only partly filled the measuring stick is placed vertically in the tube with the zero end resting on the bottom. After a couple of seconds the stick is removed and the depth of water is read by observing the top of the wetted portion of the stick. When the tube is full, it is carefully removed without spilling any of the water into the overflow can, emptied, and allowed to drain for several seconds. The remaining water in the overflow can is carefully passed to the tube and measured.

The cross-sectional area of the measuring tube is exactly one-tenth of the area of the rainfall receiver. Consequently, the depth of water in the tube read in centimeters is equal to the amount of rainfall expressed as millimeters. Individual readings should be noted on the rainfall register and summed to give the total precipitation for that day. An example of a convenient rainfall register is given in the adjoining figure.

APPENDIX D — Insect Control

Maize is attacked by many insects during the growing season. The frequency and intensity of insect attacks vary from country to country, among ecological regions within a country, from season to season, and even among varieties.

Some of the more important insects attacking maize in Mexico are:

Budworm *Spodoptera* (= *Laphygma*) *frugiperda* (J. E. Smith).
Rootworm *Diabrotica balteata* Le Conte, *D. virgifera* Le Conte and *D. porracea* Harold.
Earworm *Helicoverpa* (= *Heliothis*) *zea* (Boddie).
Stalk borer *Zeadiatrea grandiosella* (Dyar) and other species.
White grub *Phyllophaga* spp.
Red spider *Paratetranychus* spp.
Weevils *Gereus* sp and *Nicentrus* sp.
Rose chafer *Macrodactylus* spp.

The attack by some of these insects is sufficiently intense at times to warrant the application of insecticides for their control. Recommended control measures are given in the following pages.

I. Control of Soil Insects

Soil insects such as the rootworm, *Diabrotica* spp., and white grub, *Phyllophaga* spp., feed on the roots of maize plants and frequently reduce production. Most of these are effectively controlled with a 2½% Aldrin dust applied in a band to the soil at planting time. The material may be applied with a hand duster.

Aldrin is applied at the broadcast rate of 2 kilograms of pure material per hectare or 80 kilograms of a 2½% preparation per hectare. An example of the calculation of the amount of 2½% Aldrin required for an experiment is as follows:

Area to treat = 15 treatments × 6 rows per treatment × 8 m in length × 3 replications × 0.30 m (width treated per row) = 648 m^2 or 0.0648 ha.

Normally the insecticide is also applied in the alleys between plots. Assuming alleys 2 meters in width, the total area in alleys is approximately 25% of the area as calculated above. Consequently the total area to treat = 0.0648 × 1.25 = 0.081 ha.

Amount of 2½% Aldrin to apply per experiment = 0.081 × 80 = 6.48 kg.

II. Control of Budworm

If, during the period from emergence to tasseling, more than 10% of the maize plants are attacked by budworm, *Spodoptera frugiperda,* an application of 1.5% granulated Telodrin, or equivalent material, is made.

The application can be made with an ordinary oil can by making four or five holes in the bottom with a small nail about 2 millimeters in diameter. The insecticide is placed in the can which is then shook over the maize plant so that the granules fall into the bud.

One and one-half percent granulated Telodrin should be applied at the rate of about 10 kilograms per hectare. For plantings with 40,000 plants per hectare this is equivalent to about 0.25 gram of Telodrin per plant. Assuming 15 treatments of 6 rows 8 meters long and 0.9 meter wide, and 3 replications the experimental area is 0.195 hectare. The approximate amount of 1.5% Telodrin needed per experiment is 0.195 × 10 = 1.95 kilograms.

III. Control of Rose Chafer

The rose chafer (*Macrodactylus* spp.) frequently reduces maize yields by destroying the silks and pollen during flowering. The insects migrate and damage generally occurs in spots.

It is advisable to control the rose chafer if appreciable numbers of adults appears in the experiment or in the vegetation surrounding it at the time of flowering. A 3% B.H.C. dust is applied directly on the insects with a hand duster. In the absence of rain a single application of insecticide usually gives adequate control. Occurrence of rain may necessitate two or more applications.

APPENDIX E — Preemergence Application of Herbicide

Simazin and Atrazin, when applied to the soil after covering the maize seed, control most weeds without damaging the maize plants. As rain or an irrigation is needed to move the herbicide into the soil before it becomes effective, it is important that the application be made as soon as possible after planting.

Fifty percent Simazin or Atrazin is applied at the broadcast rate of 3 kilograms per hectare. An example of the calculation of the amount of 50% Atrazin required for an experiment is as follows:

Area to treat = 15 treatments × 6 rows per treatment × 8 m per row × 3 replications × 0.30 m (width of band treated) = 648 m^2 or 0.0648 ha.

The herbicide is also applied in the alleys between plots. Assuming alleys 2 meters in width, the total area in alleys is approximately 25% of the area as calculated above. Consequently, the total area to treat =
0.0648 × 1.25 = 0.081 ha.

Amount of 50% Atrazin to apply per experiment
= 0.081 × 3 = 0.243 kg or 243 grams.

The capacity of each sprayer, 12 liters, is sufficient to cover an area of approximately 0.0165 hectare. Consequently, 0.081 ÷ 0.0165 = 4.91 or 5 is the number of sprayers needed to make a 30 cm band application over the entire experiment. Therefore, 243 ÷ 5 = 49 gm = amount of Atrazin needed per sprayer.

APPENDIX F — Procedure for Taking Field Observations

I. Plant Wilting

The estimations of the degree of wilting indicate both the frequency of plants showing signs of wilting and the intensity of the wilting.

The frequency component is noted by recording the number of plants per plot, or the percentage of plants, with a given intensity of wilting.

Three degrees of the intensity component are recognized:

1. No wilting.
2. Light or incipient wilting

   Plants show the first signs of loss of turgor. Generally, the color of the leaf changes slightly from dark green to grayish green on loss of turgor. The leaves become slightly flaccid, especially those surrounding the tassel just before it emerges. Sometimes the first sign of wilting is a straightening-out of the upper leaves, and a slight curling of the edges near the point upward and toward the mid rib.
3. Severe wilting

   At least one-half of the leaves are completely rolled.

To complete the observations on wilting, the date, hour of the day, degree of cloudiness (clear, partly overcast, cloudy) and windiness (calm, windy) are noted.

Example: Aug. 15; 2:30 p.m.; clear; calm; no wilting-40%; light wilting — 50%; severe wilting — 10%.

II. Excess Moisture

In heavy clays and lighter-textured soils that are slowly permeable, reduced growth due to excess soil moisture or a deficiency of oxygen in the root zone is common. Facilities are not available at present for making adequate observations of this condition. However, frequent observations on the presence of water standing in the furrows; together with daily rainfall records, will permit a rough estimation of the duration of periods when the moisture content of the root zone of the soil is above the field capacity.

At each visit an estimate is made of the percentage of the harvest area of each plot in the experiment that is covered with water. The date, hour of the day, degree of cloudiness, windiness, and the approximate time that has elapsed since the last rain are indicated.

Example: July 28; 3:00 p.m.; cloudy; calm; 2 days; 10%.

III. Weed Competition

At the time of plowing or hoeing to control an appreciable weed population, or as near to this time as possible, an estimate is made of the amount of weed growth. The estimates are made for all replications of three treatments (low, medium, and high rate of fertilization).

A representative portion of the plot is selected and the weeds are cut at ground level from an area the width of two rows and with a length equal to ten times the distance between hills. The weeds are placed in a sack and weighed using a milk scale with a precision of about 0.05 kilograms. As the distances between rows and hills are known (e. g. 0.90 meter between rows and 0.57 meter between hills) the degree of weed competition for a plot is recorded as kilograms of weeds in a certain area.

Example: July 11; degree of weed competition = 1.10 kg per 10.26 m^2.

IV. Hail Damage

The principal objective is to record the amount of leaf damage and the stage of development at the time it occurs.

Observations are made on all replications of three treatments (low, medium and high rate of fertilization). The leaves of 5 plants at each of 4 different locations in the harvest area of the plots are examined. The percentage of the leaf area that has been destroyed or severed from the remainder of the leaf by a transverse cut is estimated.

The stage of development is noted by recording the average height of the plants (ground to uppermost point of plant in normal position) in the selected plots and the average number of leaves (not counting bud).

Example: Aug. 2; 25% leaf area destroyed; 1.6 m tall; 7 leaves.

V. Budworm Damage

The estimations of budworm damage indicate both the frequency and intensity of damage.

The frequency component is noted by recording the number of plants per plot or the percentage of plants with a given intensity of damage.

Three degrees of the intensity component are recognized:

1. No damage.
2. Light effect. Visible evidence of cutting is small and limited to the bud; some excrement is present.
3. Severe effect. Bud is completely cut to pieces. The cutting extends to the adjacent leaves which are partially or completely severed.

Example: July 22; no damage — 30%; light damage — 50%; severe damage — 20%.

VI. Helminthosporium Attack

The fungus, *Helminthosporium turcicum,* kills the leaf cells in large elongated areas. *Helminthosporium maydis* kills the leaf cells in small, rectangular areas whose long dimension is bounded by straight lines corresponding to the veins of the leaf.

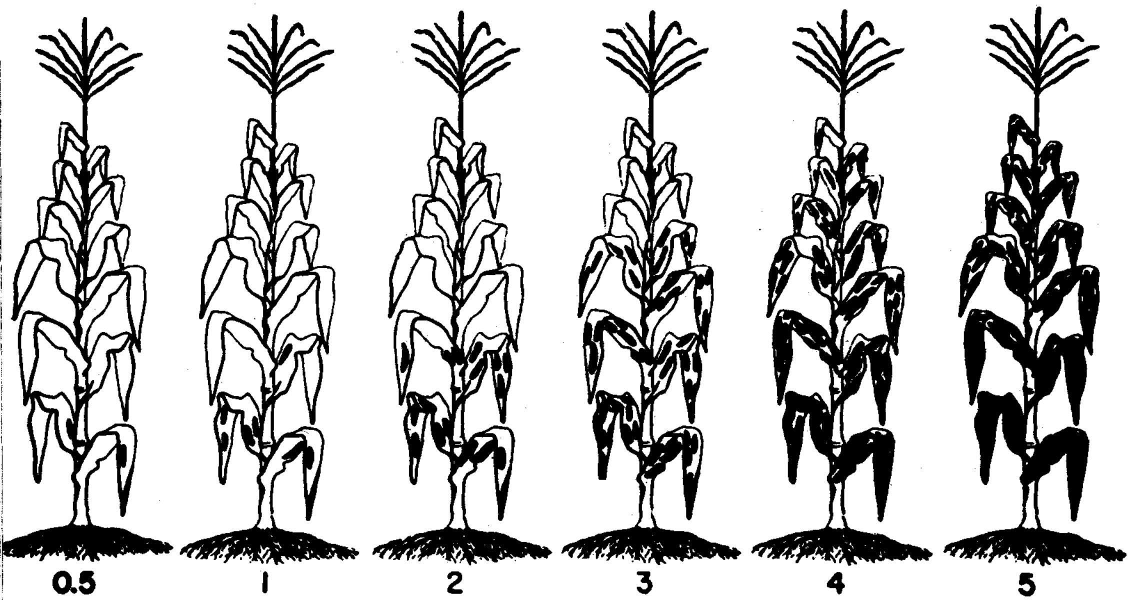


Diagram for estimating the degree of damage by *Helminthosporium turcicum.*

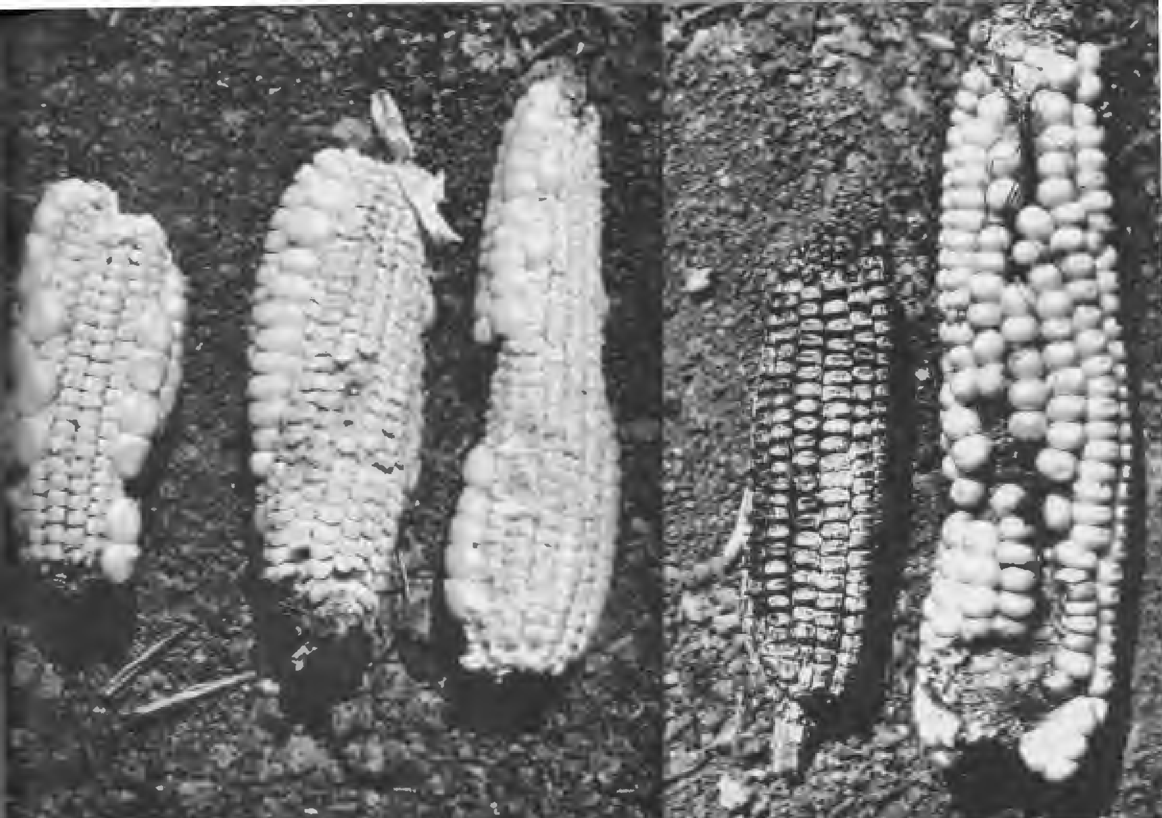
At the time of appearance of these diseases and at regular intervals thereafter, the degree of attack is estimated by comparing the leaf damage at several spots in all replications of selected treatments with the attached diagram. The degree of damage is recorded using the scale of 0 to 5.

Example: Sept. 4; *H. turcicum* 2.

VII. Pollination Percentage

After the harvest from each plot has been weighed, the pile of ears from each selected plot is examined and those ears with deficient pollination (ears not completely filled) are separated from the well-filled ears. The sizes of the two piles of ears are compared visually, and the percentage of the total harvest that has been separated into the pile with deficient pollination is estimated. Next, the ears with deficient pollination are examined, and the percentage of missing kernels on these ears is estimated. The product of these percentages is substracted from 100 to give the pollination percentage.

Example: % of ears with deficient pollination = 15
% of missing kernels on ears with defficient pollination = 30
Pollination percentage = 100 — (15% × 30%) = 95.5.



Left: Grains did not form over much of these ears due to the lack of pollination. Right: The proportion of rotten kernels affects the value of the harvest and should be taken into account.

VIII. Percentage of Rotten Kernels

The pile of harvested ears in each selected plot is examined and those ears with rotten kernels are placed in a separate pile. The sizes of the two piles of ears are compared visually, and the percentage of the total harvest that has been separated into the pile with rotten kernels is estimated. Next, the ears with rotten kernels are examined and the percentage of worthless grain is estimated. The percentage of rotten kernels is the product of the two percentages.

Example: % of ears with rotten kernels = 30
% of rotten kernels in pile of ears that was separated out = 10
Percentage of rotten kernels = 30% × 10% = 3%.

APPENDIX G — Questionnaire

Number of experiment .... Location ....

Name of farmer .... Year 1967

I. Following questions refer specifically to the experimental plot:
Previous crop:
1964 .... 1965 .... 1966 ....
Previous fertilization:
1964 .... 1965 .... 1966 ....
Barnyard manure applied in previous 3 years ....
Legumes incorporated in previous 3 years ....

II. Following questions refer to the farmer's total operation:
Yield of maize in previous years:
1964 .... 1965 .... 1966 ....
Description of crop rotation ....
....
....
....
In what percentage of years is the land left idle? ....
Why? ....
How is land prepared? ....
....
....
Cultivations ....
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....
....
Is the crop planted in dry soil or after the first rain? ....
....
Why? ....
....
What conditions (insects, diseases, weeds, drought, excess moisture, etc.) limit maize production (in order of importance)? ....
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Observations: ....
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