# THE GROWTH RESPONSE OF MAIZE
# IN DIFFERENT CLIMATES IN
# GUATEMALA

by

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TABLE OF CONTENTS

# LIST OF TABLES

## LIST OF PLATES

# INTRODUCTION

Evidence points strongly to the American Tropics as the place of origin of maize. It is well known that regions in and adjoining these mountain ranges are regions of great climatic diversity. The climatic controls of altitude, topography and oceans place each mountain valley and each mile of coastal plain in climatic provinces no two of which are identical. To nearly all of these tropical altitude-climates one or more variants of maize has become adapted. To-date no one has studied the influences or effects of these climates on the growth and development of the maize variants native to them. As a result, no one has been able to state which variations are inherent and which are merely reactions to climatic change.

Before it is possible to utilize the characters of tropical maize it becomes necessary to know which are fixed by heredity and the extent of their variability as brought about by climatic and edaphic influences. Too, such a study might afford a basis for grouping the maize of the tropics, thus simplifying the selection of germ plasm most suited for study and use in another region of the world.

All earlier studies relating to the influence of climate on maize have given little consideration to the inherent adaptability of the variant to controls and elements of different climates. Most of the variants have been judged and described from their performance in climates entirely foreign to those to which they are adapted by heredity. This lack of cognizance as to the climatic limitations of a given variant, or assemblage of variants, has resulted in a general loss of interest in further work with this valuable pool of germ plasm. There are many qualities already present in the maize variants of Guatemala which are needed in other areas.

This investigation was planned and carried out to assist those interested in searching for characters useful in other maize growing regions; describing and defining as accurately as possible the variants and their climatic variations.

Before any well-founded descriptions and type determinations could be made it was deemed necessary to ascertain: (1) the influence of different climates on maize transplants; (2) the influence of the elements of climate on specific characters of maize variants; (3) the correlations manifested by the growth response behavior among the characters measured in the different altitude-climates; (4) the separation of variants into groups on the basis of their climatic responses.

## REVIEW OF LITERATURE

The literature pertinent to this study is not great. There has been some very excellent research on the effects of new environments, in particular altitude-climates, on transplants. However most of this work has been carried on with wild annuals and perennials. Very little research has been carried on in this field with cultivated crops and in particular with maize.

The meticulous work of Kerner von Marilaun (36) has been of great value to students of the effects of different climates on plant species. His work was carried on in four altitude-climates two of which were in the Alps, one at 2,195 meters and the other at 1,215 meters. The other stations were located at Innsbruck at 569 meters and at Vienna at 180 meters. He used approximately 300 annuals and perennials in the course of his investigations. His results showed that at high altitude his annuals had fewer nodes and shorter internodes than those grown at lower altitudes. Also, pigmentation was more pronounced and green coloration less pronounced at high than at low altitudes. Kerner believed that the increased light intensity at the higher altitudes was responsible for these modifications. His most important conclusion was that modifications produced by climatic changes were not heritable. He also concluded that the ability of plants to adapt themselves to changes in environment is dependent on the protoplasmic makeup of the species.

Bonnier's publications on the effects of altitude-climates on transplants are probably the most frequently cited. Starting in 1886 with clones of wild species (7), he established over 200 clone plantings at high and at low altitudes. His high altitude plantings were located in the Pyrennes and Alps while his lowland plantings were made at Paris and several other locations in France. By 1895 he had noted striking changes in some of his transplants (8). He concluded that the factors most responsible for these changes were temperature, humidity, and differences in light. After Bonnier's transplants had been subjected to direct competition with native species and the elements for more than 30 years he drew his much publicized conclusions (9). He claimed that many of the lowland species had been completely transformed into forms identical with highland species of the same genus. The period of time required for this transformation varied depending on the species. He found, however, that unless there was a related form or species native to the highland habitat that transplants from lower altitudes did not succeed. He also found that it was very difficult to transplant alpine forms to lowland sites. Bonnier stated that the optimum altitude-climate for any plant could be determined by observation of color and other characteristics. Under optimum conditions his plants showed the greenest foliage and brightest colored flowers.

Turesson attacked the problem from a somewhat different angle. He brought together large numbers of species in a central planting at Akarp, Sweden. He grew both clone transplants and seedlings in a standard environment for many years. His masses of data on growth responses and genetic experiments were very carefully recorded. He found (74) that certain physiological and morphological characters are associated with certain habitat factors. He proposed the classification (75) of plants into the ecological units of coenospecies, ecospecies, ecotypes, and ecophenes. This classification was later adopted by Clausen (12) and has now become the generally accepted classification by workers in the field of ecology. Turesson showed, by his work with species from many different environments, (76), that in many cases the habitat modifications of a species have been given specific status by systematists. Under cultivation some species secured from exposed habitats showed marked morphological changes which were in no way hereditary. In his conclusions (77) he lists climate as the one great influence controlling the distribution of biotypes within species. His work does much to validate the work of Kerner (36) but tends to refute much of the work of Bonnier (7, 8, 9).

In a somewhat general attack on the problem, MacDougal (47) grew sets of 139 plant species at four altitude-climates. He reached the conclusions that the chief movement of species was from colder to warmer regions, that it was easier to establish species from cool regions in warm regions than the reverse, that it was easier to bring mountain species to the seashore than the reverse, and that transferred plants sometimes developed growth characters notably different from those of their native habitat. He also maintained that the habitat in which a plant is found is not always the most favorable for it.

The monumental work started by Hall and carried through to conclusion by Clausen, Keck, and Hiesey has cleared up many of the debatable points on this subject. Hall was of the opinion that every plant was the product of heredity plus environment. In 1922 he started transplant experiments in five different altitude-climates in California. He found

(29) that some plants are inherently capable of a wide range of modifications or adjustments to environment while others have a very narrow range.

The continuation of Hall's work by Clausen, Keck, and Hiesey (12) is, beyond doubt, the outstanding research into the effects of altitude-climates in this country on the growth response of plants. They worked with many families and species of wild plants, native to California, whose intergrading specific forms were found in a number of climatic habitats. Their work covered a period of sixteen years, the latter four of which were spent in gathering extensive statistical data on the growth responses of the families, species, and forms involved. They found that there was a definite combined effect of heredity and environment which, though bringing about changes in growth response, never obscured the identity of the individual. Their work showed that the individual is limited by heredity in its response to the factors of altitude, temperature, light, and moisture. In their work modifications in growth response were found to be rapid but never cumulative or permanent. Detailed studies showed that the species with widest distribution exhibited the greatest number of types. However, the number of types possible within a range as large as California was limited to only six or seven species. They also found that each species, type, and variety had a definite range of tolerance to altitude and the climatic factors connected therewith. Their work pointed out that generally plants could be transferred from a low to a high altitude with less disturbance in equilibrium than in the reverse case. This was in direct contradiction to some of the work of MacDougal.

Several other important investigations have been carried out by various workers interested in the field of the plant in relation to its environment. None of these have been on as grand a scale as the aforementioned but their findings have added considerably to the general picture.

Collins (14), in his work on new-place plantings of maize, grew four maize varieties in Kansas, Texas, and Maryland. There were definite indications of "new place" stimulation in some of his plantings. However, this did prove to be a heritable factor. He concluded that natural selection rather than reaction to environmental conditions brings about adaptation.

Christie and Grau (11), working in Norway, took pure lines of barley and oats and grew them for ten generations in ten different climates. There were varying growth reactions in the various climates and the strains were somewhat modified morphologically. However, when the lines were brought together and grown again at the central station it was shown that no heritable differences had taken place.

Stapledon (70) carried on investigations in Wales for eight years with *Dactylis glomerata* L. He grew plants from seed collected from 143 sources throughout the world. It was his opinion that it is impossible to form a correct conception of the characteristics of a species until all world forms have been collected and grown together under one set of climatic conditions. He concluded that adaptation to a given habitat is genetic in nature.

In 1929 Manglesdorf (48) published his conclusions as to the regional adaptation of maize in Texas. He noted a wide degree of regional adaptation for some varieties while other were confined within a very narrow range of climatic adaptability. He found that there were nine climatic zones of maize production in Texas. Some varieties were adapted to a single zone while others could be grown throughout the ranges of several zones.

That the phenotypical characteristics of growth form, due to response to environment, sometimes determine the survival of a species was well illustrated by Gregor (28). Working with Plantago maritima he found phenotypical expression to be an interaction between environmental and hereditary differences.

Sprague, Farris, Colby, and Curtis (69) grew many varieties of maize from out of state sources at the New Jersey Experiment Station. They found that varieties adapted to New Jersey conditions of soil and climate outyielded out of state varieties almost without exception. Their findings were not in agreement with the results of a study of maize varieties from other states made in Connecticut by Jones and Huntington (33). They concluded that maize may be moved from a less favorable to a more favorable climatic region without loss of productive capacity, and usually with a distinct gain, providing the length of the growing season permits satisfactory maturity. They also stated that most of the loss in productivity, when seed corn is taken from one region to another, is due to less favorable conditions. H. B. Sprague (68), on the basis of New Jersey, Kansas, and Nebraska data differed with their conclusions on the basis that the varieties used were not well adapted to the localities from which they were selected.

Evans (24) grew selections of timothy, graded from early to late, at varying latitudes and altitudes. He found that the season for blooming progressed from south to north. In the north the stems of the later selections grew to as great, or even greater, length than those of the early selections.

A great deal of research has been done on the effect on the plant of climatic factors, both individually and collectively. Unfortunately, much of this work has been done in the laboratory under conditions removed from any natural environment. Lundegårdh (45) found in his extensive investigations with plants and their environment that laboratory experiments with living plants often lead to erroneous conclusions as to the reaction of the plant in nature.

Some work was carried on by Sellick (65) in Rhodesia on the relationship of maize to meteorological factors. He found that there was a close mathematical relationship between all weather factors and that the singling out of any one was difficult. His calculations showed that in Rhodesia rainfall and sunshine were responsible for approximately 40 per cent of the variation in yield in maize.

Bair (5) studied climatic factors in and near maize plantings at Ames, Iowa. He arrived at the conclusion that weekly means of relative humidity and air temperature records of stations within a radius of several miles can be used for conditions within maize fields.

Working under laboratory conditions Lehenbauer (42) showed that the optimum growth temperature for maize seedlings, for a 12 hour period, was 32°C. Growth fell off above 31°C. for any exposure over 12 hours. He found that the minimum temperature for growth was near 12-14°C. but growth continued at these temperatures without decrease in rate for 12 hours. Time of exposure was proven to be the important factor. His records showed a doubling of the rate of growth for each rise of 9° or 10°C.

In his work with growth rates of maize plants MacDougal (46) found that the highest rate of growth occurred between 27°-30°C. Growth ceased when the temperature stood at 30°-35°C. for any extended period of time.

Hanna (30) completed some very careful measurements on the growth of maize in Alberta, Canada. He found that growth had a closer correlation with temperature than with any other single climatic factor.

Loomis (43) found that the growth of maize drops rapidly as the temperature approaches 10°C., which was somewhat lower than the minimum temperatures recorded by Lehenbauer.

A very detailed analysis of the effects of temperature and sunlight on the rate of elongation of the stems of maize and gladiolus was made by McCalla, Weir, and Neatby (52). They showed that 60 to 90 per cent of the variability in growth can be accounted for in temperature and sunlight. The effect of humidity was found to be relatively unimportant in their particular experiment. They found that the effect of sunlight was not as great on maize as on gladiolus. The minimum temperature at which growth would take place in maize was determined as 41.2°F. for daylight and 40.5°F. for darkness.

Collins (15) reported that at San Diego, California *Zea hirta* Bonafous would make satisfactory growth at a lower temperature than any of the types and varieties of maize with which he worked.

A mathematical inquiry into the influence of rainfall on the yield of maize was made by Wolfe (81) who found that alternate periods of dry and wet weather were most favorable for corn production.

Using long term data from Ohio and North Dakota, Davis and Pallesen (20) found little association between total seasonal rainfall and the yield of maize. Their results showed that maize yields are higher when there is a constant rate of increase in precipitation during the growth period.

In some early investigation into the effects of light intensity on plants Lubimenko (44) found that root development was better under high light intensities. He also found that leaf area was greatest at moderate intensities and lessened with extremes.

In research with various plants, Rosé (60) found that root development was best at high light intensities and that as light intensity decreased leaf area increased at the expense of root development. He concluded that the optimum light intensity for a plant was that at which the greatest leaf area developed.

Dorno (22) found that the intensity of light varied greatly with time of day, season of the year, latitude, and altitude. According to him the greatest intensity ever recorded was 1.64 gr. cal./min./sq. cm. or approximately 1,200 foot candles. This value was recorded at 4,420 meters at Mt. Whitney, California, and at 3,683 meters at Teneriffe in the Canary Islands. He also found that at sea level the earth receives only one half the total radiation received at 1,800 meters.

In partly completed work, Gourley (26) found that the area of peach leaves increased by 69 per cent in one variety and by 59 per cent in another through partial shading. Other plants reacted accordingly with the exception of Antirrhinium which showed the opposite reaction. All plants grown in shade increased more in length than those in sunlight. In later work Gourley and Nightingale (27) found that in some cultivated plants the leaf area could be increased by as much as 200 per cent by various degrees of shading. They likewise found that the root systems of all plants were reduced by shading.

Popp (57) studied the growth of soybeans under six different light intensities. The greatest height was attained under 560 foot candles. His results showed that the thickness of stems was directly proportional to the light intensity and was greatest under the highest intensity used, 4,285 foot candles.

Hoffman (31) grew plants in sunlight and shade and made detailed measurements of leaf areas and thicknesses. Her findings showed a greater leaf area in shade but a greater leaf thickness in full sunlight.

In a study on effects of light intensity and light quality, Shirley (66) concluded that leaf area and height attained maxima at light intensities of about 20 per cent of full summer sunlight. He likewise concluded that chlorophyll concentration was highest at the lower intensities.

Working with <u>Lemna minor</u>, Ashby found that growth increased as light intensity was increased up to 700 foot candles. Above 1,400 foot candles light had a destructive effect.

Shirley (67) found, as did Dorno (22), that solar radiation is highly variable in intensity and quality. Shirley states that plants attain maximum height and leaf area in light intensities of 25 to 50 per cent of normal summer sunlight in temperate regions. Light intensities above 50 per cent of full sunlight decrease height and leaf area. Light favors hardening of plants against cold if accompanied by warm days and cold nights. He also states that plants frequently may perform their entire daily photosynthesis in a few morning hours.

After extensive experiments with pea seedlings and oat coleoptiles, Went (80) arrived at the conclusion that the intensity of light is more important for the quantitative expression of growth response than the total light energy applied.

Adams (1) darkened maize plants for varying periods each day and found that plants exposed to the longest action of light had the greatest weight, greatest average height and earliest flowers.

McClelland (53) lengthened daylight with artificial light and found that under lengthened light exposure blossoming was delayed, height increased, and production and size of ears reduced.

Research into the effects of climatic versus edaphic factors has been limited. However, there have been four studies made in the past which have some bearing on this investigation.

It was demonstrated quite conclusively by LeClerc and Yoder (40), in their soil exchange experiments, that the climate is the important factor in determining the physical appearance and chemical composition of the plant and that the soil plays a minor role.

In an experiment conducted in eastern Nebraska, Goodding and Kiesselbach (25) reached the conclusion that no heritable differences of plant characters or grain yields existed in maize varieties planted on upland and on bottom land soils.

The differential yield response due to different seasons was found by Stringfield and Salter (71) to be much greater than that due to fertility levels. They found that changes in climatic factors affect relative varietal performance considerably more than will a quantitative change in available nutrients. It was likewise found that a variety may be relatively better at low than at high fertility levels, or vice versa. The difference found, however, seemed to be largely associated with adaptation to different geographical regions.

In an eleven year experiment Marsden-Jones and Turril (50) used five different types of British soil in which to grow eight wild species of plants. They found that, though species varied in their growth response in the different soils, morphological modifications were relatively insignificant.

Kuleshov (38) planted a large number of varieties of Mexican and Central and South American maize at Sukhum, U.S.S.R. He found a very definite relationship between the number of leaves and the time of maturity. A very close relationship between height and the length of the vegetative period was also noted. He states that in _Zea hirta_ Bona. there are two subtypes, a vigorous one with 19-25 leaves and a less vigorous one with 14-18 leaves. It is quite apparent that he was confusing the Giant and Mountain Types of Melhus (54). He also found vegetative characters more definite than differences in grain structure. While in Mexico he noted that the anthocyanin content of the maize plants became more marked as he progressed southward.

A study of the number of leaves on the main stem of the maize plant and dates of maturity led Kuleshov (37) to the conclusion that the number of leaves might be used as a reliable index of the length of the vegetative period of a given variety. He predicted that with the knowledge of the vegetative period one could judge the suitability for a given region. His findings were based on the growth response of maize from tropical and other regions which were not adapted to the climates of Russia.

In his study on the world's diversity of maize phenotypes Kuleshov (39) observes that maize geneticists have worked almost entirely with "middle-early" varieties and that the extra-early as well as the extra-late varieties have not been used. He states that the extra-early varieties are found on the cold frontiers of the north as well as the south, namely: Canada and Chile. He does not mention the early varieties of Central America but does recognize that his samples are not complete. He concludes with the belief that the extra-late Giant Types of Central America and elsewhere hold great promise for the breeder.

In his experiments on the variability of maize Sayre (64) found that the number of leaves (or number of nodes) is not influenced by fertility treatments. He concluded that this character was one of the best for studying growth response in maize.

Raunkiaer (58) found, in his statistical researches on plant formations, that leaf size was one of the most desirable characters for measurement of plant growth response to climate. He maintained that no two plants units were ever completely alike in their response to conditions.

During studies on leaf area and growth rate in maize, Eisele (23) recorded a decrease in leaf area with number of plants per hill. No appreciable difference in height was found with number of plants per hill. There was, however, a very appreciable decrease in basal area as number of plants per hill increased.

In their studies on yield forecasts Aikman, Eisele, and Bair (2) kept records taken at 10 day intervals over a period of nine years on height, area of stalk, number of leaves, leaf area, time of tasseling, and other growth responses. Records were also kept of climatic factors. They showed that there were critical dates on which correlation between individual growth responses and yield reached their peak. Correlation between basal area and soil moisture was especially important in predicting yield. They found that the maize plant had approximately completed full elongation at tasseling time. They concluded that the multiple correlation stalk area, height, leaf area, and available soil moisture on June 15 gave the best prediction.

Ito and Furukawa (32) found that the number of leaves on maize grown in Manchuria, Japan, Formosa, and North China varied between 11 and 27. There was a correlation coefficient between length of growing season and leaf number of $r = .9379 = 0.0451$. They also found that the higher the altitude at which a variety grew the fewer was the number of its leaves.

The first investigators to surmise that the innumerable varieties and strains of maize of Central America, and in particular, Guatemala, might be classified on an altitude-climate basis were Mangelsdorf and Cameron (49). They found that there was a very close relationship between chromosome knob numbers and other plant characters. However, they did not offer any classification based on their findings. This study is related primarily to the relationship of species of the tribe Maydeae and not to the grouping of maize generally.

It remained for Melhus (54) to arrive at a definite division of the maize varieties of Central America based largely on differences in plant characters found in the varieties growing in different altitude-climates. He concluded that there were four general groups into which all of the maize varieties and strains of Central America could be placed, namely, Mountain, Giant, Early, and Coast. Earlier Melhus, Semeniuk, and Wallin (55) had grouped these varieties of maize as short, mid, and long season.

The high altitude Mountain Type has long been recognized as a distinct form. Bonafous (6) gave it specific status calling a variant of it Zea hirta in 1829. The plants which he described were grown in France from seed sent from California but his description and illustrations leave little doubt in the mind of anyone who has seen this maize in the mountainous regions of Central America or Mexico. In Costa Rica it is distinguished from other types by the name of mais de Olancho (56). Anderson and Cutler (3) refer to it as "Mexican pyramidal". N. N. Kuleshov (38) described Melhus' Mountain Type in his description of Central Mexican types.

Melhus' Giant Type was given specific status by Rojas (59) who named it Zea guatemalensis. Rojas had reference to the "salpor" or flour variant of the Giant Type. Kuleshov (38) calls this maize the Boyaca Type after the state of Boyaca in Colombia where Bukasov (10) found it common. Kuleshov (38) attempts to synchronize the endosperm classifications of Sturtevant (72, 73) with the morphological characters and growth habits of this type as well as others. Kempton's Jala maize (35) answers very closely the description of our Giant Type 138A-46.

Kuleshov (38) mentions another Giant Type distinct from the Boyaca which he calls the Central American type.

The Coast Type of Melhus is referred to as "tropical flints" by Kuleshov (38) and as "Guatemalan tropical flints" by Anderson and Cutler (3). Endosperm characters can hardly be used in separating types because this character is common to more than 90 per cent of the maize of Central America.

Melhus et al. (55) are apparently the only workers who clearly recognized the Early Type.

# MATERIALS ↙'

Nine planting sites were chosen (Plate 1) in varied climates within three altitude ranges in Guatemala. The low altitude Sites 1, 2, 3, and 4, with mean altitude of 67 meters, were located on the Tiquisate Division of the United Fruit Company in the Department of Escuintla. Sites 1 and 2 were within 0.8 kilometers of each other at approximately Lat. N. 14°8'54" and Long. G.W. 91°21'52". These two sites were, by Koppen's classification Awi (63), in a tropical savanna (62) type climate. Sites 3 and 4 were located at a distance of 22.5 kilometers from Sites 1 and 2 in a monsoon rainforest (62) climate of the type Amwi. These two sites were within 200 meters of each other at approximately Lat. N. 14°19'30", Long. G.W. 91°21'52". The mid altitude Sites 5, 6, and 7 were located on the outskirts of Antigua, Department of Sacatepequez, at approximately Lat. N. 14°33'18", Long. W.G. 90°44'48". These three sites were in an upland climate Cwbi on the level floor of the Ponchoy Valley at 1,533 meters. Sites 8 and 9 were both in high altitude-climate Cwb. Site 8 was located at Finca Manzanales, Department of Sacatepequez, at an altitude of 2,286 meters, Lat. N. 14°36'30" and Long. G.W. 90°40'56". Site 9 was three kilometers from Quetzaltenango, in the Department of the same name, at an altitude of 2,499 meters, Lat. N. 14°54'32" and Long. G.W. 90°31'17".

Standard meteorological instruments were used for recording climatological data at the various sites. These included soil-air thermographs, direct-reading rain gauges, evaporation pans, psychrometer,

↙' = work done in guatemala in 1947

PLATE 1

Guatemala and Belize showing location areas of the nine planting sites. 1-4, Low Altitude Sites, 5-7, Mid Altitude Sites, 8 and 9, High Altitude Sites.


COROZAL DIST.
ORANGE WALK DIST.
BELIZE DIST.
EL CAYO DIST.
STANN CREEK DIST.
TOLEDO DIST.
EL PETEN
ALTA VERAPAZ
IZABAL
HUEHUETENANGO
EL QUICHE
BAJA VERAPAZ
ZACAPA
SAN MARCOS
TOTONICAPAN
QUETZALTENANGO
SOLOLA
CHIMALTENANGO
GUATEMALA
EL PROGRESO
CHIQUIMULA
JALAPA
RETALHULEU
SUCHITEPEQUEZ
SAC.
ESCUINTLA
SANTA ROSA
JUTIAPA
9
8
5-7
1-4
SAC. = SACATEPEQUEZ

Table 1. Maize entries used in the study of growth responses at nine sites in Guatemala.

| Type Number | Source | | Alt. in meters | Size of original sample |
|---|---|---|---|---|
| | United States | | | |
| Single crosses | Kanawha, Iowa | | | |
| 153 x WF9 | " " | | 363 (41) | from bulk |
| 205 x 289 | " " | | 363 | " " |
| 205 x 234 | " " | | 363 | " " |
| M14 x WF9 | " " | | 363 | " " |
| M14 x Wis.22 | " " | | 363 | " " |
| | Guatemala | | | |
| Early | Place | Department | | |
| 30A - 46 | Sanarate, | El Progresso | 884 (34) | 10 ears |
| 32A - 46 | Sanarate, | El Progresso | 884 | 10 ears |
| 25 - 44 | San Antonio Huista, | Huehuetenango | 1,200 | 5 ears |
| Coast | | | | |
| 101A - 46 | Santiago, | Atitlan | * | from bulk |
| 13 - 44 | Jutiapa, | Jutiapa | 892 | 10 ears |
| 42A - 46 | Chupadero, | Santa Rosa | 853 | 35 ears |
| 12A - 46 | Chocola, | Suchitepequez | 884 | 50 ears |
| 7A - 46 | Tiquisate, | Suchitepequez | 67 | 1 ear |
| 125A - 46 | San Sebastian, | Retalhulen | 241 | 10 ears |
| 9A - 46 | Patulul, | Suchitepequez | 219 | 50 ears |
| 96A - 46 | Finca La Cuchilla, | Escuintla | 170 | 10 ears |
| Mountain | | | | |
| 1A - 46 | Quetzaltenango, | Quetzaltenango | 2,438 | 35 ears |
| 39A - 46 | Finca Panabajal, | Quiche | 2,200 | 35 ears |
| 106A - 46 | Santa Lucia Utatlan, | Solola | 2,488 | 27 ears |
| 33A - 46 | Tecpan, | Chimaltenango | 2,347 | 10 ears |

Table 1. (Continued)

| Type Number | Source | | Alt. in meters | Size of original sample |
|---|---|---|---|---|
| <u>Giant</u> | | | | |
| 15A - 46 | Finca Barcena, | Guatemala | 1,524 | from bulk |
| 17A - 46 | Ciudad Vieja, | Sacatepequez | 1,520 | 12 lbs. grain |
| 47A - 46 | Finca Fulpan, | Alta Verapaz | 1,828 | 35 ears |
| 138A - 46 | Chimaltenango, | Chimaltenango | 2,245 | 35 ears |
| 14A - 46 | Antigua, | Sacatepequez | 1,533 | 35 ears |

* Coast Type maize seed apparently transported from Patulul area.

and a Weston model 756 light meter. The meteorological equipment needed for the investigation was fortunately limited. The presence of reliable cooperating meteorological stations at or near all of the sites except Site 8 eliminated much of the instrumentation expense and difficulty of securing data.

Twenty entries[1] of maize, from different climatic regions of Guatemala, were selected as indicators of growth response in this investigation. These twenty entries were selected from among collections already tested for type[2] grouping by Dr. I. E. Melhus during his 1946 studies at Antigua, Guatemala. The variants selected included three Early Type, five Coast Type, five Giant Type, and four Mountain Type. Three variants of uncertain grouping were also included. These three variants proved to be of the Coast Type. Five single-crosses, from seed produced at Kanawha, Iowa, were used to provide genetically uniform checks. Table 1 lists the source, number, and sample size of all entries in the experiment. These entries are illustrated in Plates 3-27.

## Description of Maize Entries

The descriptions which follow on subsequent pages, contain the usual data found in botanical descriptions of species, varieties, and

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[1] To avoid circumlocution the name entry will be used for all single-crosses and open pollinated maize variants in this investigation.

[2] The word type will be used throughout this dissertation as designating those groups of variants having similar morphological and growth characteristics.

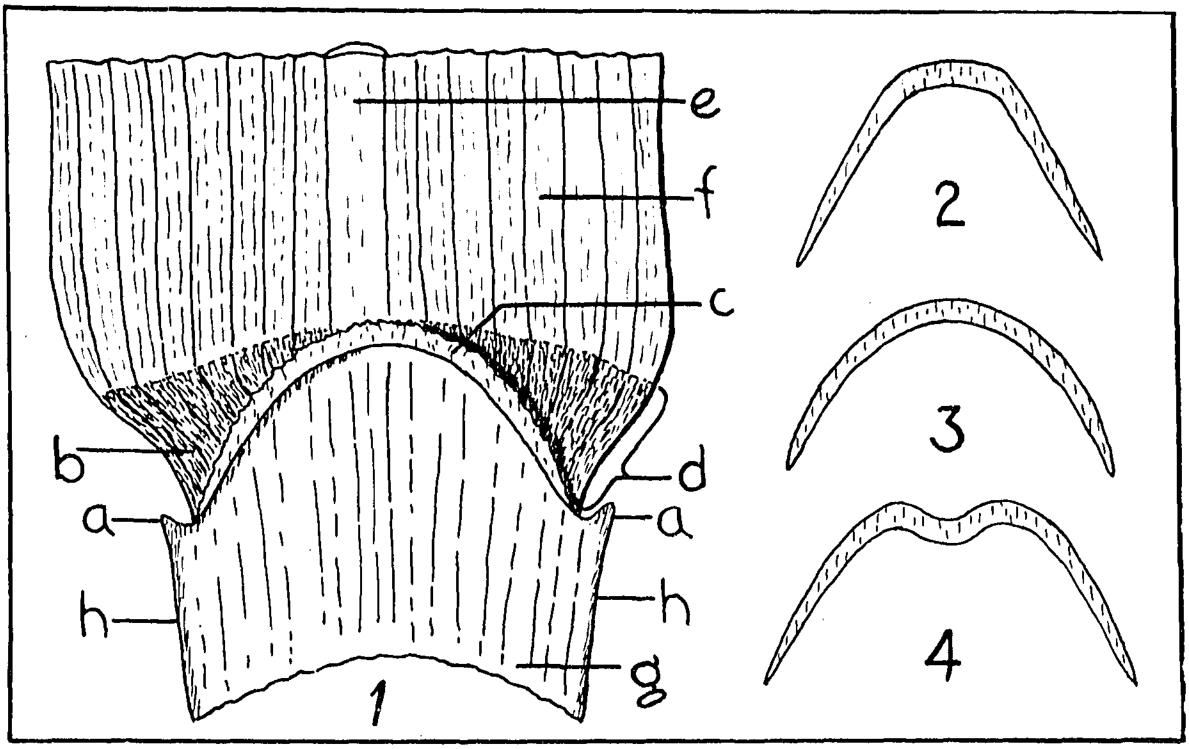


Plate 2 : Terminology, as applied to leaf sheath and adjacent structures, in the accompanying descriptions (pages 26 - 74).

Figure 1. Diagram of region at juncture of leaf blade and sheath, view from inside of latter:

a, a - auricles
b - flange
c - ligule
d - outer edge of flange
e - midrib
f - basal part of blade
g - upper part of sheath
h, h - margins of sheath

Figures 2 - 4. Diagrams of types of ligule-arc:
2 - truncate
3 - obtuse
4 - retuse

PLATE 3

EARLY TYPE

Entry No. 30A-46

Culm sun-red to sun-purple; leaves at anthesis and at maturity divergent-ascending, rather sharply recurved beyond the middle; leaf sheaths clasping culm and somewhat overlapping, green to slightly reddish, the color first appearing in intervein areas, varying from completely glabrous to sparsely villous on the margins; median sheaths slightly longer than corresponding internodes; midrib white; auricles small; flange stramineous to purplish, minutely velutinous, to 2 cm. wide at outer edge; ligule 4 mm. wide, stramineous-hyaline, erose-ciliate, outer surface glabrous; ligule-arc truncate, about 4 cm. broad, 1/3 to 1/4 as high. Ears per plant 1-2 (mean number, 1.5), generally at 7th or 8th node below tassel; husks 9-10, sparsely scabridulous, firm in texture, generally bladeless but occasionally with leafy tips to 25 cm. long; silks pink; husked ears narrow-tapered, truncate at base; cob stiff, white; kernels white, obovate to narrowly obdeltoid, rarely subrotund, sometimes slightly dented, usually with flinty endosperm. Tassel loosely pyramidal, lateral branches 11-22 (mean number, 15.4), spreading at anthesis; median branches about equalling lower ones, which are 29-39 cm. long; about 20 per cent of branches with secondary branches; rachis of branches straight, subterete, velutinous to hispidulous; terminal spike about equalling the longer branches, 1-1.5 cm. in diameter, with 4-6 rows of spikelet pairs. Staminate spikelets 7-8 mm. long, 2-2.3 mm. wide, lanceolate, acute to obtuse, densely hispidulous, varying from completely greenish to pale pinkish at base, with light red spot at base of each glume; pedicels of pedicellate spikelets 3-5 mm. long; anthers yellow to pink, 4-5 mm. long.

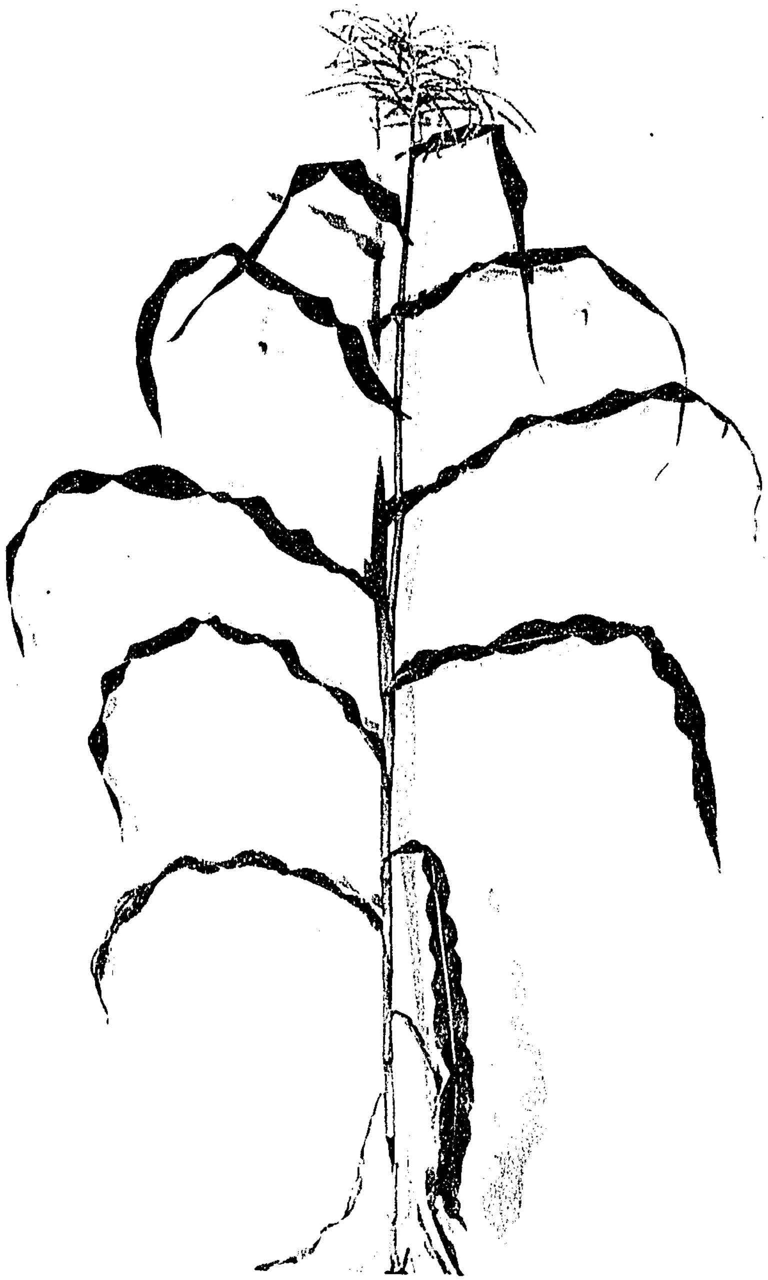

PLATE 4

EARLY TYPE

Entry No. 32A-46

Culm green, occasionally sun-red; leaves at anthesis and maturity divergent-ascending, rather sharply recurved beyond middle; leaf sheaths tightly clasping culm, green to red-tinged, the color first appearing over veins, varying from completely glabrous to sparsely hirsute or sub-lanate on margins; median sheaths equalling to about 3/4 the length of corresponding internodes; midrib white; auricles prominent; flange stramineous to brownish, sparsely to densely pilosulous, to 1.5 cm. wide at outer edge; ligule 4 mm. wide, stramineous-hyaline, erose-ciliate, outer surface minutely pubescent to glabrous; ligule-arc truncate, 3.5-4.5 cm. broad, 1/2 to 2/3 as high as broad. Ears per plant 1-3 (mean number, 1.6), generally at 7th or 8th node below tassel; husks 8-9, scabridulous, thin but firm in texture, outer ones sometimes with blade-like tips to 25 cm. long; silks pale greenish-yellow; husked ears lanceolate-tapering, slightly rounded at base; cob firm, white; kernels yellow, obovate to obdeltoid, rarely slightly dented, usually with flinty endosperm. Tassel pyramidal, lateral branches 11-22 (mean number, 15.9), ascending at anthesis; lower branches (25-33 cm. long) equalling or slightly shorter than median ones; 10-22 per cent of branches with secondary branches; rachis of branches straight, triangular-subterete, scabridulous; terminal spike equalling or slightly shorter than longest branches, 1.3-1.8 cm. in diam., with 4-6 rows of spikelet pairs. Staminate spikelets 8-9 mm. long, 2.5-2.75 mm. wide, elliptical, obtuse to acute, densely to sparsely appressed-hispidulous, intervein areas of lower 2/3 of length reddish to medium red, tips green, veins green; pedicels of pedicellate spikelets 1-2 mm. long; anthers pink to medium red, 4-5.5 mm. long.

PLATE 5

EARLY TYPE

Entry No. 25-44

Culm green; leaves at anthesis and at maturity divergent-ascending, sharply recurved beyond middle; leaf sheaths loosely clasping culm, overlapping at margins, green, sparsely to moderately strigillose on margins, otherwise scabridulous; median sheaths equalling or slightly longer than corresponding internodes; midrib white; auricles small to prominent; flange purplish-brown, sparsely velutinous to glabrous, to 2.5 cm. wide at outer edge; ligule 4 mm. wide, white-hyaline to stramineous-hyaline, erose-ciliate, outer surface glabrous; ligule-arc truncate, 3.5-5 cm. broad, about 1/3 as high as broad. Ears per plant 1-2 (mean number, 1.4), generally at 7th to 9th node below tassel; husks 8-10, hispidulous to strigillose, firm-textured, sometimes bladeless but generally with leaflike blades up to 25 cm. long; silks purplish; husked ears lanceolate-tapering, slightly rounded at base, abruptly pointed at apex; cob stiff, white; kernels white, subrotund to broadly obovate, (undented), usually with flinty endosperm. Tassel cylindric-pyramidal, lateral branches 13-37 (mean number, 24.7), ascending at anthesis; median branches equalling or somewhat longer than lower ones, which are 20-27 cm. long; 20-50 per cent of branches with secondary branches; rachis of branches straight, subterete to subtriangular, velutinous; terminal spike equalling or slightly longer than longest branches, 1.2-1.8 cm. in diam., with 4-6 rows of spikelet pairs. Straminate spikelets 7-8 mm. long, 1.75-2 mm. broad, lanceolate, acute, minutely puberulent, entirely green to greenish except for pale purple line at base of glumes; pedicels of pedicellate spikelets about 5 mm. long; anthers pale yellow to stramineous, 3-4 mm. long.

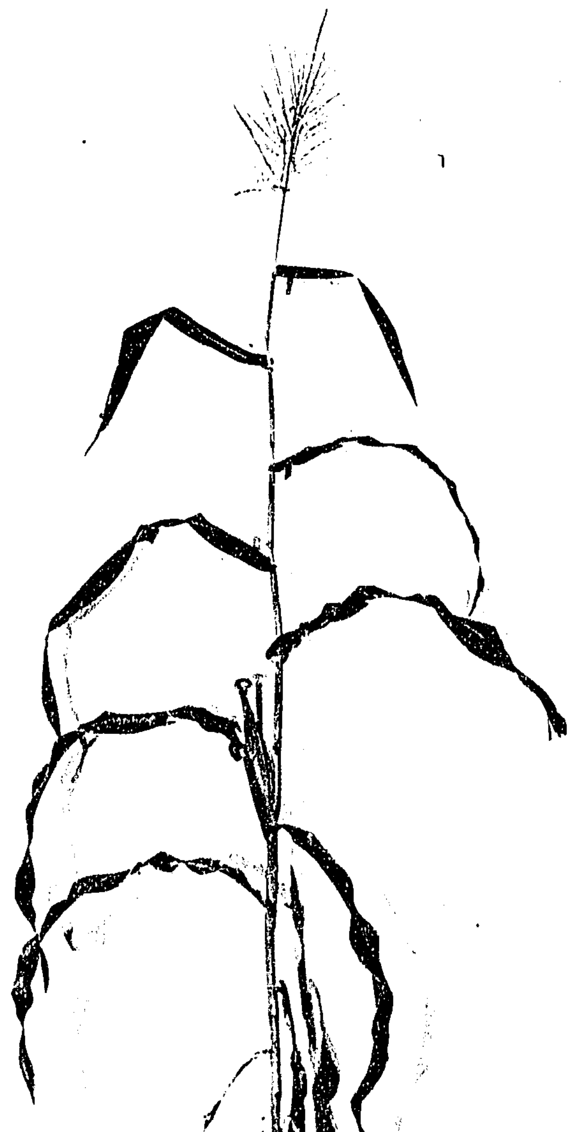

PLATE 6

COAST TYPE

Entry No. 101A-46

Culm green or occasionally with sun-purple; leaves at anthesis and maturity arcuate-ascending, the distal 1/3 sharply recurved; leaf sheaths closely surrounding culm, more or less overlapping at margins, varying from green through medium reddish to almost purple-black, the color appearing first in intervein areas, moderately villous on margins, otherwise sparsely strigillose; median sheath about 7/8 as long as corresponding internodes; midrib white; auricles medium to prominent; flange brownish to purplish, densely velutinous, to 3 cm. wide at outer edge; ligule 5 mm. wide, white-hyaline, erose-ciliate, outer surface glabrous; ligule-arc obtuse, 5-5.5 cm. wide, about 1/3 as high. Ears per plant 1-3 (mean number, 1.6), generally at 9th to 11th node below tassel; husks 14-18, scabridulous, tough in texture, generally bladeless; silks scarlet; husked ears thick cylindrical, gradually pointed, slightly enlarged at butt; cob stiff, whitish with purple glume bases; kernels orange to salmon or pale purple, obdeltoid to obovate-rectangular, slightly dented, usually with flinty endosperm. Tassel ovate-cylindrical to ovate-pyramidal, lateral branches 11-38 (mean number, 24.1), stiffly spreading to arcuate-ascending at anthesis; median branches somewhat longer than lower ones, which are 18-29 cm. long; 25-34 per cent of branches with secondary branches; rachis of branches straight to slightly flexuous, subterete, velutinous; terminal spike about equalling longest branches, 1.5-2 cm. in diameter, with 8-10 rows of spikelet pairs. Staminate spikelets 7-8 mm. long, 2-2.25 mm. wide, elliptical, acutish, minutely appressed-pubescent, entirely dark red-purple; pedicels of pedicellate spikelets 2-4 mm. long; anthers dark purple-red, occasionally almost black, 4-5 mm. long.

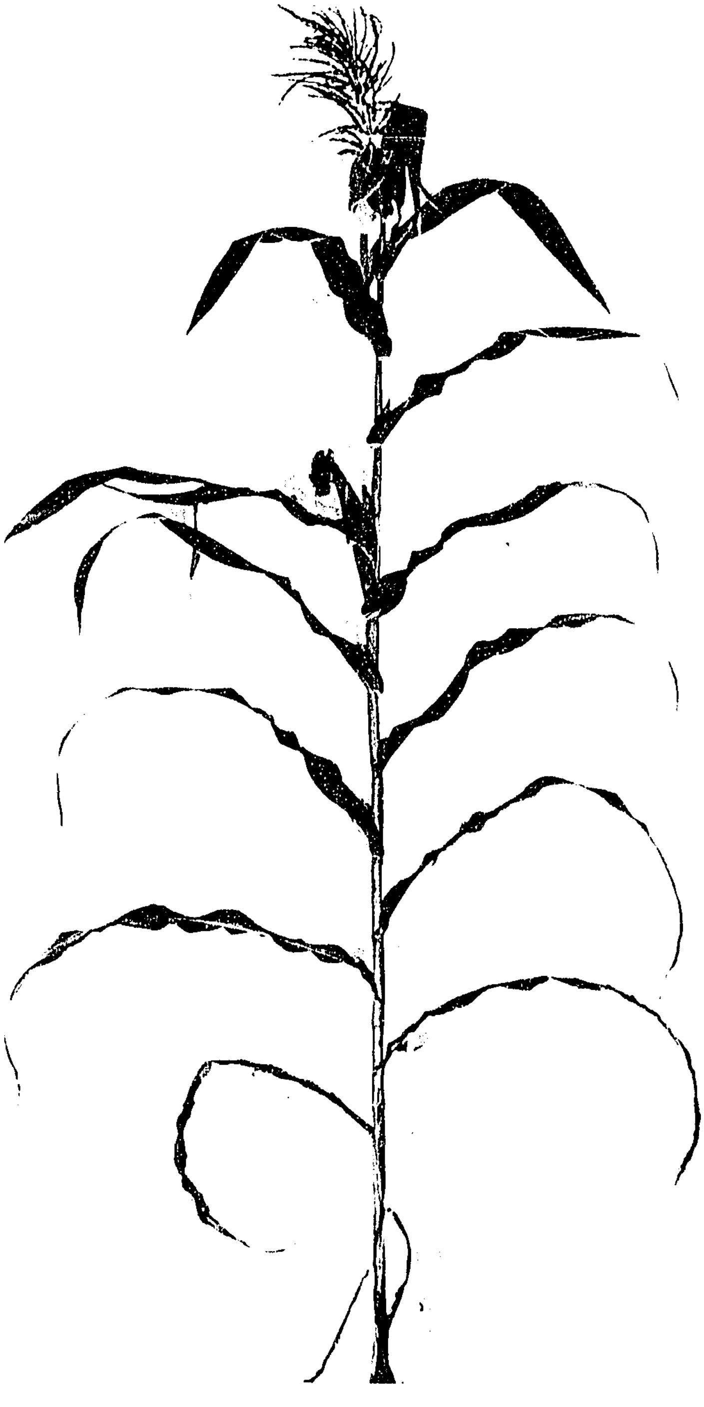

PLATE 7

COAST TYPE

Entry No. 13-44

Culm green to slightly sun-red; leaves at anthesis ascending to spreading, recurved beyond middle, at maturity somewhat drooping; leaf sheaths loosely surrounding culm, green (or rarely dark purple), somewhat glaucous, sparsely villous on margins, otherwise hispidulous; median sheaths equalling to 3/4 as long as corresponding internodes; midrib white; auricles minute to obsolete; flange greenish to brownish, velutinous, to 2.5 cm. wide at outer edge; ligule 4 mm. wide, basal 2/3 greenish-opaque, remainder stramineous-hyaline, erose-ciliate, outer surface glabrous to densely pubescent; ligule-arc truncate, 4.5-5 cm. broad, 1/2 as high. Ears per plant 1-2 (mean number, 1.6), generally at 8th to 9th node below tassel; husks 12-16, scabridulous, tough in texture, generally bladeless but sometimes with blades up to 15 cm. long; silks flesh to pink; husked ears narrowly cylindrical-tapering, somewhat rounded at base; cob stiff, white with reddish glumes; kernels from white through lavendar to bluish-black, broadly obovate to obovate-deltoid, usually with flinty endosperm. Tassel ovate-pyramidal to quadrate, lateral branches 17-26 (mean number, 22.3), stiffly to flexuously spreading or arcuate ascending at anthesis; median branches shorter than lower ones, which are 24-31 cm. long; 39-42 per cent of branches with secondary branches; rachis of branches straight, subterete to triangular, velutinous to scabridulous; terminal spike shorter than longest branches, 1.5-2.2 cm. in diameter, with 6-8 rows of spikelet pairs. Staminate spikelets 9-10 mm. long, 2.5-2.75 mm. wide, elliptical, acutish to obtuse, minutely hirsutulous, green to pale pink with red spot at base of each glume; pedicels of pedicellate spikelets 1-3 mm. long; anthers pale yellow to pink, 4-5 mm. long.

PLATE 8

COAST TYPE

Entry No. 42A-46

Culm varying from green to dark purple; leaves at anthesis and maturity spreading, strongly recurved; leaf sheaths closely surrounding culm, varying from green to purple-black but majority medium purple, the color generally first appearing over veins, heavily strigose-lanate along margin and in collar-like zone immediately below flange, otherwise scabridulous; median sheaths about 2/3 as long as corresponding internodes; midrib white; auricles prominent; flange varying from greenish to brownish, sparsely velutinous, to 2.5 cm. wide at outer edge; ligule 5 mm. wide, stramineous-hyaline or somewhat greenish-opaque at base, erose, outer surface sparsely pubescent; ligule-arc obtuse, about 4 cm. broad, 1/3 to 1/4 as high. Ears per plant 1-2 (mean number, 1.4), generally at 8th or 9th node below tassel; husks 12-15, scabridulous to hirsutulous, firm in texture, generally bladeless; silks pink; husked ears lanceolate-cylindrical, rounded at base, abruptly pointed; cob stiff, pink to pinkish; kernels from white through pinkish to rarely dark purple, broadly obovate, usually slightly dented, usually with flinty endosperm. Tassel irregularly ovate-pyramidal, lateral branches 13-19 (mean number, 15.8), stiffly spreading to arcuate-recurved at anthesis; median branches usually considerably longer than lower ones, which are 25-33 cm. long; about 25 per cent of branches with secondary branches; rachis of branches straight, subterete to compressed, densely velutinous; terminal spike equalling or somewhat longer than longest branches, 1.5-2 cm. in diameter, with 6-8 rows of spikelet pairs. Staminate spikelets 8-9 mm. long, 2.25-2.5 mm. wide, elliptical, acutish, densely pilose-lanate, entirely dull red-purple; pedicels of pedicellate spikelets 4-6 mm. long; anthers pink to red, 4-5 mm. long.

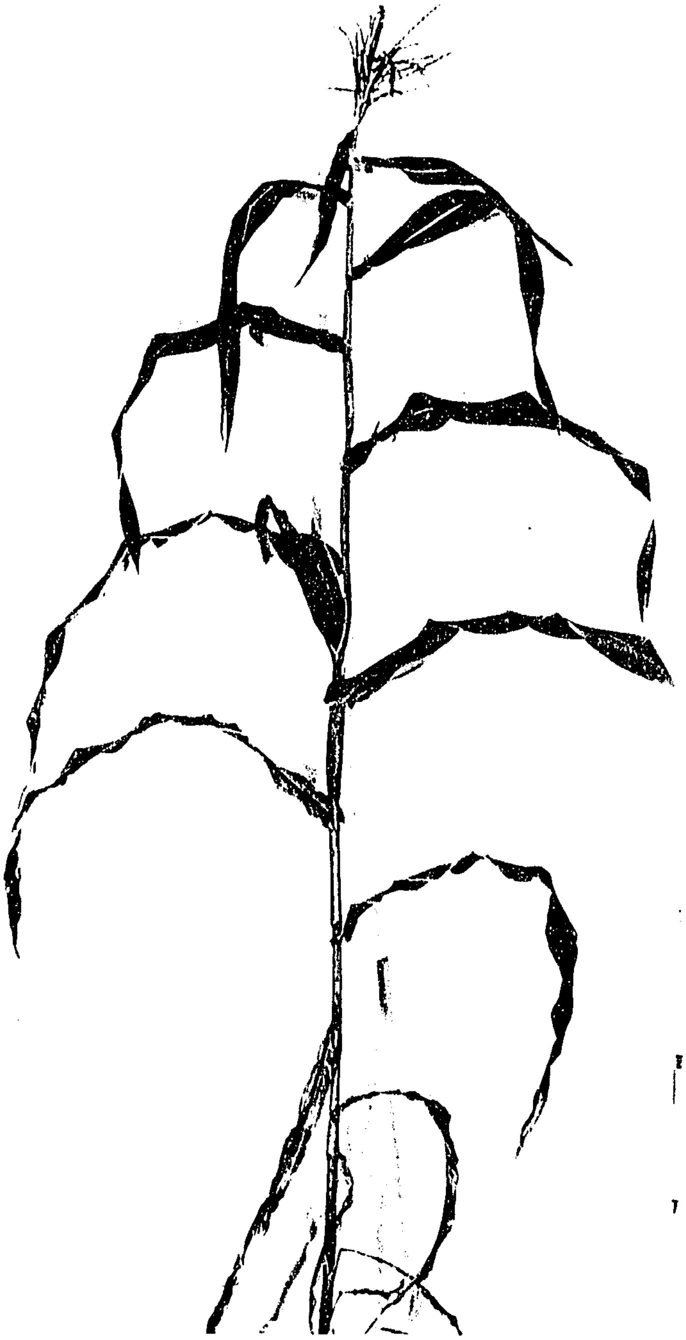

PLATE 9

COAST TYPE

Entry No. 12A-46

Culm green with sun-purple; leaves at anthesis ascending, sharply recurved beyond middle, at maturity arcuate-spreading; leaf sheaths closely surrounding culm, medium purple to dark purple-black (rarely green), the color first appearing in intervein areas, densely pilose to strigose along margin, otherwise scabridulous; median sheaths 2/3 to 3/4 as long as corresponding internodes; midrib white; auricles small to inconspicuous; flange greenish to pale brown with red-purple veins, velutinous to glabrate, to 2 cm. wide at outer edge; ligule 4 mm. wide, basal 1/2 greenish-opaque, remainder stramineous-hyaline to white-hyaline, erose-ciliate, outer surface usually glabrous; ligule-arc truncate, about 6 cm. broad, 3/4 to 5/6 as high. Ears per plant 1-3 (mean number, 1.9), generally at 6th to 8th node below tassel; husks 14-16, scabridulous to hirsutulous, tough in texture, generally bladeless; silk color purple; shape of husked ear cylindrical to lanceolate-cylindrical, gradually or abruptly tapered to apex and rounded to base; cob stiff, dark purple; kernels yellow to pinkish-red with white or yellowish cap, broadly obovate to suborbicular, slightly dented, usually with flinty endosperm. Tassel pyramidal, lateral branches 12-23 (mean number, 17.6), stiff-flexuously spreading to arcuate-ascending at anthesis; median branches generally shorter than lower ones, which are 28-33 cm. long; 30-40 per cent of branches with secondary branches; rachis of branches triangular to subcompressed, velutinous to strigillose; terminal spike shorter than longest branches, 1.7-2.5 cm. in diameter, with 6-8 rows of spikelet pairs. Staminate spikelets 7-8 mm. long, 2-2.25 mm. wide, elliptical, acutish, densely appressed-hispidulous, dull purple-red with green veins; pedicels of pedicellate spikelets 3-5 mm. long; anthers mahogany-red, 4-5 mm. long.

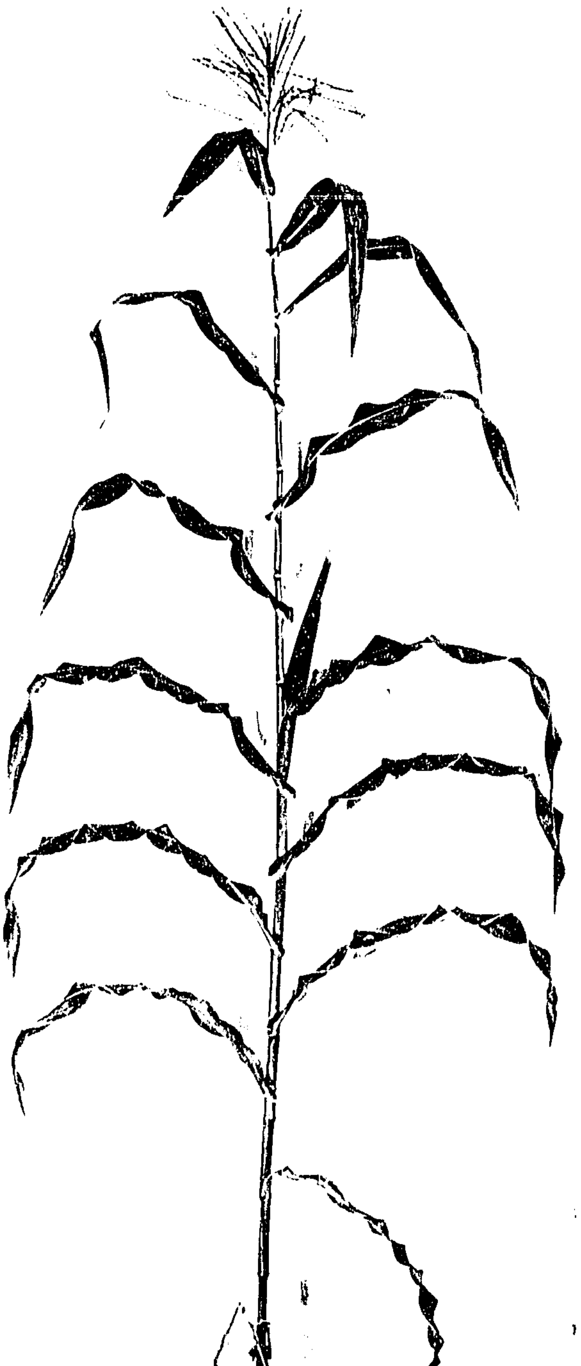

PLATE 10

COAST TYPE

Entry No. 7A-46

Culm usually green, sometimes with sun-red; leaves at anthesis and at maturity strongly ascending, the distal 1/2 strongly recurved; leaf sheaths loosely surrounding culm, varying from green to dull red-purple, densely pilose-lanate along margins, otherwise sparsely scabridulous to glabrous; median sheaths about equalling corresponding internodes; midrib white; auricles prominent; flange brownish, densely velutinous, to 1.5 cm. wide at outer edge; ligule 6 mm. wide, basal 1/3 greenish-opaque, remainder stramineous-hyaline, erose-ciliate, outer surface glabrous; ligule-arc retuse, about 4 cm. broad, 1/3 to 1/4 as high. Ears per plant 1-2 (mean number, 1.2), generally at 8th or 9th node below tassel; husks 13-22, minutely scabridulous to almost glabrous, firm in texture, generally bladeless; silk color greenish or rarely red; shape of husked ears narrowly cylindrical, truncate to rounded at base; cob stiff, white; kernels orange-yellow, obovate to suborbicular (undented), usually with flinty endosperm. Tassel pyramidal to cylindric-pyramidal, lateral branches 9-21 (mean number, 14.2), flexuously spreading to arcuate-ascending at anthesis; median branches equalling or slightly longer than lower ones, which are 19-25 cm. long; 20-25 per cent of branches with secondary branches; rachis of branches flexuous (or rarely straight), subterete, velutinous; terminal spike equalling or slightly shorter than longer branches, 1.5-2 cm. in diameter, with 3-4 rows of spikelet pairs. Staminate spikelets 8-9 mm. long, 2.25-2.5 mm. wide, lanceolate, acute at apices, minutely hispidulous, green to pale pinkish with green veins; pedicels of pedicellate spikelets 3-4 mm. long; anthers pink to medium red, 3-4 mm. long.

PLATE 11

COAST TYPE

Entry No. 125A-46

Culm generally green, but with slight sun-purple; leaves at anthesis and maturity arcuate-spreading to somewhat ascending; leaf sheaths more or less closely surrounding culm, usually green but sometimes reddish, moderately villous to hirsute along margins, otherwise scabridulous; median sheaths 2/3 to 3/4 as long as corresponding internodes; midrib white, auricles prominent; flange green, occasionally with reddish veins, velutinous, to 3 cm. wide at outer edge; ligule 5 mm. wide, stramineous-hyaline, erose-ciliate, outer surface glabrous; ligule-arc truncate to truncate-retuse, 5-6 cm. broad, about 1/3 as high. Ears per plant 1-3 (mean number, 1.7), generally at 8th node below tassel; husks 10-14, scabridulous, firm-textured, the inner very narrow, generally bladeless but sometimes with bladelike tips to 10 cm. long; silks pink to red; husked ears pyramidal-lanceolate, slightly rounded at base, tapered to apex; cob stiff, white; kernels white, varying to pinkish-tinged, obovate to subrotund, slightly to strongly dented, usually with flinty endosperm. Tassel cylindrical to cylindric-pyramidal, lateral branches 17-34 (mean number, 22.6), arcuate-ascending, flexuously spreading or somewhat drooping at anthesis; median branches usually shorter than lower ones, which are 25-34 cm. long; 33-50 per cent of branches with secondary branches; rachis of branches essentially straight, subterete to triangular, velutinous to hirsutulous; terminal spike considerably shorter than longest branches, 1-1.5 cm. in diameter, with 6-8 rows of spikelet pairs. Staminate spikelets 7-8 mm. long, 2-2.25 mm. wide, lanceolate, acute to acutish, minutely appressed-hirsutulous, green to pale pinkish with red spot at base of each glume (rarely completely dark red-purple); pedicels of pedicellate spikelets 3-4 mm. long; anthers yellow to pink, 3-4 mm. long.

## PLATE 12

## COAST TYPE

### Entry No. 9A-46

Culm green, with sun-purple; leaves at anthesis and maturity sharply ascending, recurved beyond middle; leaf sheaths loosely surrounding culm, overlapping at margins, green or red-tinged at base, the color first appearing over veins, sparsely to moderately villous to strigose along margins, otherwise scabridulous to glabrous; median sheaths 2/3 as long as corresponding internodes; midrib white; auricles small to obscure; flange brownish, sparsely velutinous to almost glabrous, to 2 cm. wide at outer edge; ligule 5 mm. wide, basal 1/2 greenish-opaque, remainder stramineous-hyaline, erose, outer surface glabrous; ligule-arc truncate, about 4 cm. broad, slightly more than 1/2 as high. Ears per plant 1-2 (mean number, 1.8), generally at 8th node below tassel; husks 14-18, tough in texture, generally bladeless; silks yellow to greenish, rarely red; husked ears lanceolate-cylindrical, almost truncate at base; cob stiff, white; kernels white or medium yellow, obovate to obdeltoid-rectangular, slightly dented, usually with flinty endosperm. Tassel pyramidal to ovate-pyramidal, lateral branches 14-32 (mean number, 21.3), stiffly ascending to arcuate-ascending at anthesis; median branches usually shorter than lower ones, which are 26-29 cm. long; 40-50 per cent of branches with secondary branches; rachis of branches straight or slightly flexuous, subterete, velutinous; terminal spike equalling or shorter than longest branches, 1-1.8 cm. in diameter, with 6-8 rows of spikelet pairs. Staminate spikelets 9-10 mm. long, 2.25-2.5 mm. wide, lanceolate-elliptical, acute at apices, sparsely and minutely hispidulous to hirsutulous, green to pale pinkish with red line at base of each glume; pedicels of pedicellate spikelets 2.5-3 mm. long; anthers yellow to pink, 3-4 mm. long.

PLATE 13

COAST TYPE

Entry No. 96A-46

Culm green to slight sun-red; leaves at anthesis ascending, the distal half gradually recurved, at maturity widely spreading; leaf sheaths loosely surrounding culm, overlapping at margins, generally green but occasionally pale reddish toward maturity, the color first appearing in intervein areas, sparsely hirsute to hirsutulous on upper part of margin, otherwise glabrous; median sheaths equalling to 2/3 as long as corresponding internodes; midrib white; auricles prominent; flange brownish, densely velutinous, to 2.5 cm. wide at outer edge; ligule 5 mm. wide, basal 1/2 to 3/5 greenish-opaque, the remainder stramineous-hyaline, erose, outer surface pubescent; ligule-arc obtuse, about 5 cm. broad and 3/4 as high. Ears per plant 1-4 (mean number, 1.9), generally at 8th node below tassel; husks 10-15, scabridulous to hirsutulous, firm in texture, sometimes with bladelike tips uo to 15 cm. long; silk color yellow; shape of husked ear lanceolate-cylindrical, subtruncate at base, gradually pointed; cob stiff, white; kernels white, obdeltoid to narrowly obovate, slightly dented, usually with flinty endosperm. Tassel pyramidal, lateral branches 11-24 (mean number, 18.5), flexuously spreading to arcuate-drooping at anthesis; median branches shorter than lower ones, which are 22-34 cm. long; about 33 per cent of branches with secondary branches; rachis of branches straight, subterete to triangular, villosulous to hirsutulous; terminal spike considerably shorter than longer branches, 1.3-2 cm. in diameter, with 6-8 rows of spikelet pairs. Staminate spikelets 9-10 mm. long, 2.5-2.75 mm. wide, lanceolate, acute hirsutulous, pale greenish to green throughout; pedicels of pedicellate spikelets 5-7 mm. long; anthers yellowish-pink to pink, 3-4 mm. long.

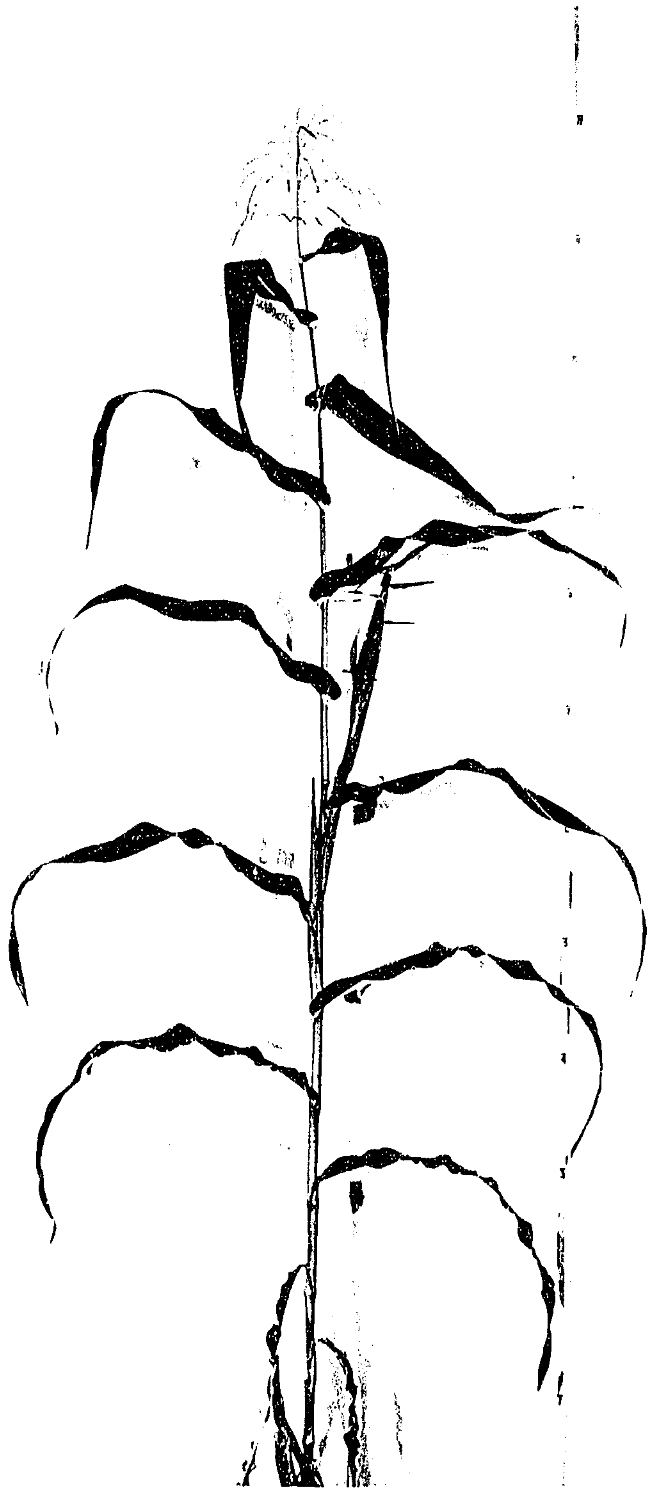

PLATE 14

MOUNTAIN TYPE

Entry No. 1A-46

Culm green to sun-purple; leaves at anthesis wide-spreading, the distal 2/3 sharply recurved, at maturity reflexed for entire length; leaf sheaths loose, compressed, generally overlapping at margins, more or less red-purple for most of length, the color first appearing in intervein areas, moderately villose-lanate over entire surface, the pubescence more dense and floccose along margins; median sheaths 2/3 to 3/4 as long as corresponding internodes; midrib pink or sometimes white; auricles small, inconspicuous; flange pale brown to brown, sparsely velutinous, to 1.5 cm. wide at outer edge; ligule 7 mm. wide, stramineous-hyaline, erose, outer surface glabrous; ligule-arc truncate, about 3 cm. broad and almost as high. Ears per plant seldom more than one, generally at 7th or 8th node below tassel; husks 7-11, almost glabrous, thin textured, generally bladeless but occasionally with blades to 15 cm. long; silks pale red to light maroon; husked ears cylindrical, slightly enlarged at butt, sharply pointed; cob stiff, white; kernels orange-yellow, broadly obovate to obovate-rectangular, undented, usually with flinty endosperm. Tassel irregularly few-branched, lateral branches 13-33 (mean number, 25.8), stiffly spreading to ascending at anthesis; median branches somewhat longer than lower ones, which are 20-29 cm. long; 8-25 per cent of branches with secondary branches; rachis of branches zig-zag-flexuous or rarely almost straight, strongly compressed, velutinous to hirsutulous; terminal spike longer than longest branches, 1.3-1.8 cm. in diameter, with about 8 rows of spikelet pairs. Staminate spikelets 9-10 mm. long, 2.75-3 mm. wide, elliptical, acute to acutish, densely lanate, dull red-purple with green veins; pedicels of pedicellate spikelets 1-3 mm. long; anthers red-purple, 5-6 mm. long.

PLATE 15

MOUNTAIN TYPE

Entry No. 39A-46

Culm green or rarely sun-red; leaves at anthesis wide-spreading, the distal 2/3 sharply recurved, at maturity reflexed for entire length; leaf sheaths loose, compressed, generally overlapping at margins, generally medium purple throughout entire surface, the color first appearing in intervein areas, densely villous to lanate throughout; median sheaths equalling or 7/8 as long as corresponding internodes; midrib white; auricles very minute or lacking; flange greenish-brown, densely velutinous, to 2.5 cm. wide at outer edge; ligule 2.5-3 mm. wide, white-hyaline, erose, outer surface densely pubescent; ligule-arc obtuse, 3-5 cm. wide, 1/2 to 3/4 as high. Ears per plant seldom more than one, generally at 7th node below tassel; husks 9-12, thin in texture, sometimes with blade-tips to 8 cm. long; silks pale red to light maroon; husked ears cylindrical-tapering, slightly thickened at butt; cob stiff, white; kernels dull white to pale tan, obovate or rarely suborbicular, usually with flinty endosperm, occasionally slightly dented. Tassel irregularly pyramidal, lateral branches 4-19 (mean number, 9.5), stiffly spreading to somewhat ascending at anthesis; median branches shorter than lower ones, which are 18-42 cm. long; 12-30 per cent of branches with secondary branches; rachis of branches strongly zig-zag-flexuous, subtriangular, villosulous to hirtellous; terminal spike equalling or somewhat shorter than longest branches, 1.5-2 cm. in diameter, with about 8 rows of spikelet pairs. Staminate spikelets 9-15 mm. long, 2.5-3 mm. wide, elliptical-lanceolate, acute, densely lanate-villous, dull purple-red with green veins; pedicels of pedicellate spikelets 1 mm. or less in length; anthers stramineous to yellow, 4-5 mm. long.

PLATE 16

MOUNTAIN TYPE

Entry No. 106A-46

Culm greenish to sun-purple; leaves at anthesis divergent-ascending, rather sharply reflexed beyond middle, at maturity reflexed for entire length; leaf sheaths loose, compressed, somewhat overlapping at margins, medium purple-red over most of surface, the color first appearing in intervein areas, densely villous over entire surface, villous-lanate along margins; median sheaths equalling or somewhat longer than corresponding internodes; midrib white; auricles very minute; flange brownish, densely velutinous, to 2.5 cm. wide at outer edge; ligule 3 mm. wide, stramineous-hyaline, erose-ciliate, outer surface glabrous; ligule-arc obtuse, 4.5-5 cm. broad, about 4/5 as high. Ears per plant seldom more than one, generally at 5th to 7th node below tassel; husks 9-12, thin in texture, generally bladeless but sometimes with blades to 25 cm. long; silks pale red to light maroon; husked ears cylindric-tapering, slightly enlarged at butt; cob stiff, white; kernels medium to orange-yellow, broadly obovate to obovate-deltoid, sometimes slightly dented, usually with flinty endosperm. Tassel irregularly ovate to pyramidal, lateral branches 7-15 (mean number, 11.1), stiffly spreading to ascending, sometimes somewhat drooping at anthesis; median branches about equalling or a bit longer than lower ones, which are 21-30 cm. long; 9-20 per cent of branches with secondary branches; rachis of branches straight to slightly flexuous, subterete to strongly compressed, hirsutulous to villosulous; terminal spike equalling or considerably shorter than longer branches, 1.5-2 cm. in diameter, with 6-8 rows of spikelet pairs. Staminate spikelets 8-9 mm. long, 2-2.25 mm. wide, elliptical-lanceolate, obtuse to acute, sparsely villous, medium red with green tips and green veins; pedicels of pedicellate spikelets 0.5 mm. or less in length; anthers yellow to pink, 4-5 mm. long.

PLATE 17

MOUNTAIN TYPE

Entry No. 33A-46

Culm green with faint sun-purple tinge; leaves at anthesis divergent-arcuate and at maturity sharply reflexed; leaf sheaths loose, compressed, somewhat overlapping at margins, medium to dark red-purple (rarely green), throughout, the color first appearing on intervein areas, moderately to densely villous over surface, margins floccose, median sheaths essentially equalling corresponding internodes; midrib white or occasionally pinkish-purple; auricles minute to lacking; flange medium-brownish, velutinous, to 3 cm. wide at outer edge; ligule to 4 mm. wide, stramineous-hyaline, erose-ciliate, outer surface minutely pubescent; ligule-arc obtuse, 4-5 cm. broad, about 1/2 as high. Ears per plant seldom more than one, generally at 7th to 9th node below tassel; husks 9-12, thin in texture, generally with bladelike tips to 30 cm. long; silks pale red to light maroon; husked ears cylindric to cylindric-tapering, slightly enlarged at butt; cob stiff, white; kernels white or tinged with pale pink, broadly obdeltoid to obovate, undented, usually with flinty endosperm. Tassel irregularly few-branched, lateral branches 7-17 (mean number, 12.4), stiffly ascending or somewhat arcuate at anthesis; median branches slightly shorter than lower ones, which are 27-36 cm. long; 20-30 per cent of branches with secondary branches; rachis of branches somewhat zig-zag-flexuous, subtriangular, hirsutulous; terminal spike equalling or somewhat exceeding longest branches in length, 1-1.5 cm. in diameter, with 6-8 rows of spikelet pairs. Staminate spikelets 10-11 mm. long, 2.5-2.75 mm. wide, elliptical, obtuse to acutish, densely hirsutulous, basal 3/4 usually dull reddish and tip portion green, veins green; pedicels of pedicellate spikelets 1-2 mm. long; anthers yellow to red-purple, 5-7 mm. long.

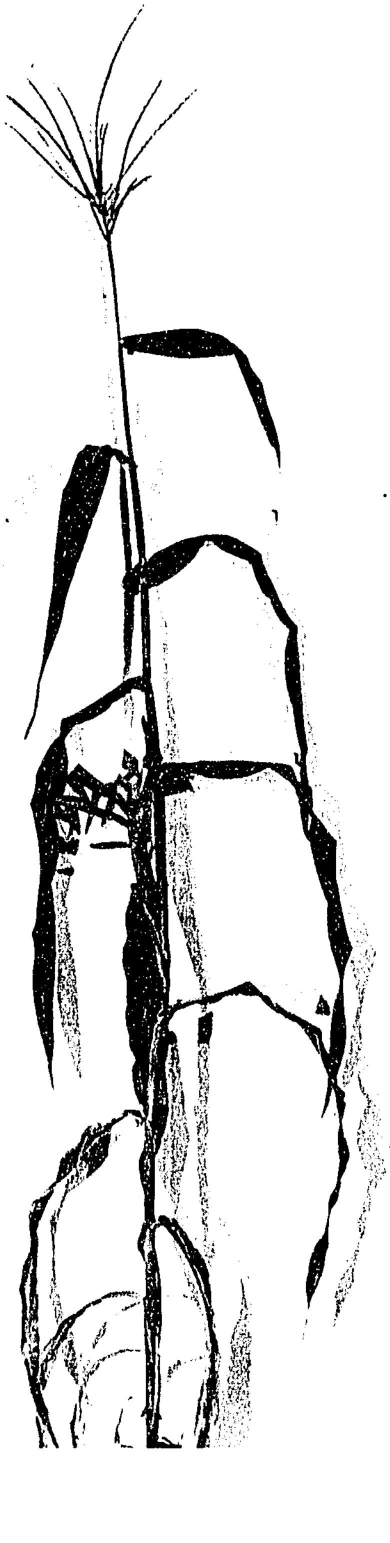

PLATE 18

GIANT TYPE

Entry No. 15A-46

Culm green or with slight sun-purple; leaves at anthesis arcuate-spreading to somewhat drooping, at maturity reflexed for entire length; leaf sheaths loosely to tightly clasping culm, overlapping only at base, green, sparsely pilose along margins and beneath flange, otherwise minutely scabridulous, median sheaths equalling or slightly exceeding corresponding internodes; midrib white; auricles medium-sized to minute or lacking; flange greenish to brownish, subvelutinous to glabrous, to 3 cm. wide at outer edge; ligule 6 mm. wide, basal 1/2 greenish-opaque, remainder stramineous-hyaline, erose, outer surface pubescent; ligule-arc truncate to truncate-retuse, about 5 cm. broad and about 3/4 as high. Ears per plant 1-2 (mean number, 1.02), generally at 7th node below tassel; husks 10-12, large, tough in texture, generally bladeless; silks yellowish-green to pink; husked ears nearly cylindrical, slightly enlarged at butt; cob white, stiff; kernels orange-yellow to yellow, broadly obovate to broadly obdeltoid or suborbicular, slightly dented, usually with flinty endosperm. Tassel pyramidal to cylindric-pyramidal, lateral branches 13-30 (mean number, 18.1), stiffly spreading to slightly drooping at anthesis; median branches equalling or somewhat longer than lower ones, which are 27-35 cm. long; 12-18 per cent of branches with secondary branches; rachis of branches zig-zag-flexuous, subtriangular to compressed, hirsutulous to strigose; terminal spike longer than longest branches, 1.5-2 cm. in diameter, with 6-8 rows of spikelet pairs. Staminate spikelets 7-9 mm. long, 1.75-2 mm. wide, elliptical to elliptical-lanceolate, acute to acutish, sparsely villosulous, stramineous with red-purple blotch at base of each glume; pedicels of pedicellate spikelets 2-4 mm. long; anthers yellow to pale pink, 5-6 mm. long.

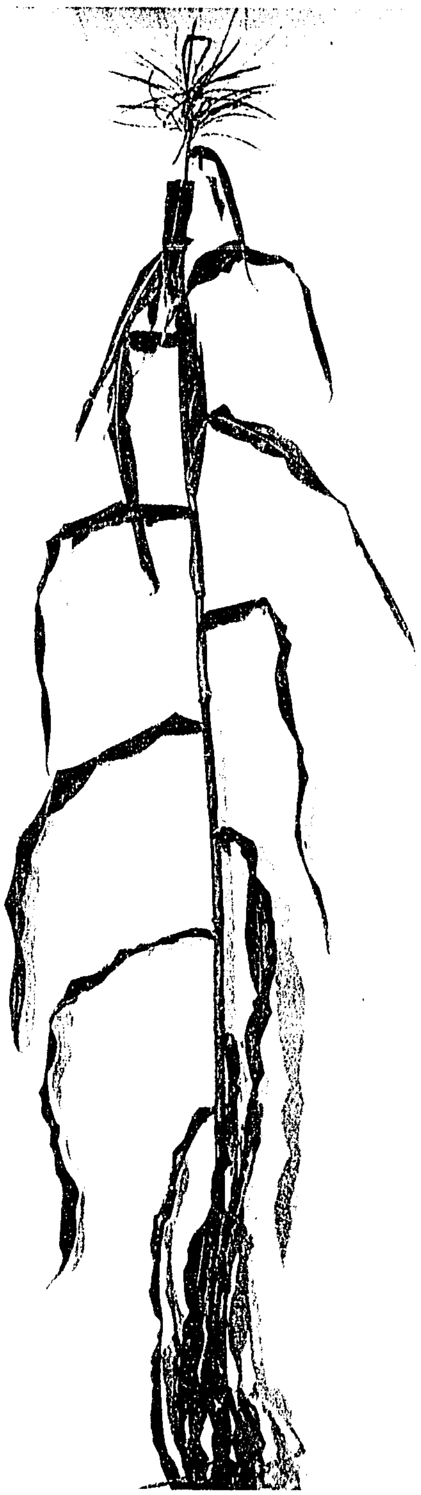

PLATE 19

GIANT TYPE

Entry No. 17A-46

Culm green or slightly sun-purple; leaves at anthesis ascending with distal 1/2 strongly recurved, at maturity essentially the same; leaf sheaths tightly clasping culm, overlapping only below the middle, varying from green to red-purple, the color first appearing in inter-vein areas, densely villous to pilose, particularly along margins and beneath flange; median sheaths longer to considerably longer than corresponding internodes; midrib white; auricles minute to lacking; flange greenish to pale brownish, densely velutinous, to 3.5 cm. wide at outer edge; ligule 3-6 mm. wide, basal 1/2 greenish-opaque, remainder stramineous- to greenish-hyaline, erose-ciliate, outer surface glabrous; ligule-arc truncate, about 4 cm. broad and almost as high. Ears per plant 1-2 (mean number, 1.2), generally at 7th node below tassel; husks 9-12, large, tough in texture, generally bladeless; silks yellowish-green to pink; husked ears nearly cylindrical and somewhat enlarged at butt; cob stiff, white; kernels white, broadly obovate to suborbicular, sometimes slightly dented, usually with flinty endosperm. Tassel ovate-pyramidal to pyramidal, lateral branches 12-29 (mean number, 21.2), spreading to somewhat laxly recurved or strongly drooping at anthesis; median branches equalling or shorter than lower ones, which are 18-28 cm. long; 8-15 per cent of branches with secondary branchlets; rachis of branches straight to slightly flexuous, subterete, velutinous to hirsutulous; terminal spike shorter than longer branches which are 1-1.5 cm. in diameter, with 6-8 rows of spikelet pairs. Staminate spikelets 7-9 mm. long, 1-1.5 mm. wide, lanceolate to narrowly lanceolate, acute to acuminate, densely appressed-hirsutulous, entirely green; pedicels of pedicellate spikelets 3-6 mm. long; anthers pinkish, 4.5-6 mm. long.

PLATE 20

GIANT TYPE

Entry No. 47A-46

Culm green or rarely sun-purple; leaves at anthesis arcuate-divergent, at maturity reflexed for entire length; leaf sheaths tightly clasping culm, overlapping only below middle, green to slightly purplish, the color first appearing in the intervein areas, sparsely pilose to floccose-lanate on margins and below flange, otherwise essentially glabrous; median sheaths about 7/8 as long as corresponding internodes; midrib white; auricles small to inconspicuous; flange stramineous to purple-brown, essentially glabrous, to 2 cm. wide at outer edge; ligule 6 mm. wide, basal 1/2 greenish-opaque, remainder stramineous-hyaline, erose-ciliate, outer surface pubescent; ligule-arc truncate, about 6 cm. broad, 3/4 as wide. Ears per plant 1-2 (mean number, 1.1), generally at 7th node below tassel; husks 11-12, large, thin in texture, sometimes with blade-like tips to 2 cm. long; silks whitish-stramineous; husked ears narrowly cylindrical with gradual taper, abruptly pointed, sub-truncate at base; cob stiff, white; kernels white or yellow (occasionally purple), broadly obovate to suborbicular to subreniform, undented, with flinty endosperm. Tassel pyramidal, lateral branches 10-21 (mean number, 14.2), laxly spreading to arcuate-pendulous at anthesis; median branches somewhat shorter than or equalling lower ones, which are 30-48 cm. long; about 25 per cent of branches with secondary branches; rachis of branches straight, triangular, velutinous to hirsutulous; terminal spike considerably shorter than longest branches, 1.75-2.2 cm. in diameter, with about 8 rows of spikelet pairs. Staminate spikelets 9-10 mm. long, 2-3.25 mm. wide, elliptical-lanceolate, acutish, densely strigose, whitish-stramineous to green or pale pinkish at base, with red line at base of each glume; pedicels to pedicellate spikelets 5-7 mm. long; anthers medium to bright red, 4-5 mm. long.

PLATE 21

GIANT TYPE

Entry No. 138A-46

Culm greenish to sun-red; leaves at anthesis arcuate-divergent to drooping, at maturity reflexed for entire length; leaf sheaths clasping culm only below middle, green, sparsely villous along margins and under base of blade, otherwise scabridulous; median sheaths equalling or somewhat longer than corresponding internodes; midrib white; auricles small to minute; flange green to stramineous, glabrous, to 2.5 cm. wide at outer edge; ligule 6 mm. wide, basal 1/2 greenish-opaque, remainder stramineous-hyaline, erose, outer surface glabrous; ligule-arc obtuse to truncate, about 7 cm. broad, approximately 1/2 as high. Ears per plant 1-2 (mean number, 1.3), generally at 7th node below tassel; husks 9-12, very large, tough in texture, generally bladeless; silks greenish-yellow to pink; husked ears almost cylindrical with enlarged butt; cob stiff, white; kernels whitish to stramineous, obovate to subrectangular, undented, usually with flourlike endosperm; rows of kernels strongly spiralled. Tassel more or less cylindrical to cylindric-pyramidal, lateral branches 14-30 (mean number, 23.2), laxly spreading to recurved and drooping at anthesis; median branches more or less equalling lower ones, which are 20-32 cm. long; 10-18 per cent of branches with secondary branches; rachis of branches straight, velutinous; terminal spike equalling longest branches, 1-1.8 cm. in diameter, with 6-8 rows of spikelet pairs. Staminate spikelets 10-12 mm. long, 2.5-2.75 mm. wide, lanceolate, acute to acuminate, lanate-villous, green to stramineous; pedicels of pedicellate spikelets 4-7 mm. long; anthers yellow, 5-6 mm. long.

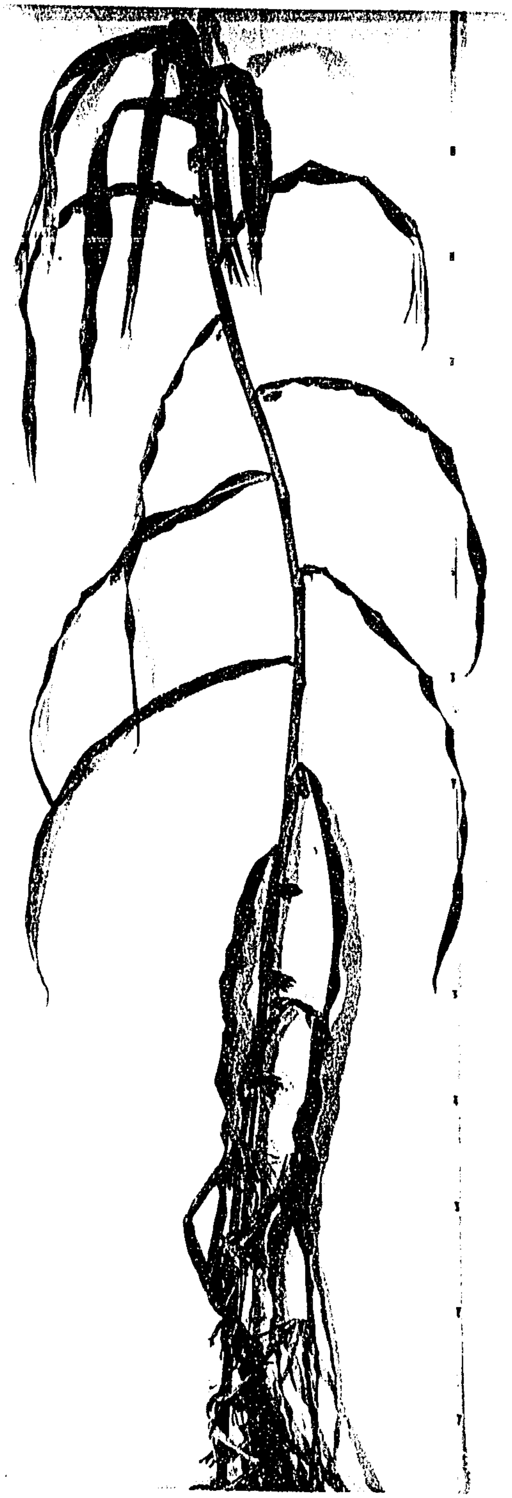

PLATE 22

GIANT TYPE

Entry No. 14A-46

Culm greenish, sometimes sun-purple; leaves at anthesis divergent-spreading, sharply recurved beyond middle, at maturity reflexed for entire length; leaf sheaths clasping culm only below middle, green with sun-purple, the color first appearing on veins, sparsely to densely villous along margins, otherwise scabridulous to hirsutulous; median sheaths equalling or 5/6 as long as corresponding internodes; midrib white or occasionally pink to purple-red; auricles minute to lacking; flange green with purplish or brownish veins, velutinous to glabrate, to 2.5 cm. wide at outer edge; ligule 5 mm. wide, basal 1/3 to 1/2 greenish-opaque, remainder stramineous-hyaline, erose-ciliate, outer surface glabrous; ligule-arc truncate, about 4.5 cm. broad and high. Ears per plant 1-2 (mean number, 1.1), generally at 7th node below tassel; husks 11-15, large, tough in texture, generally bladeless; silks greenish-yellow to pink; husked ears almost cylindrical, with enlarged butt; cob stiff, white; kernels mostly white, but some pale to medium yellow, obovate to suborbicular, undented, usually with flinty endosperm. Tassel cylindrical to cylindrical-quadrate, lateral branches 13-30 (mean number, 19.0), spreading to arcuate-ascending at anthesis; median branches longer than lower ones, which are 25-32 cm. long; 20-25 per cent of branches with secondary branches; rachis of branches straight, subterete to elliptical, puberulent to glabrate; terminal spike somewhat shorter than longest branches, 1-1.5 cm. in diameter, with 6-8 rows of spikelet pairs. Staminate spikelets 7-9 mm. long, 1-1.75 mm. wide, elliptical to elliptical lanceolate, acute to acutish, minutely hispidulous, dark red-purple throughout; pedicels of pedicellate spikelets 2.5-4 mm. long; anthers yellow to medium red, 3.5-5 mm. long.

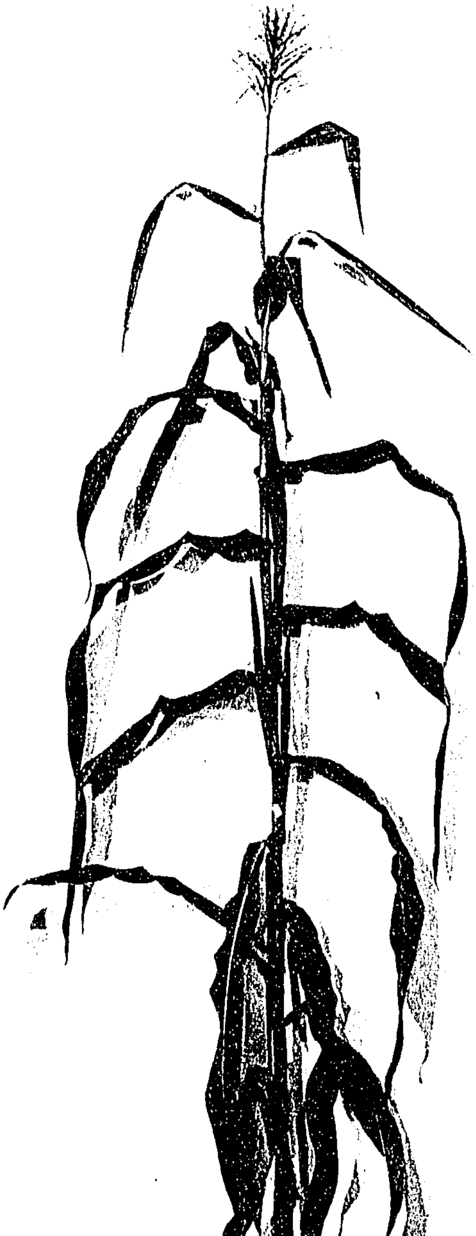

PLATE 23

U. S. SINGLE-CROSS

Entry No. 153xWF9

Culm green with slight sun-red tinge; leaves at anthesis and maturity divergent-ascending, slightly recurved to drooping beyond middle; leaf sheaths loosely surrounding culm, strongly overlapping at margins, entirely green or moderately reddish at base, densely villous at margins, otherwise scabridulous; median sheaths equalling or slightly shorter than corresponding internodes; midrib white; auricles small or obsolete; flange brownish with darker veins, densely velutinous, to 2.5 cm. wide at outer edge; ligule 3-4 mm. wide, stramineous-hyaline, erose-ciliate, outer surface glabrous; ligule-arc obtuse to slightly retuse, 5-6 cm. broad and 1/2 as high. Ears per plant 1-2 (mean number, 1.3), generally at 7th or 8th node below tassel; husks 9-12, loose, scabridulous, medium to firm in texture, generally bladeless; silks greenish-yellow, turning to pink; husked ears cylindrical; cob stiff, red; kernels medium to deep yellow, obovate, strongly dented. Tassel irregularly cylindric-pyramidal, lateral branches 11-19 (mean number, 13.2), ascending to spreading-arcuate at anthesis; median branches equalling or somewhat shorter than lower ones, which are 23-33 cm. long; 15-20 per cent of branches with secondary branches; rachis of branches straight, subterete to triangular, velutinous; terminal spike equalling or longer than longest branches, 2-3 cm. in diameter, with about 8 rows of spikelet pairs. Staminate spikelets 8-9 mm. long, 1.75-2 mm. wide, lanceolate, acute, sparsely hispidulous, stramineous to pale pink with green veins; pedicels of pedicellate spikelets 2.5-4 mm. long; anthers stramineous to pink, 3-4 mm. long.

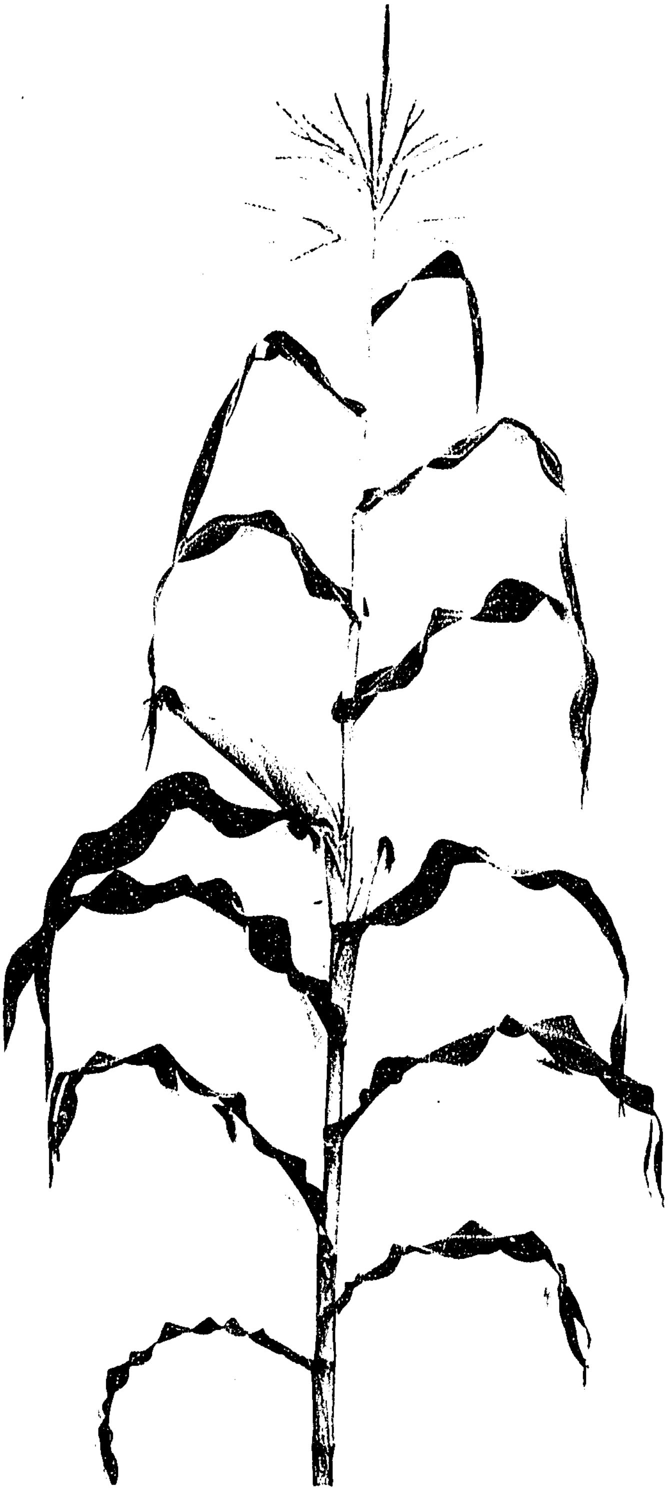

PLATE 24

U. S. SINGLE-CROSS

Entry No. 205x289

Culm green to stramineous; leaves at anthesis and maturity arcuate-ascending, somewhat drooping beyond the middle; leaf sheaths loosely surrounding culm, overlapping at margins, green, strigillose to sparsely hirsute on margins, otherwise minutely scabridulous to glabrous; median sheaths equalling to 3/4 as long as corresponding internodes; midrib white; auricles minute to lacking; flange brown with dark veins, velutinous, to 2.5 cm. wide at outer edge; ligule 2.5-3.5 mm. wide, basal 1/2 greenish-opaque, remainder stramineous-hyaline, erose-ciliate, outer surface glabrous; ligule-arc truncate, about 5.5 cm. broad and 1/2 as high. Ears per plant 1-2 (mean number, 1.5), generally at 6th or 7th node below tassel; husks 8-10, loose, hispidulous to glabrous, thin-textured, generally bladeless; silks greenish-yellow, turning pink; husked ears cylindrical; cob stiff, red; kernels median yellow, obovate to obovate-obdeltoid, slightly dented. Tassel loosely cylindrical, lateral branches 12-18 (mean number, 13.5), arcuate-divergent at anthesis; median branches about equalling lower ones, which are 23-30 cm. long; about 25 per cent of branches with secondary branches; rachis of branches slightly zig-zag-flexuous, subterete, velutinous to glabrous; terminal spike equalling or shorter than longest branches, 1.5-2.5 cm. in diameter, with about 6 rows of spikelet pairs. Staminate spikelets 9-12 mm. long, 2-2.5 mm. wide, lanceolate to lanceolate-elliptical, acute, sparsely to densely hispidulous, stramineous to greenish; pedicels of pedicellate spikelets 2-5 mm. long; anthers yellowish, 4-5 mm. long.

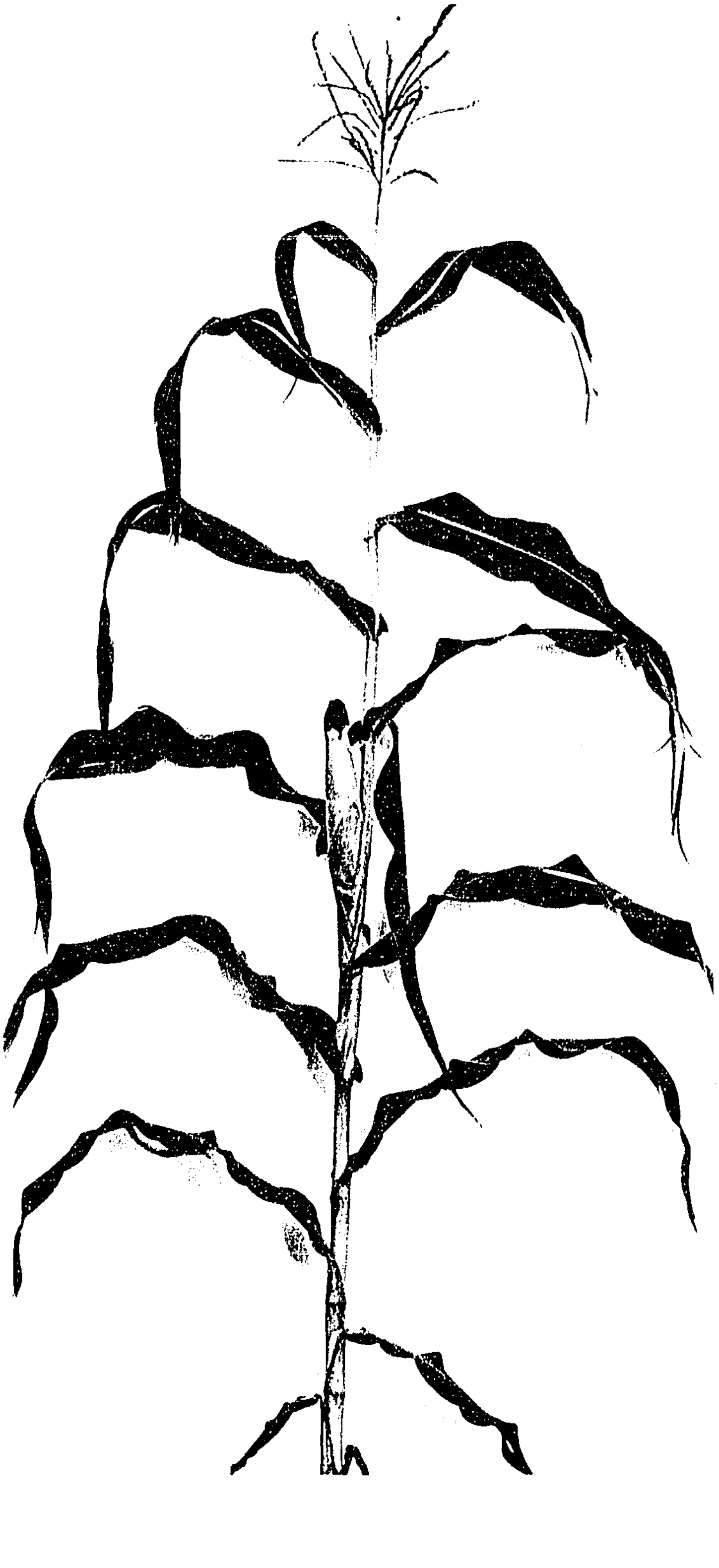

PLATE 25

U. S. SINGLE-CROSS

Entry No. 205x234

Culm green to stramineous; leaves at anthesis and maturity strongly ascending to arcuate-ascending, somewhat recurved beyond the middle; leaf sheaths surrounding culm, overlapping at margins, green, sparsely strigillose to hispid at margins, otherwise scabridulous; median sheaths equalling or slightly exceeding corresponding internodes; midrib white; auricles small or lacking; flange brown, velutinous, to 2 cm. wide at outer edge; ligule 3 mm. wide, stramineous-hyaline or somewhat opaque at base, erose-ciliate, outer surface densely pubescent; ligule-arc obtuse to truncate, about 5.5 cm. broad, 1/2 to 2/3 as high. Ears per plant 1-2 (mean number, 1.1), generally at 7th or 8th node below tassel; husks 8-10, loose, scabridulous, medium to firm in texture, generally bladeless; silks greenish-yellow, turning to pinkish; husked ears cylindrical; cob stiff, red; kernels pale to medium yellow, narrowly obovate-rectangular to obovate, strongly dented. Tassel subpyramidal, lateral branches 12-17 (mean number, 13.5), spreading to somewhat drooping at anthesis; median branches somewhat shorter than lower ones, which are 22-31 cm. long; 25-33 per cent of branches with secondary branches; rachis of branches straight to zig-zag-flexuous, subterete to strongly compressed, densely velutinous; terminal spike equalling or somewhat longer than longest branches, 1.3-1.8 cm. in diameter, with 6-8 rows of spikelet pairs. Staminate spikelets 9-11 mm. long, 1.75-2.25 mm. wide, elliptical to elliptical-lanceolate, acutish, hispidulous to velutinous, varying from green to somewhat pinkish, with pale red splotch at base of each glume; pedicels of pedicellate spikelets 5-10 mm. long; anthers stramineous to pink, 3.5-5 mm. long.

PLATE 26

U. S. SINGLE-CROSS

Entry No. M14xWF9

Culm green to stramineous, with slight sun-red; leaves at anthesis and maturity divergent to arcuate-ascending, the distal 1/3 recurved; leaf sheaths loosely surrounding culm, overlapping at margins, green, sparsely villous to lanate-villous on margins, otherwise minutely scabridulous; median sheaths equalling the corresponding internodes; midrib white to pale pinkish; auricles small to obsolete; flange brownish, velutinous, to 2 cm. wide at outer edge; ligule 3-4 mm. wide, basal 1/2 greenish-opaque, remainder stramineous-hyaline, erose-ciliate, outer surface glabrous; ligule-arc truncate, about 5.5 cm. broad and 1/2 as high. Ears per plant 1-2 (mean number, 1.1), generally at 7th node below tassel; husks 8-10, loose, scabridulous to hirsutulous, firm-textured, generally bladeless; silks greenish-yellow, turning to pink; husked ears cylindrical; cob stiff, red; kernels yellow, oblanceolate-rectangular, slightly to strongly dented. Tassel pyramidal to cylindric-pyramidal, lateral branches 12-17 (mean number, 14.1), widely spreading to somewhat drooping at anthesis; median branches equalling or shorter than lower ones, which are 20-27 cm. long; 16-27 per cent of branches with secondary branches; rachis of branches slightly flexuous, subterete, velutinous to glabrescent; terminal spike exceeding longest branches, 1.5-2 cm. in diameter, with 6-8 rows of spikelet pairs. Staminate spikelets 8-10 mm. long, 2-2.25 mm. wide, lanceolate, acute to subacuminate, minutely hispidulous, green to moderately pink; pedicels of pedicellate spikelets 3-7 mm. long; anthers pale pink, 3-4 mm. long.

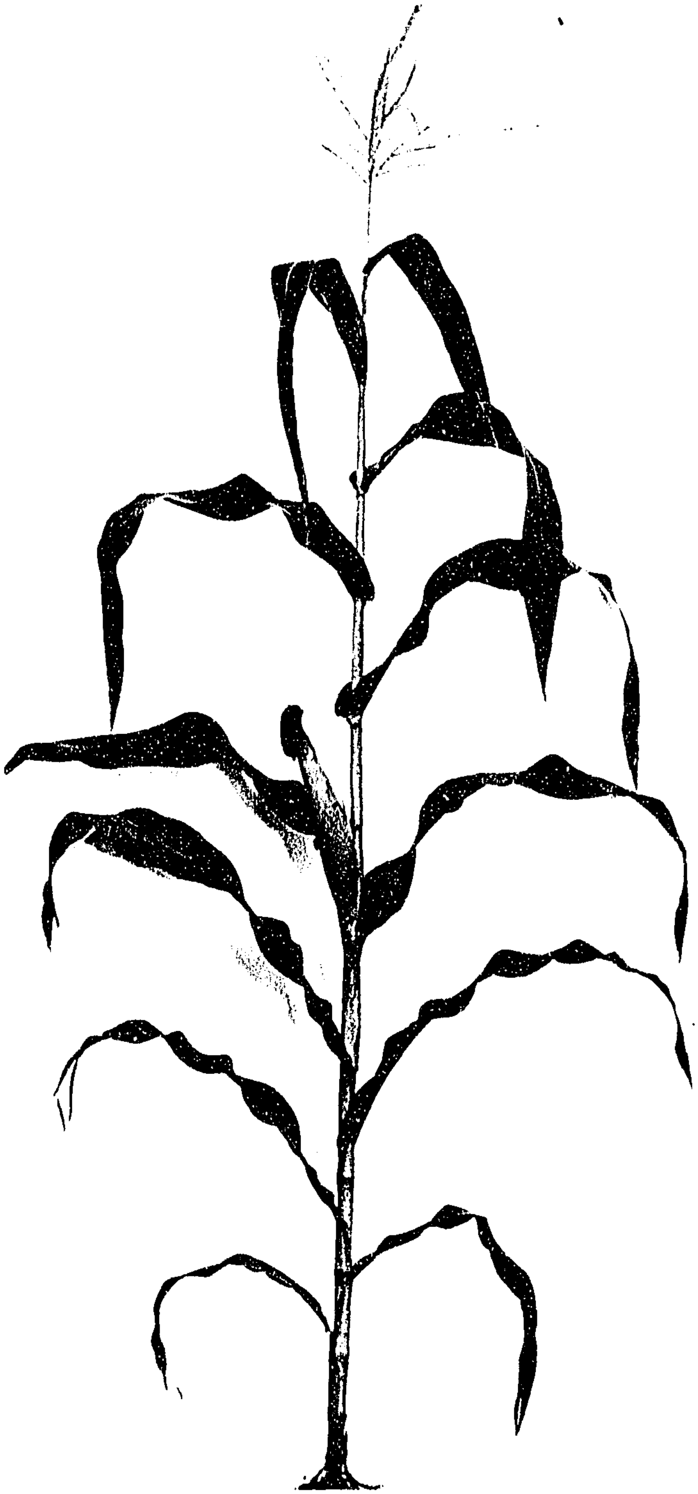

PLATE 27

U. S. SINGLE-CROSS

Entry No. M14xWis.22

Culm green to stramineous at maturity, or with slight sun-red color; leaves at anthesis and maturity spreading to ascending, the distal 1/3 recurved; leaf sheaths loosely clasping culm, overlapping at margin for most of length, green to moderately red, the color first appearing over veins, minutely hispidulous to hispidulous-lanulose along margins, otherwise glabrous; median sheaths equalling or slightly shorter than corresponding internodes; midrib white to rarely pinkish; auricles small to obsolete; flange stramineous to brown, densely velutinous, to 2.5 cm. wide at outer edge; ligule 4-5 mm. wide, stramineous-hyaline, erose-ciliate, outer surface sparsely pubescent; ligule-arc obtuse to truncate, up to 6 cm. broad and 1/2 as high. Ears per plant 1-2 (mean number, 1.4), generally at 7th or 8th node below tassel; husks 8-10, loose, scabridulous to hirsutulous, firm-textured, occasionally with bladelike tips to 5 cm. long; silks greenish-yellow turning to pink; husked ears cylindrical; cob stiff, red; kernels pale to medium yellow, obovate, very slightly dented. Tassel pyramidal, lateral branches 10-17 (mean number, 14.6), spreading to somewhat ascending; median branches equalling or somewhat shorter than lower ones, which are 20-28 cm. long; 20-25 per cent of branches with secondary branches; rachis of branches subterete, puberulous to hirsutulous; terminal spike somewhat shorter than longest branches, 1.5 cm. in diameter, with 4-6 rows of spikelet pairs. Staminate spikelets 8-10 mm. long, 1.5-2 mm. wide, elliptical, acutish at apices, densely strigillose to hirsutulous, green or medium pink with green veins and broad pink to red line at base of each glume; pedicels of pedicellate spikelets 3-5 mm. long; anthers yellow to pale pink, 4-5 mm. long.

PLATE 28

Sample ears of two variants of each of the four types of maize found in Guatemala.

| | | |
|---|---|---|
| 1. | 9A-46 ) | Coast Type |
| 2. | 12A-46 ) | |
| 3. | 47A-46 ) | Giant Type |
| 4. | 138A-46 ) | |
| 5. | 1A-46 ) | Mountain Type |
| 6. | 39A-46 ) | |
| 7. | 32A-46 ) | Early Type |
| 8. | 30A-46 ) | |

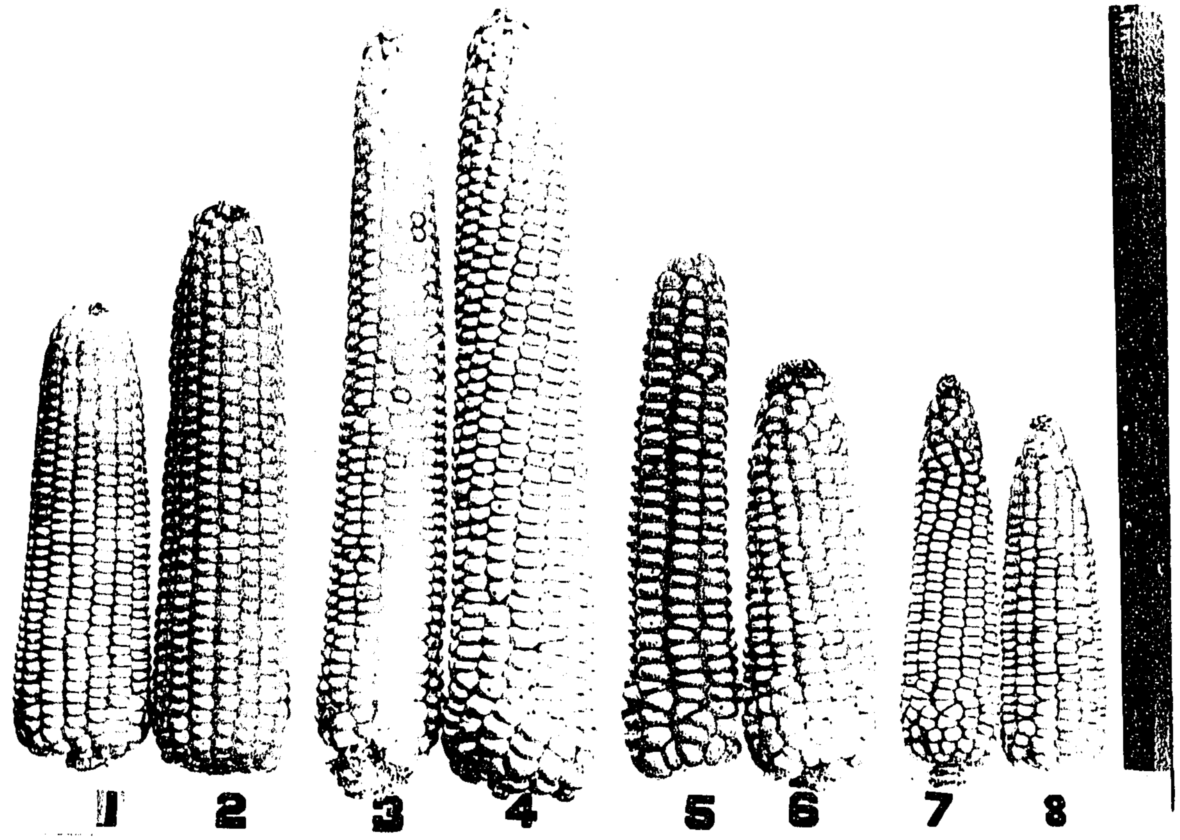
1
2
3
4
5
6
7
8

Table 2. Means and extremes of plant height, culm diameter and number of nodes, recorded in natural environments, to supplement entry descriptions on pages 26 to 74.

| Number | Height in cm. | | | Culm diameter in cm. | | | Number of nodes | | |
|---|---|---|---|---|---|---|---|---|---|
| | Min. | Mean | Max. | Min. | Mean | Max. | Min. | Mean | Max. |
| | | | | U. S. Single Crosses | | | | | |
| 153 x WF9 | 233 | 246.7 | 263 | 2.3 | 2.9 | 3.6 | 17 | 17.9 | 20 |
| 205 x 289 | 257 | 270.3 | 286 | 2.2 | 2.6 | 3.0 | 17 | 17.8 | 18 |
| 205 x 234 | 247 | 261.0 | 278 | 2.4 | 2.9 | 3.4 | 17 | 18.1 | 20 |
| M14 x WF9 | 247 | 253.0 | 262 | 2.4 | 2.9 | 3.2 | 17 | 18.3 | 20 |
| M14 x Wis. 22 | 224 | 246.1 | 265 | 2.8 | 3.1 | 3.4 | 17 | 18.1 | 20 |
| | | | | Early Type | | | | | |
| 30A - 46 | 163 | 199.3 | 236 | 1.3 | 1.9 | 2.5 | 11 | 13.8 | 16 |
| 32A - 46 | 182 | 230.8 | 271 | 1.5 | 1.9 | 2.8 | 13 | 15.3 | 18 |
| 25 - 44 | 187 | 221.5 | 258 | 1.5 | 2.2 | 2.8 | 12 | 14.9 | 18 |
| | | | | Coast Type | | | | | |
| 101A - 46 | 257 | 354.2 | 402 | 2.1 | 3.2 | 3.2 | 18 | 20.3 | 22 |
| 13 - 44 | 281 | 323.8 | 364 | 2.0 | 2.7 | 3.2 | 14 | 18.0 | 20 |
| 42A - 46 | 320 | 364.2 | 434 | 2.3 | 2.8 | 3.5 | 17 | 19.5 | 22 |
| 12A - 46 | 344 | 386.3 | 434 | 2.5 | 3.1 | 3.9 | 18 | 20.0 | 23 |
| 7A - 46 | 260 | 304.3 | 369 | 1.9 | 2.5 | 3.4 | 16 | 18.6 | 22 |
| 125A - 46 | 286 | 333.1 | 372 | 2.0 | 2.8 | 3.5 | 17 | 18.6 | 21 |
| 9A - 46 | 316 | 356.8 | 404 | 2.4 | 3.1 | 3.6 | 18 | 19.8 | 22 |
| 96A - 46 | 300 | 345.7 | 404 | 2.1 | 2.9 | 3.6 | 17 | 19.4 | 22 |
| | | | | Mountain Type | | | | | |
| 1A - 46 | 223 | 235.5 | 247 | 2.0 | 2.2 | 2.5 | 14 | 15.6 | 18 |
| 39A - 46 | 222 | 246.7 | 272 | 2.0 | 2.2 | 2.6 | 14 | 15.8 | 18 |
| 106A - 46 | 226 | 252.1 | 274 | 2.2 | 2.5 | 3.2 | 15 | 17.1 | 20 |
| 33A - 46 | 213 | 231.9 | 246 | 2.3 | 2.4 | 2.6 | 16 | 17.2 | 18 |
| | | | | Giant Type | | | | | |
| 15A - 46 | 303 | 334.1 | 390 | 2.4 | 3.1 | 4.0 | 19 | 21.3 | 25 |
| 17A - 46 | 334 | 372.1 | 414 | 2.3 | 3.2 | 3.6 | 20 | 22.4 | 26 |
| 47A - 46 | 263 | 296.9 | 345 | 2.5 | 3.1 | 4.0 | 19 | 20.2 | 23 |
| 138A - 46 | 344 | 372.2 | 426 | 2.7 | 3.5 | 4.3 | 21 | 24.4 | 27 |
| 14A - 46 | 312 | 342.9 | 401 | 2.4 | 3.0 | 3.7 | 19 | 21.7 | 26 |

Table 3. Means and extremes of median leaf measurements, recorded in natural environments, to supplement entry descriptions on pages 26 to 74.

| Number | Length in cm. | | Width in cm. | | Area in sq. cm. | | |
|---|---|---|---|---|---|---|---|
| | Min. | Max. | Min. | Max. | Min. | Mean | Max. |
| | | | U. S. Single Crosses | | | | |
| 153 x WF9 | 84 | 100 | 10.5 | 14.5 | 690 | 878.2 | 1,125 |
| 205 x 289 | 88 | 103 | 9.2 | 11.8 | 669 | 739.6 | 902 |
| 205 x 234 | 85 | 96 | 10.2 | 13.5 | 701 | 784.5 | 931 |
| M14 x WF9 | 85 | 97 | 10.5 | 13.0 | 669 | 823.8 | 926 |
| M14 x Wis. 22 | 82 | 97 | 12.0 | 15.0 | 815 | 912.4 | 1,057 |
| | | | Early Type | | | | |
| 30A - 46 | 46 | 86 | 7.0 | 10.0 | 289 | 456.7 | 710 |
| 32A - 46 | 57 | 91 | 6.1 | 10.4 | 344 | 498.1 | 722 |
| 25 - 44 | 52 | 89 | 7.0 | 9.8 | 338 | 570.6 | 749 |
| | | | Coast Type | | | | |
| 101A - 46 | 78 | 120 | 8.0 | 11.6 | 604 | 843.3 | 1,122 |
| 13 - 44 | 86 | 122 | 7.8 | 11.3 | 608 | 729.6 | 900 |
| 42A - 46 | 87 | 122 | 8.3 | 11.3 | 616 | 787.3 | 990 |
| 12A - 46 | 92 | 127 | 9.0 | 12.5 | 748 | 816.8 | 990 |
| 7A - 46 | 84 | 113 | 8.0 | 11.0 | 470 | 715.6 | 945 |
| 125A - 46 | 78 | 124 | 8.8 | 12.0 | 527 | 814.2 | 1,035 |
| 9A - 46 | 99 | 128 | 8.2 | 12.6 | 638 | 915.2 | 1,344 |
| 96A - 46 | 92 | 120 | 6.7 | 12.0 | 689 | 846.2 | 1,008 |
| | | | Mountain Type | | | | |
| 1A - 46 | 60 | 82 | 8.0 | 10.4 | 389 | 497.1 | 624 |
| 39A - 46 | 65 | 87 | 8.5 | 13.4 | 453 | 577.4 | 790 |
| 106A - 46 | 72 | 102 | 8.0 | 10.0 | 432 | 598.3 | 765 |
| 33A - 46 | 65 | 89 | 8.5 | 11.0 | 485 | 576.0 | 689 |
| | | | Giant Type | | | | |
| 15A - 46 | 84 | 114 | 9.0 | 14.0 | 660 | 903.4 | 1,153 |
| 17A - 46 | 102 | 128 | 8.5 | 13.0 | 644 | 942.5 | 1,257 |
| 47A - 46 | 80 | 121 | 9.3 | 14.3 | 594 | 902.6 | 1,287 |
| 138A - 46 | 112 | 150 | 8.5 | 14.5 | 768 | 1,032.8 | 1,403 |
| 14A - 46 | 95 | 125 | 9.5 | 13.0 | 709 | 911.5 | 1,125 |

Table 4. Means and extremes of ear measurements, recorded in natural environments, to supplement entry descriptions on pages 26 to 74.

| | Length in cm. | | | Diameter in cm. | | | No. of kernel rows | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Number | Min. | Mean | Max. | Min. | Mean | Max. | Min. | Mean | Max. | Mode |
| | | | | U. S. Single Crosses | | | | | | |
| 153 x WF9 | 19.0 | 24.6 | 28.2 | 5.2 | 5.6 | 6.0 | 16 | 17.8 | 20 | 18 |
| 205 x 289 | 23.0 | 26.9 | 29.3 | 4.2 | 5.1 | 5.5 | 14 | 15.0 | 16 | 14/16 |
| 205 x 234 | 22.0 | 25.1 | 26.4 | 5.0 | 5.7 | 6.1 | 14 | 17.6 | 20 | 18 |
| M14 x WF9 | 20.5 | 23.1 | 26.0 | 5.6 | 5.9 | 6.2 | 18 | 19.0 | 22 | 18 |
| M14 x Wis.22 | 24.0 | 26.0 | 27.3 | 4.3 | 5.0 | 5.5 | 14 | 16.4 | 18 | 16 |
| | | | | Early Type | | | | | | |
| 30A - 46 | 8.6 | 12.2 | 15.4 | 3.1 | 3.9 | 4.2 | 10 | 12.0 | 14 | 12 |
| 32A - 46 | 10.8 | 13.0 | 15.9 | 3.2 | 4.0 | 4.4 | 10 | 12.2 | 16 | 12 |
| 25 - 44 | 12.7 | 13.8 | 17.1 | 3.1 | 4.1 | 4.4 | 10 | 12.0 | 14 | 12 |
| | | | | Coast Type | | | | | | |
| 101A - 46 | 15.9 | 18.9 | 20.3 | 3.8 | 4.2 | 5.1 | 12 | 13.1 | 16 | 12 |
| 13 - 44 | 13.9 | 15.6 | 20.3 | 3.5 | 3.7 | 4.4 | 10 | 11.0 | 12 | 10/12 |
| 42A - 46 | 12.7 | 17.4 | 22.9 | 3.8 | 4.8 | 6.4 | 12 | 14.4 | 16 | 14 |
| 12A - 46 | 14.6 | 18.0 | 23.5 | 4.5 | 4.8 | 5.7 | 12 | 14.5 | 16 | 14 |
| 7A - 46 | 12.1 | 13.8 | 17.8 | 3.8 | 4.5 | 5.1 | 12 | 14.0 | 18 | 14 |
| 125A - 46 | 16.5 | 18.1 | 20.3 | 4.4 | 4.5 | 5.1 | 14 | 16.4 | 20 | 16 |
| 9A - 46 | 14.0 | 17.1 | 21.6 | 4.5 | 4.8 | 5.7 | 12 | 13.9 | 18 | 14 |
| 96A - 46 | 13.3 | 16.8 | 19.7 | 3.8 | 4.0 | 4.4 | 14 | 16.4 | 20 | 16 |
| | | | | Mountain Type | | | | | | |
| 1A - 46 | 12.7 | 14.2 | 18.4 | 3.8 | 4.3 | 5.1 | 12 | 12.6 | 14 | 12 |
| 39A - 46 | 10.2 | 12.3 | 18.4 | 2.5 | 3.5 | 5.1 | 8 | 12.4 | 14 | 12 |
| 106A - 46 | 12.4 | 16.7 | 20.2 | 3.7 | 4.4 | 5.2 | 10 | 12.8 | 14 | 12 |
| 33A - 46 | 13.9 | 16.4 | 21.6 | 3.8 | 4.3 | 5.1 | 8 | 10.2 | 14 | 10 |
| | | | | Giant Type | | | | | | |
| 15A - 46 | 17.2 | 20.5 | 24.1 | 4.5 | 4.9 | 6.0 | 14 | 17.5 | 24 | 16 |
| 17A - 46 | 15.2 | 18.8 | 24.1 | 3.8 | 5.4 | 7.9 | 10 | 15.3 | 22 | 14/16 |
| 47A - 46 | 14.0 | 17.5 | 19.7 | 4.4 | 5.0 | 5.7 | 12 | 14.6 | 18 | 14 |
| 138A - 46 | 20.5 | 25.4 | 38.6 | 4.8 | 6.1 | 8.2 | 12 | 14.9 | 16 | 14 |
| 14A - 46 | 14.0 | 18.7 | 24.1 | 4.1 | 5.3 | 6.4 | 12 | 14.8 | 18 | 14 |

Table 5. Mean kernel measurements to supplement entry descriptions on pages 26 to 74.

| Number | Mean dimensions in mm. Length | Width | Thickness | Weight per 1000 in grams |
|---|---|---|---|---|
| | | U. S. Single Crosses | | |
| 153 x WF9 | 0.91 | 0.89 | 0.46 | 344 |
| 205 x 289 | 0.93 | 0.87 | 0.43 | 266 |
| 205 x 234 | 1.07 | 0.84 | 0.49 | 362 |
| M14 x WF9 | 1.13 | 0.76 | 0.43 | 256 |
| M14 x Wis. 22 | 0.90 | 0.68 | 0.43 | 163 |
| | | Early Type | | |
| 30A - 46 | 0.93 | 0.86 | 0.43 | 223 |
| 32A - 46 | 1.00 | 0.76 | 0.43 | 222 |
| 25 - 44 | 0.98 | 0.82 | 0.37 | 226 |
| | | Coast Type | | |
| 101A - 46 | 0.99 | 0.88 | 0.45 | 286 |
| 13 - 44 | 0.98 | 0.96 | 0.45 | 298 |
| 42A - 46 | 1.03 | 0.94 | 0.43 | 389 |
| 12A - 46 | 0.95 | 0.88 | 0.51 | 344 |
| 7A - 46 | 0.87 | 0.74 | 0.47 | 295 |
| 125A - 46 | 0.97 | 0.87 | 0.42 | 288 |
| 9A - 46 | 0.97 | 0.88 | 0.40 | 303 |
| 96A - 46 | 1.00 | 0.90 | 0.40 | 320 |
| | | Mountain Type | | |
| 1A - 46 | 1.05 | 0.96 | 0.57 | 423 |
| 39A - 46 | 1.05 | 1.02 | 0.51 | 584 |
| 106A - 46 | 1.06 | 0.98 | 0.60 | 422 |
| 33A - 46 | 1.04 | 1.05 | 0.57 | 503 |
| | | Giant Type | | |
| 15A - 46 | 0.88 | 0.86 | 0.48 | 373 |
| 17A - 46 | 0.92 | 0.90 | 0.50 | 405 |
| 47A - 46 | 0.88 | 0.92 | 0.51 | 410 |
| 138A - 46 | 1.18 | 1.04 | 0.57 | 504 |
| 14A - 46 | 1.00 | 0.99 | 0.46 | 438 |

races of flowering plants. In order to permit the arrangement of the general descriptions on a single page, opposite the photograph of each entry, the following numerical and measurement data is arranged in tabular form (Tables 2, 3, 4, and 5) immediately following the descriptions and photographs: means and extremes of plant height, culm diameter, number of nodes, area of median leaf, length of ear, and diameter of ear; means, extremes and modes of number of kernel rows; extremes of length and width of median leaf; means of kernel length, width and thickness; and mean weight per thousand kernels.

Characteristics included in the descriptions are: leaf position at anthesis and at maturity; leaf sheath relation to culm, color, pubescence, and length in relation to subtended node; size, color, and pubescence of auricles and flange1/; ligule width, texture, pubescence, and shape and size of the ligule-arc1/; ear number, position, shape, and texture and number of husks; silk color; cob color; kernel shape, and type of endosperm; tassel shape, number of branches, extent of branching, comparative length of branches and central spike, and diameter of central spike; staminate spikelet size, shape, color, pubescence, and length of pedicels when present; and size and color of anthers.

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1/ See Plate 2 for diagrammatic presentation of the structure and terminology of the region of juncture between leaf-sheath and leaf-blade.

## METHODS

All site plantings of the 25 varieties entering into the investigation were made in 5x5 triple lattice designs (19). Each plot was planted in two rows with fourteen hills in each row. The rows were planted 107 centimeters (42 in.) apart with the plants 45 centimeters (18 in.) apart in the row. Three kernels were planted in each hill and thinned to one plant per hill when the plants were 30 centimeters tall. The complete plot contained 28 plants growing singly. A border of a local, adapted variety was planted on all sides of the triple lattice. Each site planting resulted in a square of 1,024 meters. The rows were laid out true east - west by compass to bring inter-varietal shading to a minimum. Five plants were selected at random for measurement from the 28 plants in each replication.

Dates of planting, emergence, anthesis, and dry-husk maturity were recorded. Data was taken on height, mean daily increase in height, leaf area, basal area, number of nodes, and yield. Notes were taken of insect and disease damage. Date of emergence was recorded as the number of days from emergence to anthesis. The day of anthesis was selected as that on which 75 per cent of the plants of a given variety in the planting were in full state of shedding of pollen. Height was recorded at completion of anthesis as the number of centimeters from the normal ground level to the apex of the staminate inflorescence. The mean daily increase in centimeters, a function of height and anthesis, was taken as the quotient of the height at anthesis by the number of days from emergence to anthesis. Leaf area in square centimeters was calculated from the median leaf. If the number of functional leaves was an even number, the theoretical median plus 0.5 was measured. In determining the leaf area the method employed by Eisele (23) and others was used. This determination was made by multiplying the product of the length and width by 0.75. Basal area of the stalk was taken as the quotient of the mean diameter squared times pi by 4. Measurement for this determination was made approximately 15 centimeters above the normal ground level. The number of nodes at Sites 1 and 2 were taken by count. At all other sites this number was taken as the number of nodes visible above normal ground level plus 4. Yield was recorded in grams as the total air-dry weight of grain produced by the plant. Maturity was fixed at the day from emergence when the outer husks of the ear were dry and devoid of green color.

Five soil samples were taken from each of three depths within each triple lattice. These depths were 15, 45 and 75 centimeters. The five samples from a given depth were thoroughly mixed and a compound sample of one-half kilo was then drawn for analysis. The samples were weighed upon drawing for moisture determination.

With the assistance of cooperators it was possible to collect rather complete climatological data for each site. At the low altitude sites precipitation records were secured from gauges of the Compañia Agricola de Guatemala. Site 1 was planted prior to the rainy season, therefore the precipitation recorded for the early part of the growing period at this site was that supplied by overhead risers of the banana irrigation system. The rate of irrigation by this system was set at two inches

(50.8 mm.) in six hours every six days. All other precipitation records for Sites 1 and 2 were taken from the records of Alotenango Farm (16). For Sites 3 and 4 the direct readings of precipitation for Solola Farm (18) were recorded. At this altitude the relative humidity records of the central recording station at Tiquisate (17, 61) were used. Site checks were made by sling psychrometer. At Antigua (Sites 5, 6 and 7) the records of the Observatorio Nacional (78) of insolation and degree of cloudiness were used. This station is at approximately the same altitude as Antigua and has similar conditions of these two factors. At this altitude it was also necessary, on several occasions, to use data from Finca Retana (13) which is adjacent to the plantings. This data consisted of occasional daily temperatures and rainfall observations taken on direct-reading instruments. At Site 5 three dry-season surface irrigations were calculated as precipitation in mm. from weir measurements. All data for high altitude Site 9 was secured from the records of the Observatorio de Occidente (21) because of the proximity of this station to the planting site. Records of the length of day from sunrise to sunset were furnished by the Director of the Observatorio Nacional (79). All other observations for each of the nine sites were made by the writer. Vapor pressure and temperature of dew point were calculated (51).

# SITE FACTORS

## Climatic Factors

### Atmospheric temperature

Temperature was considered the most important factor controlling the growth responses of the maize planted in the different altitude-climates in Guatemala. Altitude, in turn, was the principal factor controlling temperature at the various sites. The seasonal temperature effects were barely discernable at the low altitude sites, apparent at the mid altitude sites, and limiting at the high altitude sites.

Plates 29, 30, and 31 clearly illustrate the daily trends of the means and extremes of atmospheric temperatures during the growth periods at the various sites and altitudes. Tables 6 and 7 give the means, extremes and variations of atmospheric temperature for the growth period of each of the site plantings.

At low altitude (67 meters) the difference between the mean atmospheric temperatures of the growth periods of the four site plantings varied by only 1.5°C. The maximum temperature recorded at low altitude was 36.7°C.; the minimum recorded was 17.8°C. The greatest variation between extreme maximum and extreme minimum temperatures at low altitude was 18.4°C., recorded at Site 1 for the greatest low altitude growth period of 113 days.

The mid altitude sites, being located in the deep Ponchoy Valley

Table 6 Summary of climatic factors recorded, from the day of planting to the maturity of the earliest maturing entry, for each of the nine sites in Guatemala.

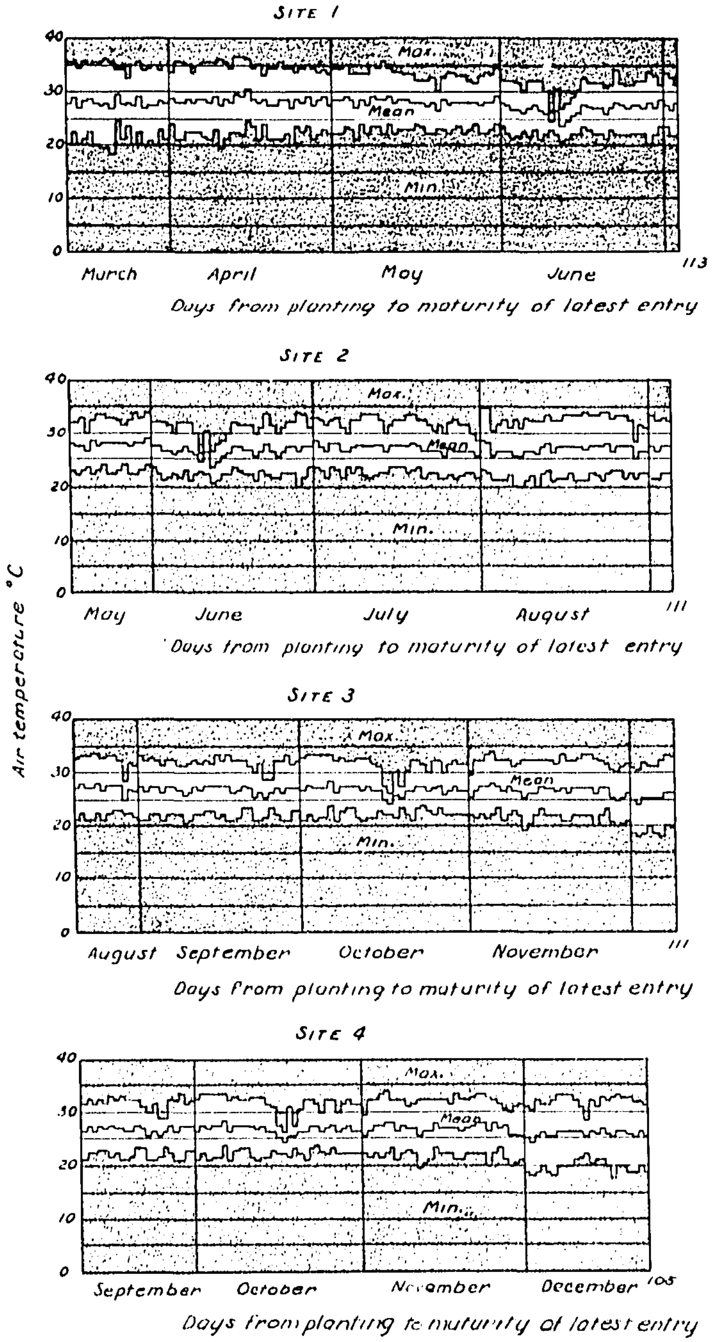
| Site number | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| Planting date 1947 | | March 13 | May 17 | August 20 | Sept. 10 | March 20 | May 20 | August 4 | May 30 | May 19 |
| Altitude | meters | 67.00 | 67.00 | 67.00 | 67.00 | 1,533.00 | 1,533.00 | 1,533.00 | 2,286.00 | 2,497.00 |
| " | feet | 220.00 | 200.00 | 200.00 | 200.00 | 5,029.00 | 5,029.00 | 5,029.00 | 7,500.00 | 8,300.00 |
| Growth period of earliest maturing entry | days | 69.00 | 75.00 | 69.00 | 67.00 | 113.00 | 119.00 | 118.00 | 161.00 | 166.00 |
| Air temperature, mean | °C. | 28.22 | 26.94 | 26.96 | 26.94 | 18.06 | 18.67 | 17.48 | ---- | 16.45 |
| " " , extreme max. | " | 36.70 | 33.90 | 33.90 | 33.90 | 26.00 | 26.00 | 26.00 | ---- | 28.00 |
| " " , extreme min. | " | 18.30 | 20.00 | 19.40 | 19.40 | 9.00 | 11.00 | 10.00 | ---- | 6.00 |
| " " , variation | " | 18.40 | 13.90 | 14.50 | 14.50 | 17.00 | 15.00 | 16.00 | ---- | 22.00 |
| Soil temperature at 30 cm., mean | " | 30.56 | 31.52 | 28.19 | 27.96 | 22.67 | 22.73 | 20.83 | 18.10 | 16.88 |
| " " " " " , extreme max. | " | 31.40 | 32.60 | 29.80 | 29.80 | 23.50 | 23.50 | 23.50 | 20.40 | 19.00 |
| " " " " " , extreme min. | " | 28.80 | 30.70 | 26.10 | 26.10 | 19.40 | 18.90 | 17.80 | 14.90 | 16.40 |
| " " " " " , variation | " | 2.60 | 1.90 | 3.70 | 3.70 | 4.10 | 5.40 | 5.70 | 5.60 | 2.60 |
| Precipitation, total | mm. | 675.64 | 651.42 | 1,148.75 | 966.29 | 581.93 | 651.75 | 460.74 | 825.00 | 662.50 |
| " , duration | hrs. | ---- | ---- | ---- | ---- | 177.20 | 323.30 | 228.00 | ---- | 181.73 |
| " , intensity | mm./hr. | ---- | ---- | ---- | ---- | 3.28 | 2.02 | 2.02 | ---- | 3.64 |
| Relative humidity, mean | % | 78.59 | 70.15 | 88.15 | 88.40 | 85.60 | 87.20 | 88.90 | ---- | 87.10 |
| " " , extreme min. | " | 40.00 | 58.50 | 58.50 | 58.50 | 21.50 | 38.00 | 25.50 | ---- | 50.00 |
| Vapor pressure, mean | mm. | 28.68 | 26.58 | 26.60 | 26.58 | 15.54 | 16.07 | 14.90 | ---- | 13.98 |
| " " , extreme max. | " | 46.30 | 39.67 | 39.67 | 39.67 | 25.21 | 25.21 | 25.21 | ---- | 28.35 |
| " " , extreme min. | " | 15.77 | 17.53 | 16.89 | 16.89 | 8.61 | 9.84 | 9.21 | ---- | 7.01 |
| " " deficit, extreme max. | " | 20.74 | 15.92 | 15.92 | 15.92 | 17.00 | 14.16 | 16.37 | ---- | 14.19 |
| " " " , extreme min. | " | 0.49 | 0.64 | 0.57 | 0.57 | 3.24 | 0.31 | 3.61 | ---- | 0.24 |
| Dew point, mean | °C. | 24.44 | 21.11 | 23.89 | 23.89 | 15.00 | 16.11 | 15.56 | ---- | 14.44 |
| " " , extreme max. | " | 25.56 | 25.00 | 25.00 | 25.00 | 8.33 | 11.11 | 9.44 | ---- | 16.67 |
| " " , extreme min. | " | 17.78 | 19.44 | 18.89 | 18.89 | 2.22 | 10.56 | 2.78 | ---- | 5.56 |
| Evaporation, total | mm. | ---- | ---- | ---- | ---- | 367.60 | 259.40 | 299.70 | ---- | 1,736.60 |
| " , mean | " | ---- | ---- | ---- | ---- | 3.25 | 2.18 | 2.54 | ---- | 7.10 |
| " , extreme max. | " | ---- | ---- | ---- | ---- | 6.60 | 8.20 | 8.20 | ---- | 8.30 |
| " , extreme min. | " | ---- | ---- | ---- | ---- | 0.80 | 0.80 | 0.80 | ---- | 2.00 |
| Precipitation - evaporation ratio | | ---- | ---- | ---- | ---- | 1.58 | 2.51 | 1.54 | ---- | 0.38 |
| Light intensity, mean max. in full sun | f.c. | 6,922.29 | 8,698.33 | 9,583.90 | 8,949.58 | 9,368.59 | 10,260.71 | 10,648.35 | 10,775.60 | 10,782.20 |
| " " , extreme max. " " | " | 7,904.00 | 9,240.00 | 10,160.00 | 10,160.00 | 10,620.00 | 10,800.00 | 10,920.00 | 11,160.00 | 11,700.00 |
| Insolation, total | hrs. | 506.05 | 377.75 | 600.20 | 478.00 | 724.40 | 682.20 | 717.20 | ---- | 1,012.60 |
| " , mean | " | 7.33 | 4.97 | 8.70 | 7.13 | 6.41 | 5.73 | 6.08 | ---- | 6.10 |
| " , extreme max. | " | 11.00 | 11.50 | 11.00 | 11.00 | 11.00 | 11.00 | 11.70 | ---- | 9.35 |
| Cloudiness, mean | % | 52.00 | 64.00 | 53.00 | 52.00 | 66.19 | 75.38 | 69.32 | ---- | 74.57 |

Table 7 Summary of climatic factors recorded, from the day of planting to the maturity of the latest maturing entry, for each of the nine sites in Guatemala.

| Site number | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| Planting date 1947 | | March 13 | May 17 | August 20 | Sept. 10 | March 20 | May 20 | August 4 | May 30 | May 19 |
| Altitude | meters | 67.00 | 67.00 | 67.00 | 67.00 | 1,533.00 | 1,533.00 | 1,533.00 | 2,286.00 | 2,499.00 |
| " | feet | 220.00 | 220.00 | 220.00 | 220.00 | 5,029.00 | 5,029.00 | 5,029.00 | 7,500.00 | 8,300.00 |
| Growth period of latest maturing entry | days | 113.00 | 111.00 | 110.00 | 105.00 | 190.00 | 185.00 | 187.00 | ---- | 227.00 |
| Air temperature, mean | °C. | 27.70 | 26.30 | 26.20 | 26.70 | 18.00 | 18.20 | 17.10 | ---- | 16.40 |
| " " , extreme max. | " | 36.70 | 33.90 | 33.90 | 33.90 | 26.00 | 26.00 | 26.00 | ---- | 28.00 |
| " " , extreme min. | " | 18.30 | 19.40 | 18.30 | 17.80 | 9.00 | 11.00 | 7.00 | ---- | - 1.70 |
| " " , variation | " | 18.40 | 14.50 | 15.60 | 16.10 | 17.00 | 15.00 | 19.00 | ---- | 29.70 |
| Soil temperature at 30 cm., mean | " | 30.40 | 31.90 | 28.40 | 28.00 | 22.60 | 21.70 | 20.10 | ---- | 17.20 |
| " " " " " , extreme max. | " | 31.40 | 32.60 | 29.80 | 29.80 | 23.50 | 23.50 | 23.50 | ---- | 19.20 |
| " " " " " , extreme min. | " | 28.80 | 30.70 | 26.10 | 26.10 | 19.40 | 18.90 | 17.80 | ---- | 13.80 |
| " " " " " , variation | " | 2.60 | 1.90 | 3.70 | 3.70 | 4.10 | 4.60 | 5.70 | ---- | 5.40 |
| Precipitation, total | mm. | 1,076.87 | 831.76 | 1,480.83 | 1,015.05 | 850.42 | 879.17 | 466.81 | ---- | 701.20 |
| " , duration | hrs. | ---- | ---- | ---- | ---- | 349.50 | 416.90 | 427.20 | ---- | 223.01 |
| " , intensity | mm./hr. | ---- | ---- | ---- | ---- | 2.43 | 2.11 | 1.09 | ---- | 3.14 |
| Relative humidity, mean | % | 81.99 | 77.34 | 85.43 | 85.63 | 87.29 | 88.43 | 89.16 | ---- | 87.20 |
| " " , extreme min. | " | 40.00 | 58.50 | 58.50 | 58.50 | 21.50 | 38.00 | 23.50 | ---- | 50.10 |
| Vapor pressure, mean | mm. | 27.85 | 25.66 | 25.51 | 26.27 | 15.11 | 15.64 | 14.55 | ---- | 13.98 |
| " " , extreme max. | " | 46.30 | 39.67 | 39.67 | 39.67 | 25.95 | 25.95 | 25.95 | ---- | 28.35 |
| " " , extreme min. | " | 15.77 | 16.89 | 15.77 | 15.28 | 8.48 | 9.83 | 7.56 | ---- | 4.04 |
| " " deficit, extreme max. | " | 20.74 | 15.92 | 15.92 | 15.92 | 17.74 | 14.04 | 17.83 | ---- | 14.19 |
| " " " , extreme min. | " | 0.56 | 0.62 | 0.59 | 0.57 | 2.68 | 0.32 | 1.51 | ---- | 0.15 |
| Dew point, mean | °C. | 24.44 | 21.67 | 23.33 | 23.89 | 15.50 | 16.10 | 15.50 | ---- | 14.40 |
| " " , extreme max. | " | 25.56 | 25.00 | 25.00 | 25.00 | 8.30 | 11.10 | 6.60 | ---- | 16.67 |
| " " , extreme min. | " | 17.78 | 18.80 | 17.70 | 17.20 | 3.30 | 10.50 | 3.90 | ---- | - 2.22 |
| Evaporation, total | mm. | ---- | ---- | ---- | ---- | 553.60 | 414.50 | 636.50 | ---- | 1,844.90 |
| " , mean | " | ---- | ---- | ---- | ---- | 2.93 | 2.31 | 3.40 | ---- | 8.13 |
| " , extreme max. | " | ---- | ---- | ---- | ---- | 6.60 | 8.20 | 8.20 | ---- | 10.30 |
| " , extreme min. | " | ---- | ---- | ---- | ---- | 0.80 | 0.80 | 0.80 | ---- | 2.00 |
| Precipitation - evaporation ratio | | ---- | ---- | ---- | ---- | 1.54 | 2.12 | 0.73 | ---- | 0.38 |
| Light intensity, mean max. in full sun | f.c. | 6,809.26 | 9,292.72 | 9,158.10 | 8,847.91 | 9,697.00 | 10,343.07 | 10,458.19 | ---- | 10,750.67 |
| " " , extreme max. " " | " | 7,904.00 | 10,132.00 | 10,132.00 | 10,160.00 | 10,800.00 | 10,920.00 | 10,920.00 | ---- | 11,700.00 |
| Insolation, total | hrs. | 730.05 | 594.70 | 792.75 | 768.00 | 1,181.60 | 1,022.40 | 1,171.40 | ---- | 1,237.15 |
| " , mean | " | 6.46 | 5.36 | 7.21 | 7.31 | 6.22 | 5.53 | 6.26 | ---- | 5.45 |
| " , extreme max. | " | 11.00 | 11.50 | 11.00 | 11.00 | 11.00 | 11.00 | 10.70 | ---- | 8.45 |
| Cloudiness, mean | % | 54.00 | 58.00 | 56.00 | 53.00 | 71.30 | 70.60 | 64.20 | ---- | 72.00 |

PLATE 29

Daily range of air temperature, from date of planting to maturity of the latest maturing entry, at each of the four low altitude sites in Guatemala.


SITE 1
Max.
Mean
Min.
March
April
May
June
113
Days from planting to maturity of latest entry
SITE 2
Max.
Mean
Min.
May
June
July
August
111
Days from planting to maturity of latest entry
SITE 3
Max.
Mean
Min.
August
September
October
November
111
Days from planting to maturity of latest entry
SITE 4
Max.
Mean
Min.
September
October
November
December
105
Days from planting to maturity of latest entry
Air temperature °C
40
30
20
10
0

with slow air drainage, were planted under remarkably uniform temperature conditions for that altitude (1,533 meters). Although both maximum and minimum temperatures, recorded during the three growth periods at this altitude, were lower than at Sites 1 to 4, the variation between the extremes remained much the same. The maximum variation was at Site 7, which showed a variation of 19.0°C. for the growth period of 187 days. This variation was only 0.6°C. greater than the low altitude variation of 18.4°C. for Site 1. Had it been possible to carry plantings through the rainless mid-winter months temperatures as low as 2.0°C. might have been recorded at this altitude.

At high altitude, temperatures varied considerably more between night and day, sun and cloud, and wind and calm than at the lower altitudes. The maximum temperature recorded during the 227 days growth period at Site 9 (2,499 meters) was 28.0°C. which was 2.0°C. higher than that recorded at any of the mid altitude sites 966 meters below. The minimum temperature recorded was -1.7°C. which naturally terminated the growth period of the latest maturing entry. The variation between extremes at Site 9 was 29.7°C. which was 10.7°C. greater than the variation at any of the other sites where temperatures were recorded.

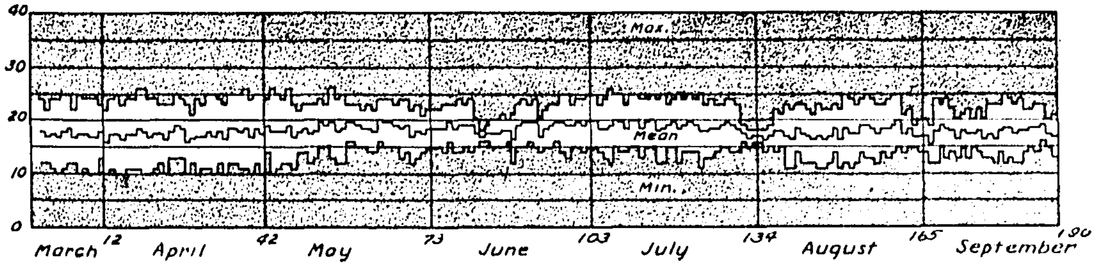
Light quantity

Insolation was controlled by length of day and degree of cloudiness. Likewise the total insolation received by any entry of maize was controlled by the growth period of that entry. As may be seen from Tables 6 and 7, the total insolation received varied considerably from site to site at low and mid altitudes. The low value received at Sites 2 and 6

PLATE 30

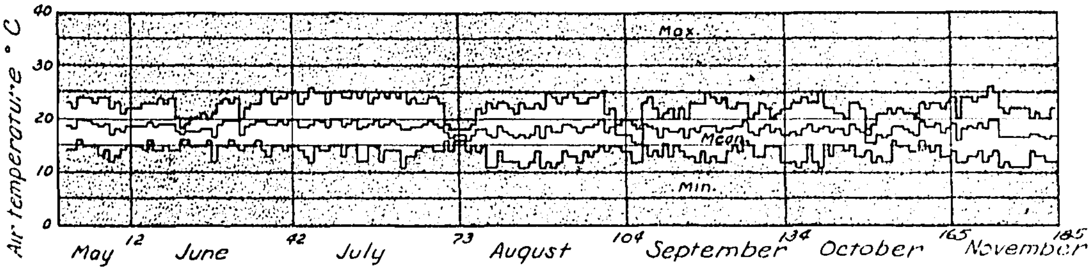
Daily range of air temperature, from date of planting to maturity of the latest maturing entry, at each of the three mid altitude sites in Guatemala.

Site 5



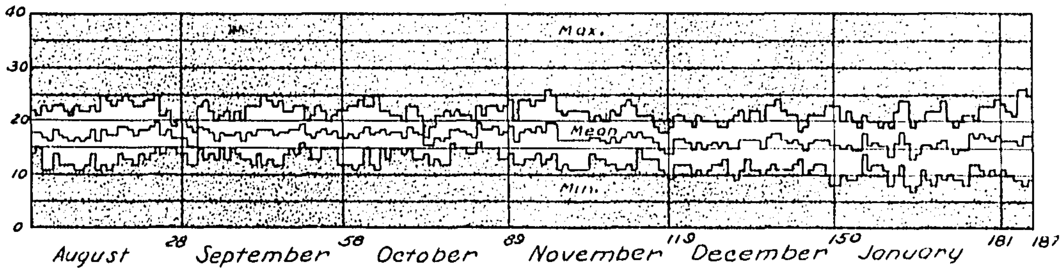

Days from planting to maturity of latest entry.

Site 6




Days from planting to maturity of latest entry.

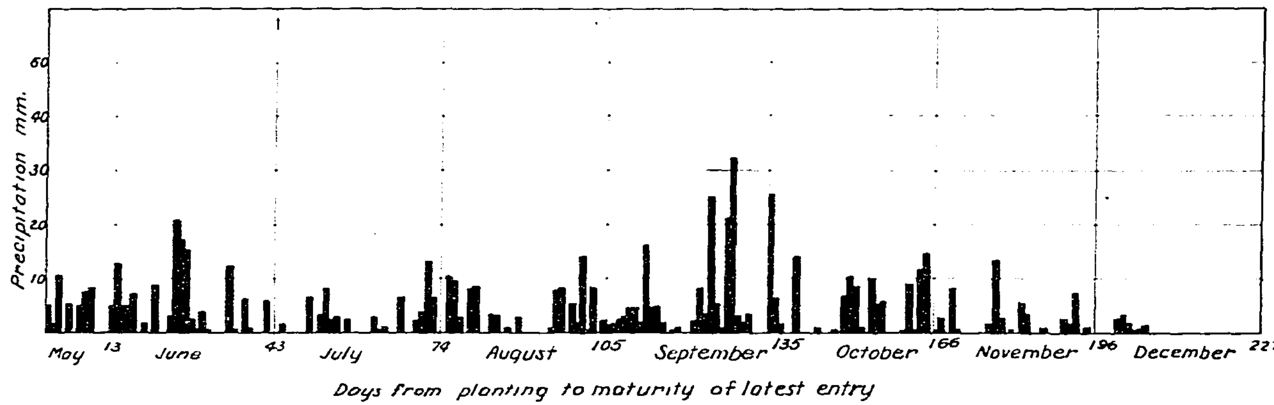
Site 7



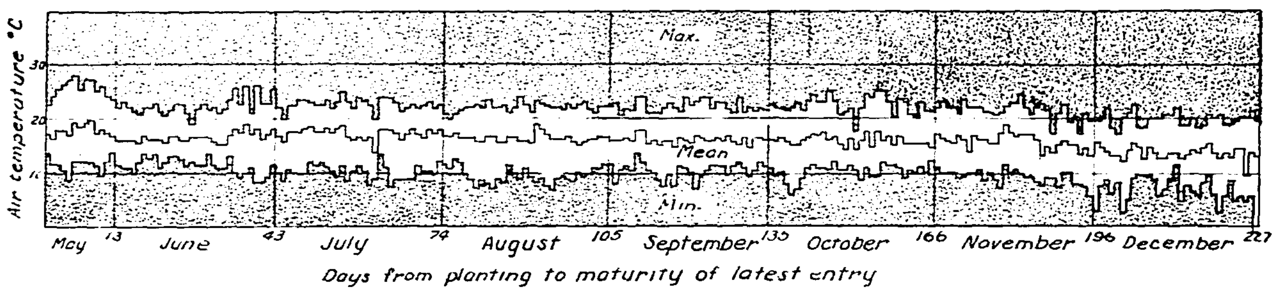

Days from planting to maturity of latest entry.

PLATE 31

Daily range of air temperature and precipitation, from date of planting to maturity of the latest maturing entry, at high altitude Site 9 in Guatemala.



Precipitation mm.
60
40
30
20
10
May
13
June
43
July
74
August
105
September
135
October
166
November
196
December
227
Days from planting to maturity of latest entry

Air temperature °C
30
20
Max.
Mean
Min.
May
13
June
43
July
74
August
105
September
135
October
166
November
196
December
227
Days from planting to maturity of latest entry

were due, in large part, to the increased cloudiness of the spring rainy season and the resultant low value of mean daily insolation. The almost daily afternoon clouding at high altitude resulted in a very low value for the 227 day growth period at Site 9. Had it been recorded this value for Site 8 would have been even lower.

Cloudiness, in general, increased with altitude. As may be seen from the tables the mean per cent of cloudiness at mid altitude was from 6.2 to 13.3 per cent greater than the maximum recorded for any of the growth periods at low altitude. At high altitude the increase was even greater. Most of the clouding took place after noon; the hour becoming later as altitude was decreased.

Intensity of light was a most difficult factor to measure under the conditions present in Guatemala. With the almost constant clouding effects it was impossible to record daily intensity curves that were accurate. With the instrument at hand it was, however, possible to record the maximum daily intensity and a mean maximum for the growth periods. These recordings in Tables 6 and 7 show that there was a definite increase in light intensity with altitude. The low values for Sites 1 and 5 were due to these two plantings having been made under irrigation in the latter part of the dry season. At that time the intensity of light was greatly reduced by the quantity of dust and smoke in the atmosphere.

Most of the high light intensities were recorded during weather in which there was a thin veil of cirrus clouds. At high altitude this type of weather was common. The great amount of intermittent cloudiness, at high altitude, during the morning hours and the more or less constant afternoon cloudiness had a very depressing effect on the otherwise high light intensities at that altitude. At mid altitude, the intensity was somewhat less but the period of daily insolation usually greater. At the low altitude sites the intensity was considerably less but the total number of hours of full sunshine was much greater.

Thus, the recordings of light intensity are somewhat deceptive. The maximum recording of 11,700 foot candles at 2,499 meters was an almost instantaneous reading as the sun shone through a cloud-break. Some of the low readings at near sea level continued over a period due to unclouded skies.

The daily trend of light intensity in Guatemala began with near zero just before sunrise to a maximum peak at approximately 12:25. There was an extremely rapid drop or sudden fall with the afternoon clouding which began at varying hours depending on altitude. During the clearer weather the intensity curve was sigmoid but did not reach as high a peak due to atmospheric dust and smoke. Afternoon recordings at all altitudes were frequently less than 500 foot candles due to clouds and rain.

<u>Length</u> <u>of</u> <u>day</u> variation between the longest and shortest days in Guatemala was only 1 hr. 48 min. As might be expected with this variation there were no apparent indications of the effect of photoperiodism on growth response at any of the planting sites. Table 8 gives the hours of sunrise and sunset and shows the small but gradual changes in the limited daylight range.

Table 8. Length of day in Guatemala.
Local time (U.T. Meridian 90 W. Gr.) Lat. 14°35'

| Month | Day | Sunrise hr. | Sunrise min. | Sunset hr. | Sunset min. | Daylight hr. | Daylight min. |
|---|---|---|---|---|---|---|---|
| Jan. | 1 | 6 | 26 | 17 | 41 | 11 | 15 |
| | 11 | 6 | 29 | 17 | 46 | 11 | 17 |
| | 21 | 6 | 30 | 17 | 53 | 11 | 23 |
| Feb. | 1 | 6 | 30 | 17 | 58 | 11 | 28 |
| | 11 | 6 | 27 | 18 | 2 | 11 | 35 |
| | 21 | 6 | 23 | 18 | 6 | 11 | 43 |
| March | 1 | 6 | 17 | 18 | 7 | 11 | 50 |
| | 11 | 6 | 11 | 18 | 10 | 11 | 59 |
| | 21 | 6 | 4 | 18 | 12 | 12 | 08 |
| April | 1 | 5 | 56 | 18 | 12 | 12 | 14 |
| | 11 | 5 | 49 | 18 | 14 | 12 | 25 |
| | 21 | 5 | 42 | 18 | 16 | 12 | 34 |
| May | 1 | 5 | 37 | 18 | 17 | 12 | 40 |
| | 11 | 5 | 33 | 18 | 20 | 12 | 47 |
| | 21 | 5 | 30 | 18 | 23 | 12 | 53 |
| June | 1 | 5 | 29 | 18 | 26 | 12 | 57 |
| | 11 | 5 | 29 | 18 | 30 | 13 | 01 |
| | 21 | 5 | 30 | 18 | 32 | 13 | 02 |
| July | 1 | 5 | 32 | 18 | 34 | 13 | 02 |
| | 11 | 5 | 36 | 18 | 34 | 12 | 58 |
| | 21 | 5 | 38 | 18 | 33 | 12 | 55 |
| August | 1 | 5 | 41 | 18 | 31 | 12 | 50 |
| | 11 | 5 | 44 | 18 | 26 | 12 | 42 |
| | 21 | 5 | 46 | 18 | 21 | 12 | 35 |
| Sept. | 1 | 5 | 48 | 18 | 14 | 12 | 26 |
| | 11 | 5 | 49 | 18 | 4 | 12 | 15 |
| | 21 | 5 | 49 | 17 | 56 | 12 | 07 |
| Oct. | 1 | 5 | 50 | 17 | 48 | 11 | 58 |
| | 11 | 5 | 51 | 17 | 41 | 11 | 50 |
| | 21 | 5 | 53 | 17 | 35 | 11 | 42 |
| Nov. | 1 | 5 | 57 | 17 | 31 | 11 | 34 |
| | 11 | 6 | 1 | 17 | 29 | 11 | 28 |
| | 21 | 6 | 5 | 17 | 27 | 11 | 22 |
| Dec. | 1 | 6 | 10 | 17 | 28 | 11 | 18 |
| | 11 | 6 | 16 | 17 | 31 | 11 | 15 |
| | 21 | 6 | 22 | 17 | 36 | 11 | 14 |

## Light quality

Seasonal variation effects on the light quality were not measured or recorded. That such effects were present was certain but other controlling factors only indirectly due to season were of a magnitude sufficient to obscure any or all true seasonal effects. This was especially true at the lower altitudes.

Atmospheric conditions, closely related to season, were the main factor affecting light quality. The clearing and burning operations during the period from early December to May so filled the atmosphere with smoke as to greatly alter light quality. Combined with this smoke was the heavy load of dust, from fallow fields and highways, that continually hovered over the earth during the dry months. The continuous high relative humidity, rain and cloudy weather made alterations, of a different nature, on the light quality during the humid months.

Altitudinal effects on light quality were, no doubt, the usual ones of decrease in absorption rate of solar radiation with increase in altitude. No attempt was made to measure this quality factor.

## Moisture relationships

At no time during the growth period of any entry at any site did moisture relationships become a limiting factor in growth response.

Precipitation during the growth period at all sites was abundant. The smallest amounts falling during the growth periods of any entries were those recorded at Site 7. At that site the precipitation varied from 460.74 mm. during the 118 day growth period of the earliest maturing

PLATE 32

Daily precipitation, from date of planting to maturity of the latest maturing entry, at each of the four low altitude sites in Guatemala.

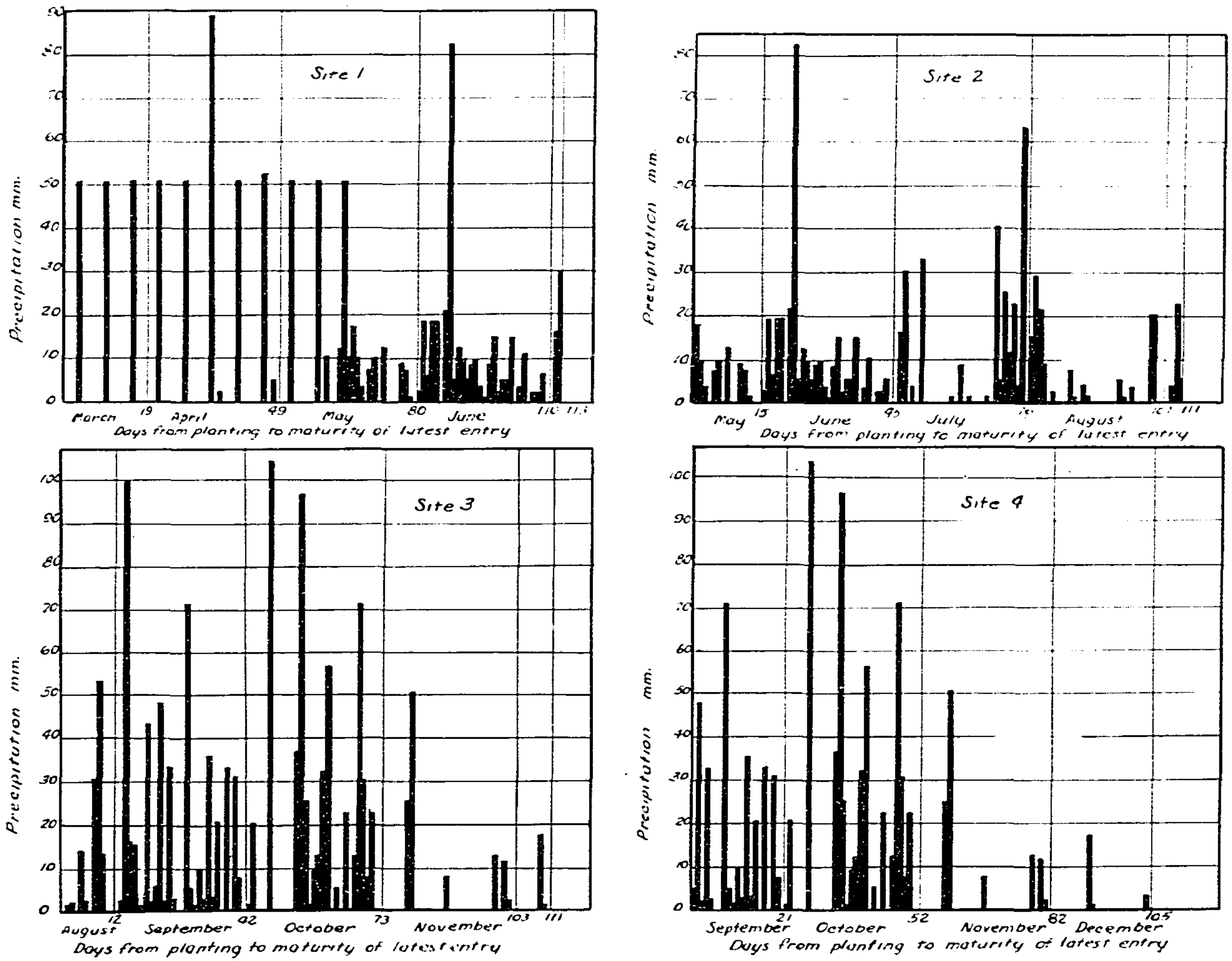
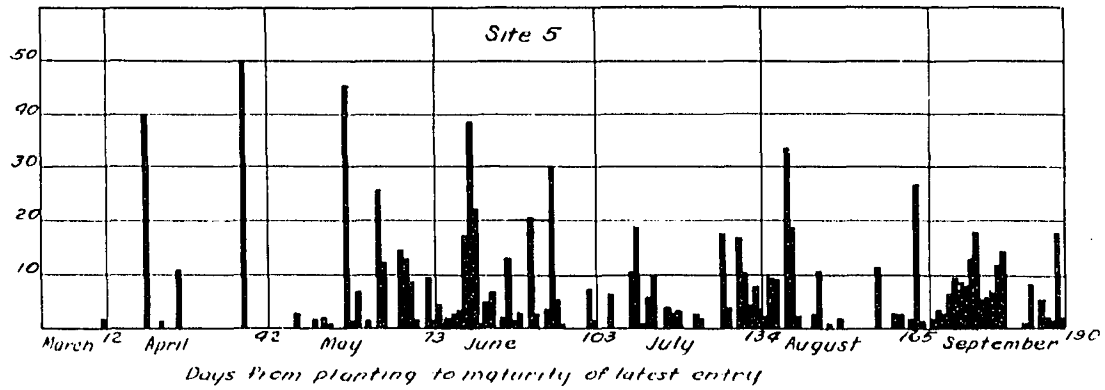
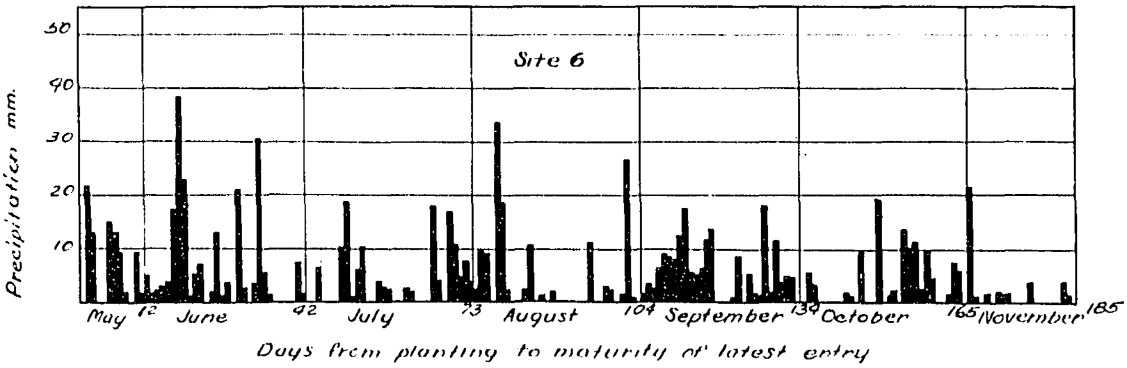
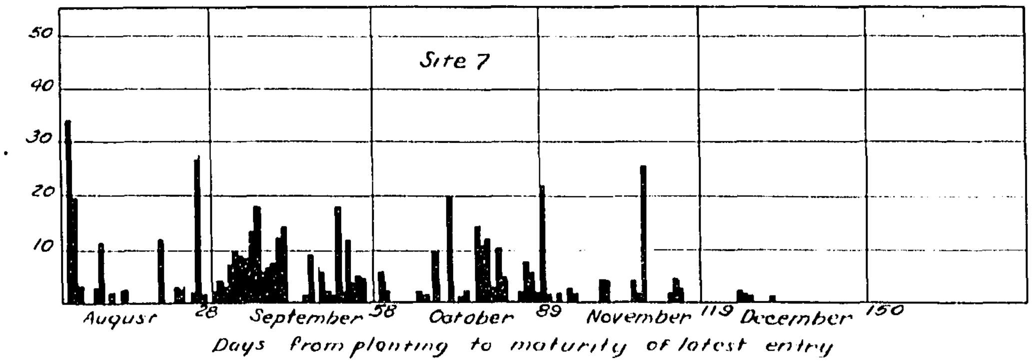

Site 1
Site 2
Site 3
Site 4
Precipitation mm.
March
April
May
June
July
August
September
October
November
December
Days from planting to maturity of latest entry

PLATE 33

Daily precipitation, from the date of planting to maturity of the latest maturing entry, at each of the three mid altitude sites in Guatemala.


Site 5
50
40
30
20
10
March 12 April 42 May 73 June 103 July 134 August 165 September 190
Days from planting to maturity of latest entry


Site 6
Precipitation mm.
50
40
30
20
10
May 12 June 42 July 73 August 104 September 134 October 165 November 185
Days from planting to maturity of latest entry


Site 7
50
40
30
20
10
August 28 September 58 October 89 November 119 December 150
Days from planting to maturity of latest entry

entry 25-44 and 466.81 mm. during the 187 day growth period of the latest maturing entry 138A-46. Tables 6 and 7 show the total quantity recorded at each of the nine sites in Guatemala. The greatest quantity recorded for any single growth period was that for the monsoon rainforest Site 3. At this site 1,480.83 mm. of precipitation was recorded during the 110 day growth period of Entry 138A-46. Plates 30, 31, and 32 illustrate the daily precipitation and its even distribution throughout the growth periods at all of the nine sites with the exception of Site 7. The growth period at this site extended into the beginning of the dry season.

The recording of duration of precipitation was possible only at Sites 5, 6, 7, and 9. Duration for Site 8 was very similar to that of Site 9. Duration for the low altitude sites was, of course, greatest but it was impossible to secure time records at that altitude. Likewise, intensity of precipitation could be calculated only for those sites at which duration records were taken. In this case also the intensity of precipitation was greatest at low altitude. Tables 6 and 7 give such data for duration and intensity of precipitation as were possible to secure.

Practically all precipitation was effective in increasing and/or maintaining soil moisture. Run-off at all sites except the high altitude Sites 8 and 9 was negligible. At the two high altitude sites the slope was sufficient to cause run-off during the heavier periods of precipitation.

Atmospheric vapor

Relative humidity was recorded at all sites except Site 8. It is believed that the relative humidity for Site 8 would be somewhat higher than for the other high altitude site. Plate 34 shows this factor graphed by ten-day means for the minimum recorded at each of the altitudes. Tables 6 and 7 give the mean and extreme minimum for each of the sites where records were taken. Maximum was not recorded as this value usually reached or approached 100 per cent daily. Low values of relative humidity were obtained only at the beginning and end of the combined growth period before and after the rainy season. However, the mean relative humidity for all growth periods was high.

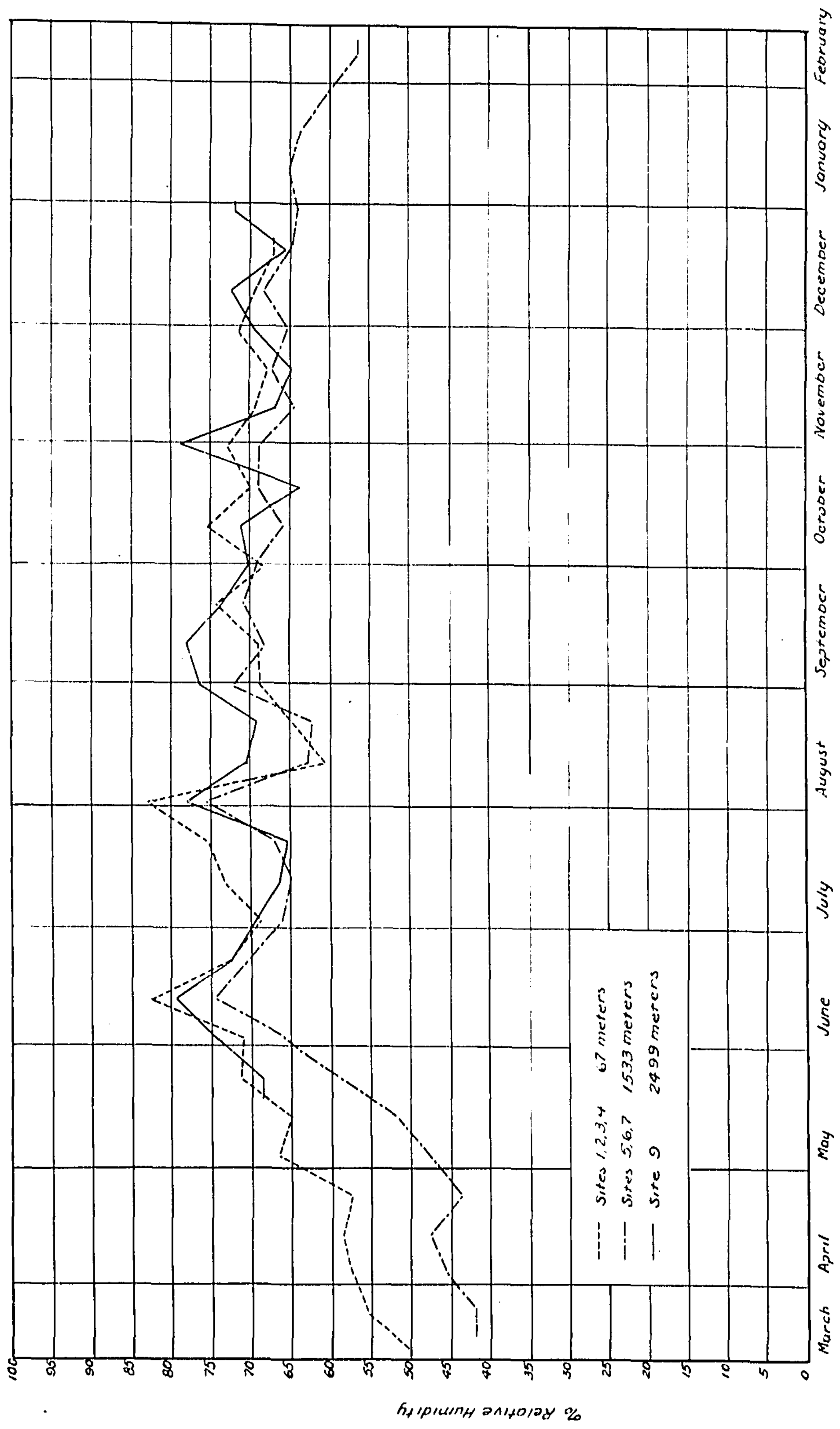
Vapor pressures calculated for eight of the nine planting sites are shown in Tables 6 and 7. Mean, maximum, and minimum values for this factor varied but little from site to site at any one altitude. They were, of course, lower as altitude increased. The maximum at high altitude was slightly higher than at mid altitude as was true with temperature.

Vapor pressure deficits at all sites were generally low although a maximum deficit of 20.74 mm. was reached in dry weather at Site 1. The higher vapor pressure deficits recorded were never sustained for any extended period, dropping rapidly with afternoon cooling and clouding.

Dew point temperatures were also calculated for eight of the nine sites. A casual study of relative humidity, atmospheric temperatures, and dew pointtemperatures in Tables 6 and 7 shows that temperatures were near the dew point at all of the sites during the various growth periods.

PLATE 34

Minimum relative humidity, based on ten day means, for each of three altitudes in Guatemala.


% Relative Humidity
March
April
May
June
July
August
September
October
November
December
January
February
Sites 1,2,3,4 67 meters
Sites 5,6,7 1533 meters
Site 9 2499 meters

Relative humidity was sufficiently high, most of the time, to require a temperature drop of but a few degrees to reach dew point.

Evaporation was recorded at Sites 5, 6, 7, and 9 only. The values at Site 8 for this factor were similar to Site 9. Evaporation at the low altitude sites was certainly less than at the others although it proved impossible to take data. As shown by the tables, evaporation was greatest at high altitude.

Precipitation-evaporation ratios were incomplete but varied with altitude. Very high values of 1.54 and 2.12 were recorded for Sites 5 and 6 respectively. At the high altitude Site 9 the ratio was 0.38.

## Edaphic Factors

### Soil moisture

Soil moisture at time of planting was recorded at all sites. These values are shown below in Table 9. Site 6 showed the lowest values but was subjected to heavy and continuous rainfall immediately after planting.

Table 9. Mean per cent of soil moisture at time of planting.

| Sample depth in cm. | Sites | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 15 | 37.39 | 26.19 | 42.00 | 48.29 | 25.37 | 19.00 | 25.60 | 29.31 | 26.31 |
| 45 | 38.11 | 26.19 | 40.24 | 51.51 | 27.93 | 16.92 | 26.33 | 27.54 | 30.64 |
| 75 | 38.05 | 25.70 | 32.62 | 47.89 | 20.27 | 18.72 | 20.48 | 27.98 | 35.29 |

At no time during the growth period at any site was there evidence of a

Table 10. Soil analyses for each of the nine planting sites in Guatemala.

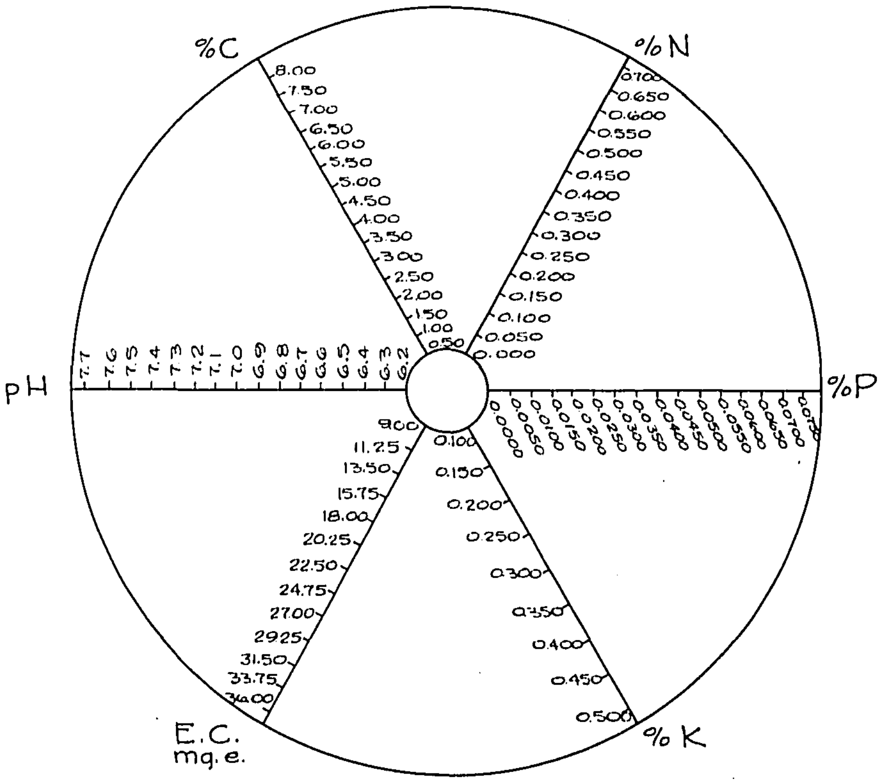
| Site | Sample depth cm. | Mean pH | Carbon, mean % | Nitrogen, mean % | C/N ratio | Available phosphorus, mean % | Available potassium, mean % | Exchange capacity, m.l./100 gr. |
|---|---|---|---|---|---|---|---|---|
| 1 | 15 | 7.6 | 3.15 | 0.267 | 11.79 | 0.0160 | 0.400 | 21.98 |
| | 45 | 7.7 | 2.89 | 0.257 | 11.24 | 0.0135 | 0.400 | 19.34 |
| | 75 | 7.7 | 2.50 | 0.201 | 12.43 | 0.0080 | 0.300 | 18.22 |
| 2 | 15 | 7.0 | 1.95 | 0.169 | 11.54 | 0.0750 | 0.400 | 28.20 |
| | 45 | 7.1 | 0.98 | 0.086 | 11.39 | 0.0420 | 0.400 | 16.33 |
| | 75 | 7.0 | 0.73 | 0.058 | 12.58 | 0.0350 | 0.400 | 14.88 |
| 3 | 15 | 7.1 | 5.42 | 0.446 | 12.15 | 0.0200 | 0.175 | 20.95 |
| | 45 | 6.9 | 3.92 | 0.342 | 11.46 | 0.0070 | 0.145 | 19.11 |
| | 75 | 7.1 | 2.65 | 0.192 | 13.80 | 0.0045 | 0.145 | 9.91 |
| 4 | 15 | 7.0 | 7.21 | 0.652 | 11.05 | 0.0750 | 0.400 | 26.20 |
| | 45 | 7.3 | 4.94 | 0.615 | 8.03 | 0.0420 | 0.400 | 24.36 |
| | 75 | 7.4 | 4.80 | 0.417 | 11.51 | 0.0175 | 0.500 | 18.50 |
| 5 | 15 | 6.6 | 1.75 | 0.176 | 9.94 | 0.0170 | 0.400 | 16.77 |
| | 45 | 7.0 | 1.43 | 0.135 | 10.59 | 0.0050 | 0.400 | 17.95 |
| | 75 | 7.0 | 0.69 | 0.045 | 13.11 | 0.0035 | 0.400 | 11.40 |
| 6 | 15 | 6.8 | 1.24 | 0.094 | 13.19 | 0.0100 | 0.300 | 14.27 |
| | 45 | 7.1 | 0.98 | 0.083 | 11.80 | 0.0025 | 0.300 | 14.21 |
| | 75 | 7.3 | 0.91 | 0.066 | 13.78 | 0.0015 | 0.260 | 18.98 |
| 7 | 15 | 6.5 | 1.91 | 0.151 | 12.64 | 0.0180 | 0.400 | 18.95 |
| | 45 | 7.0 | 1.20 | 0.099 | 12.12 | 0.0060 | 0.400 | 28.55 |
| | 75 | 7.0 | 0.66 | 0.046 | 14.34 | 0.0040 | 0.400 | 36.02 |

Table 10. (Continued)

| Site | Sample depth cm. | Mean pH | Carbon, mean % | Nitrogen, mean % | C/N ratio | Available phosphorus, mean % | Available potassium, mean % | Exchange capacity, m.l./100 gr. |
|---|---|---|---|---|---|---|---|---|
| 8 | 15 | 7.3 | 1.16 | 0.101 | 11.48 | 0.0160 | 0.500 | 11.83 |
| | 45 | 7.3 | 0.99 | 0.126 | 7.86 | 0.0125 | 0.500 | 11.27 |
| | 75 | 7.3 | 0.90 | 0.104 | 8.65 | 0.0085 | 0.500 | 11.93 |
| 9 | 15 | 6.2 | 1.38 | 0.130 | 10.61 | 0.0065 | 0.300 | 11.13 |
| | 45 | 6.4 | 1.22 | 0.150 | 8.13 | 0.0030 | 0.300 | 10.76 |
| | 75 | 6.6 | 1.05 | 0.097 | 10.82 | 0.0025 | 0.300 | 10.99 |

PLATE 35

Scale showing the maximum range of mean values determined from soil samples, from nine sites in Guatemala, analyzed for percentages of carbon (C), nitrogen (N), available phosphorous (P), available potassium (K), exchange capacity (E.C.), and soil pH. Refer to Plate  for results of analyses for individual sites.

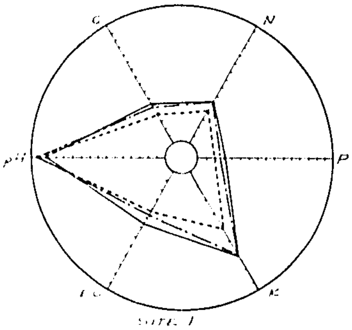



SCALE

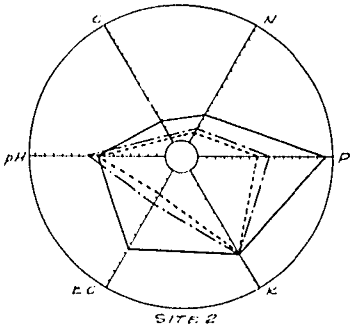
PLATE 36

Mean percentages of carbon, nitrogen, available phosphorous, available potassium, exchange capacity and soil pH, based on samples from each of the nine planting sites in Guatemala. Refer to Plate for scale.

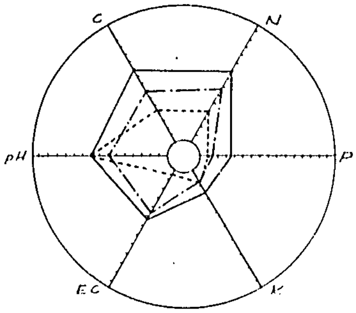
Sample depths; ________15 cm., _._._.__45 cm., _ _ _ _ _ _75 cm.



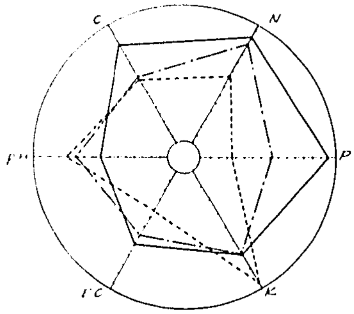
SITE 1



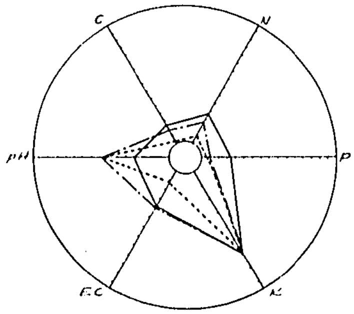
SITE 2



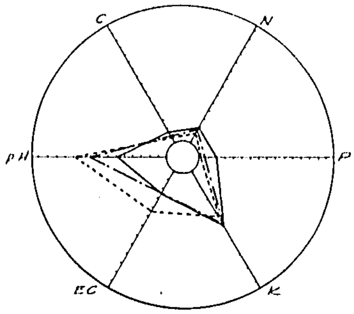
SITE 3



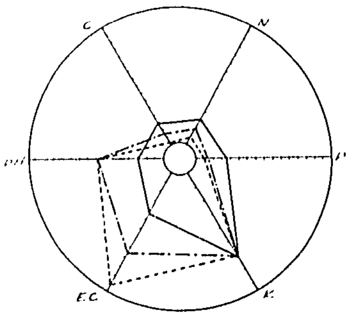
SITE 4



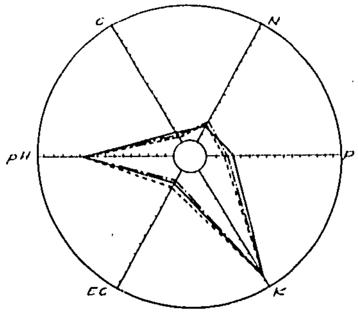
SITE 5



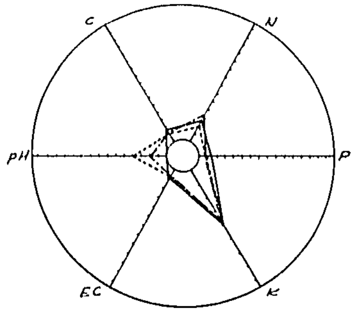
SITE 6



SITE 7



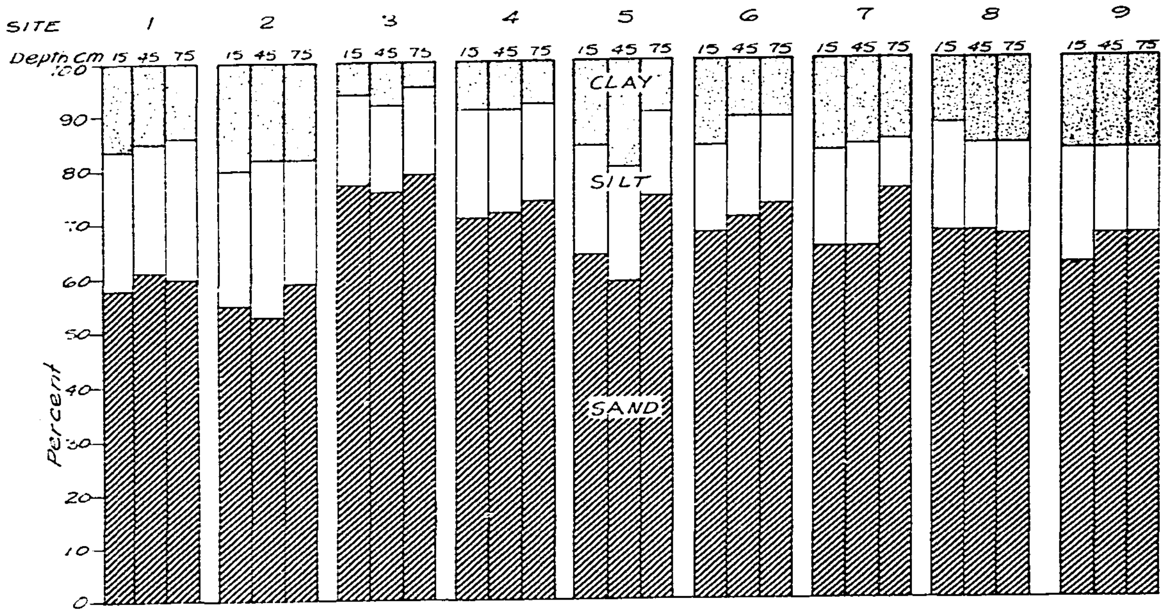
SITE 8



SITE 9

PLATE 37

Mechanical analyses of the soils from the nine planting sites in Guatemala.


SITE
1
2
3
4
5
6
7
8
9
Depth cm
15 45 75
Percent
100
90
80
70
60
50
40
30
20
10
0
CLAY
SILT
SAND

soil moisture deficit. The soils were porous enough so that water was left on the surface for only short periods.

## Chemical conditions

The soil samples taken from the nine planting sites in Guatemala all yielded pH values at or approaching neutrality. Though available nutrients were present in limited quantity, as shown in Table 10, there was no indication of mineral deficiency in any of the site plantings. None of the sites had ever received either commercial fertilizers or stable manures of any kind nor were any applied during the growth periods at any site. There was no indication of difference in soil effects between the site plantings at any given altitude. Plates 35 and 36 and Table 10 illustrate quite clearly the comparative differences in chemical conditions of the soils at the nine sites.

## Mechanical conditions

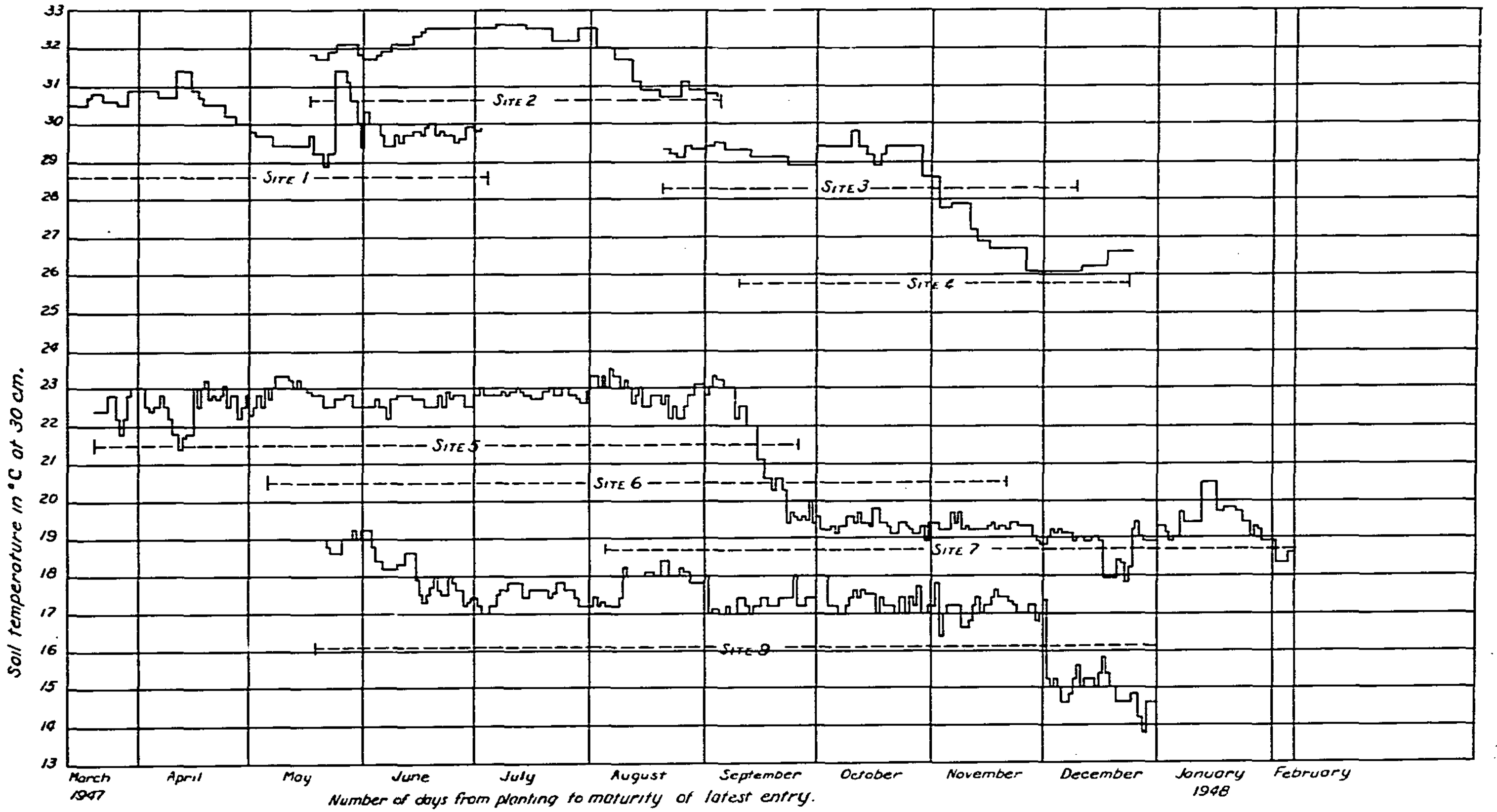
There were no marked differences in the mechanical conditions between the soils of the various sites. As shown in Plate 37 the soils varied from fine sandy loams to sandy clays. All soils were very friable, porous and remarkably free from adhesive qualities even during or immediately after rains.

## Soil temperature

Tables 6 and 7 show the remarkable uniformity of soil temperatures in the growth periods at any one altitude. Also shown is the very small margin of variation between maximum and minimum temperatures during the

PLATE 38

Mean daily soil temperature, from date of planting to maturity of the latest maturing entry, at each of the nine sites in Guatemala.


Soil temperature in °C at 30 cm.
33
32
31
30
29
28
27
26
25
24
23
22
21
20
19
18
17
16
15
14
13
Site 1
Site 2
Site 3
Site 4
Site 5
Site 6
Site 7
Site 9
March 1947
April
May
June
July
August
September
October
November
December
January 1948
February
Number of days from planting to maturity of latest entry.

growth periods at the nine sites. The graphical illustration of soil temperatures in Plate 38 brings out the daily march of these temperatures during the growth periods at eight of the nine sites. The fact that these soils were continuously moist, and the comparative stability of the atmospheric temperatures, were factors largely responsible for the uniformity of these soil temperatures. The higher temperatures recorded for Site 2 were believed to be due to its drier location and darker soil color. The downward trends shown in Plate 38 were due to continued cold rains. The sudden drop shown in Site 9 was due to a very heavy hail storm followed by cold rain.

## ANALYSES OF GROWTH RESPONSES

The analyses of variance for the various growth responses were based on the site means for those responses. These site means are tabulated under their respective character or response headings. In the case of the number of days to anthesis the analysis was made on the actual numbers of days. This response was recorded on a per entry basis rather than on a per plant basis.

### Number of Days from Emergence to Anthesis

The values of this response for the 25 entries of maize, as recorded in Guatemala, are tabulated in Table 11. This table presents the differences in response between sites, altitudes, types, and entries. The mean values for entries and types at each and all altitudes is also shown.

The variation in days to anthesis was very slight between sites at mid altitude, the greatest variation exhibited being eight days in the case of Entry 39A-46 at Sites 5 and 6. The Mountain Type proved the most variable at that altitude. The Giant Type proved most variable at low altitude where Entry 17A-46 exhibited a difference of fifteen days between the values recorded at Sites 1 and 2. In almost all entries greater site differences were shown at low than at mid altitude. The fact that there was an altitude difference of 213 meters, with corresponding climatic differences, was considered largely responsible for

Table 11. Antheses of 25 entries of maize planted at nine sites at low, intermediate and high altitudesin Guatemala.

| Maize tested | | Mean number of days from emergence to anthesis at different sites | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number | Type | Low altitude sites | | | | | Mid altitude sites | | | | High altitude sites | | | All alt. mean |
| | | 1 | 2 | 3 | 4 | Mean | 5 | 6 | 7 | Mean | 8 | 9 | Mean | |
| 153 x WF9 | S. cross | 39 | 47 | 42 | 40 | 42.0 | 61 | 63 | 64 | 62.7 | 96 | 108 | 102.0 | |
| 205 x 289 | " " | 41 | 47 | 44 | 45 | 43.2 | 68 | 70 | 70 | 69.3 | 98 | 105 | 101.5 | |
| 205 x 234 | " " | 46 | 49 | 44 | 41 | 45.0 | 68 | 68 | 70 | 68.3 | 99 | 121 | 110.0 | |
| M14 x WF9 | " " | 42 | 50 | 55 | 44 | 47.7 | 70 | 69 | 68 | 69.0 | 106 | 97 | 101.5 | |
| M14 x Wis.22 | " " | 43 | 53 | 45 | 46 | 46.7 | 70 | 70 | 70 | 70.0 | 100 | 109 | 104.5 | |
| Altitude means for U.S. single crosses | | | | | | 45.1 | | | | 67.9 | | | 103.9 | 65.8 |
| 30A - 46 | Early | 41 | 47 | 43 | 45 | 44.0 | 69 | 69 | 67 | 68.3 | 98 | 105 | 101.5 | |
| 32A - 46 | " | 42 | 51 | 49 | 45 | 46.7 | 69 | 68 | 71 | 69.3 | 99 | 122 | 110.5 | |
| 25 - 44 | " | 39 | 45 | 40 | 42 | 41.5 | 61 | 61 | 64 | 62.0 | 94 | 103 | 98.5 | |
| Altitude means for early type | | | | | | 44.1 | | | | 66.6 | | | 103.5 | 64.8 |
| 101A - 46 | Coast | 46 | 43 | 55 | 56 | 50.0 | 87 | 86 | 87 | 86.6 | 117 | 133 | 125.0 | |
| 13 - 44 | " | 53 | 61 | 52 | 50 | 54.0 | 77 | 78 | 76 | 77.0 | 103 | 117 | 110.0 | |
| 42A - 46 | " | 48 | 61 | 50 | 50 | 52.2 | 83 | 82 | 80 | 81.6 | 115 | 126 | 120.5 | |
| 12A - 46 | " | 52 | 62 | 60 | 61 | 58.7 | 86 | 88 | 86 | 86.6 | 114 | 137 | 125.5 | |
| 7A - 46 | " | 50 | 58 | 54 | 52 | 53.5 | 78 | 78 | 78 | 78.0 | 117 | 130 | 123.5 | |
| 125A - 46 | " | 50 | 57 | 58 | 58 | 55.7 | 78 | 76 | 76 | 76.6 | 108 | 125 | 116.5 | |
| 9A - 46 | " | 55 | 63 | 60 | 58 | 57.2 | 82 | 84 | 83 | 83.0 | 115 | 132 | 123.5 | |
| 96A - 46 | " | 52 | 64 | 62 | 60 | 59.5 | 86 | 86 | 85 | 85.6 | 118 | 132 | 125.0 | |
| Altitude means for coast type | | | | | | 55.3 | | | | 81.9 | | | 121.2 | 78.8 |
| 1A - 46 | Mountain | 59 | 62 | 60 | 60 | 60.2 | 83 | 79 | 81 | 81.0 | 99 | 108 | 103.5 | |
| 39A - 46 | " | 64 | 67 | 65 | 66 | 65.5 | 90 | 82 | 83 | 85.0 | 103 | 112 | 107.5 | |
| 106A - 46 | " | 60 | 63 | 60 | 61 | 61.0 | 90 | 84 | 87 | 87.0 | 113 | 123 | 118.0 | |

Table 11. (Continued)

| Maize tested | | Mean number of days from emergence to anthesis at different sites | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number | Type | Low altitude sites | | | | | Mid altitude sites | | | | High altitude sites | | | All alt. mean |
| | | 1 | 2 | 3 | 4 | Mean | 5 | 6 | 7 | Mean | 8 | 9 | Mean | |
| 33A - 46 | Mountain | 52 | 56 | 55 | 60 | 55.7 | 91 | 91 | 91 | 91.0 | 115 | 127 | 121.0 | |
| Altitude means for mountain type | | | | | | 61.0 | | | | 86.0 | | | 112.5 | 80.6 |
| 15A - 46 | Giant | 81 | 75 | 77 | 75 | 77.0 | 112 | 103 | 106 | 107.0 | 133 | 144 | 138.5 | |
| 17A - 46 | " | 60 | 75 | 70 | 66 | 67.7 | 111 | 103 | 105 | 106.3 | 135 | 147 | 141.0 | |
| 47A - 46 | " | 59 | 67 | 62 | 61 | 62.2 | 105 | 99 | 100 | 101.3 | 130 | 142 | 136.0 | |
| 138A - 46 | " | 77 | 71 | 70 | 70 | 72.0 | 130 | 128 | 129 | 129.0 | 160 | 176 | 168.0 | |
| 14A - 46 | " | 58 | 67 | 60 | 63 | 62.0 | 107 | 100 | 100 | 102.3 | 144 | 157 | 150.5 | |
| Altitude means for giant type | | | | | | 68.2 | | | | 109.2 | | | 146.8 | 99.3 |
| Altitude means for all types | | | | | | 55.5 | | | | 83.4 | | | 119.3 | 78.9 |

Table 12. Combined analysis of variance of the numbers of days from emergence to anthesis of 25 entries of maize for nine sites in Guatemala.

| Source of variation | Degrees of freedom | | Mean squares |
|---|---|---|---|
| Altitudes | 2 | | 69,321.00 |
| Entries | 24 | | 1,480.50 |
| Between types | | 4 | 8,000.25 |
| Within types | | 20 | 176.55 |
| Altitudes x Entries | 48 | | 125.19 |
| Altitudes x Between types | | 8 | 433.50 |
| Altitudes x Within types | | 40 | 6.35 |
| Sites within altitudes | 6 | | 404.30 |
| Entries x Sites within altitudes | 144 | | 9.82 |
| Total | 224 | | 821.54 |

the variation in response of anthesis between the two high altitude sites. The Early Type Entry 25-44 was the earliest in anthesis and maturity at all altitudes while the Giant Type Entry 138A-46 was latest.

The combined analysis of variance for days to anthesis (Table 12) indicates that the chief sources of variation were attributable to altitudinal and between type differences. The greater part of interaction was shown to be between types. The negligible altitude x within type interaction was considered attributable to minor differences between entries within types. There was a small but apparent variation between sites within altitudes which was considered attributable to differences in the anthesis responses at the low and high altitude sites. The mean square for entries x sites within altitudes was classed as experimental error.

It was found that the period from emergence to anthesis could be predicted by the analysis of variance for linear regression of this response on node number (Table 16).

## Numbers of Nodes

The number of nodes was found to be a very constant character in all of the entries grown in Guatemala. That this was true, regardless of altitude or site, is shown in Table 13 and Plate 39. A very slight decrease in the number was exhibited by all except the Giant Type at mid altitude. This type showed a perceptible increase in node number in its natural environment at that altitude. The mean number of nodes recorded

PLATE 39

Mean and extreme numbers of nodes of five maize types grown at low, mid, and high altitudes in Guatemala.

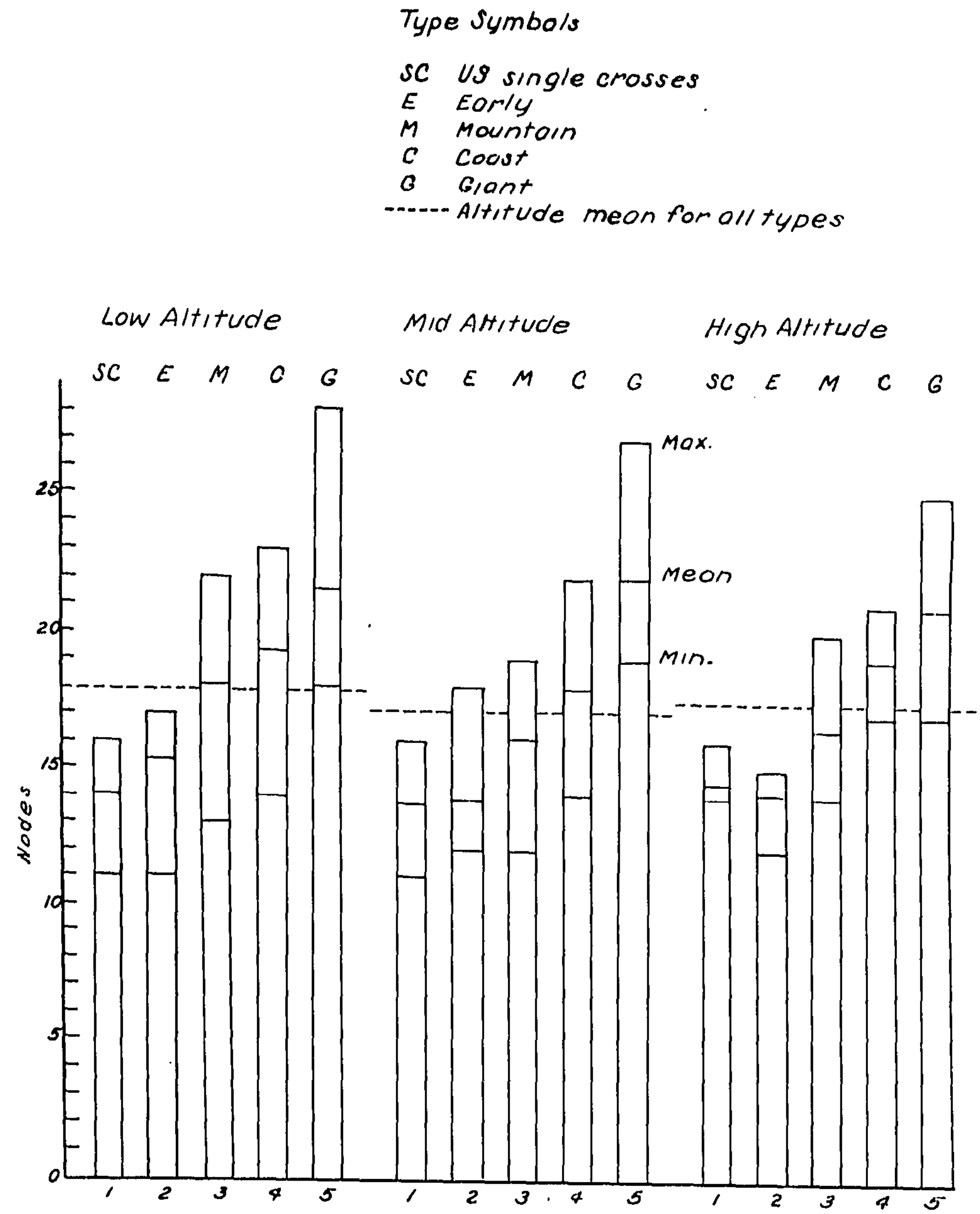

Type Symbols
SC US single crosses
E Early
M Mountain
C Coast
G Giant
------ Altitude mean for all types
Low Altitude
Mid Altitude
High Altitude
SC E M C G
SC E M C G
SC E M C G
Max.
Mean
Min.
Nodes
0
5
10
15
20
25
1 2 3 4 5
1 2 3 4 5
1 2 3 4 5

Table 13. Numbers of nodes of 25 entries of maize planted at nine sites at low, intermediate and high altitudes in Guatemala.

| Maize tested | | Mean number of nodes at different sites | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number | Type | Low altitude sites | | | | | Mid altitude sites | | | | High alt. sites | | | All alt. mean |
| | | 1 | 2 | 3 | 4 | Mean | 5 | 6 | 7 | Mean | 8 | 9 | Mean | |
| 153 x WF9 | S. cross | 13.3 | 12.4 | 14.6 | 14.5 | 13.7 | 12.9 | 13.5 | 14.3 | 13.6 | 14.7 | 14.7 | 14.7 | |
| 205 x 289 | " " | 13.2 | 13.3 | 14.2 | 14.9 | 13.9 | 12.8 | 13.8 | 14.5 | 13.7 | 15.0 | 14.9 | 14.9 | |
| 205 x 234 | " " | 13.9 | 12.4 | 14.5 | 14.7 | 13.8 | 13.4 | 13.4 | 14.6 | 13.8 | 14.2 | 14.8 | 14.5 | |
| M14 x WF9 | " " | 14.1 | 12.9 | 15.0 | 15.4 | 14.4 | 13.3 | 14.0 | 14.6 | 14.0 | 14.3 | 14.3 | 14.3 | |
| M14 x Wis.22 | " | 14.2 | 12.6 | 14.7 | 15.0 | 14.1 | 13.4 | 13.5 | 13.9 | 13.6 | 14.3 | 14.1 | 14.2 | |
| Altitude means for U.S. single crosses | | | | | | 14.0 | | | | 13.7 | | | 14.5 | 14.02 |
| 30A - 46 | Early | 13.9 | 15.0 | 16.2 | 16.8 | 15.5 | 14.1 | 14.1 | 15.6 | 14.6 | 14.6 | 14.4 | 14.5 | |
| 32A - 46 | " | 16.0 | 16.0 | 16.5 | 16.6 | 16.3 | 13.7 | 13.8 | 15.5 | 14.3 | 14.8 | 14.9 | 14.9 | |
| 25 - 44 | " | 13.8 | 14.0 | 14.5 | 15.0 | 14.3 | 12.0 | 13.2 | 13.4 | 12.9 | 13.1 | 13.2 | 13.6 | |
| Altitude means for early type | | | | | | 15.4 | | | | 13.9 | | | 14.2 | 14.62 |
| 101A - 46 | Coast | 20.2 | 19.9 | 20.2 | 20.8 | 20.3 | 17.1 | 17.7 | 18.2 | 17.7 | 18.5 | 18.9 | 18.7 | |
| 13 - 44 | " | 17.6 | 17.7 | 18.3 | 18.4 | 18.0 | 15.9 | 16.3 | 16.2 | 16.1 | 18.5 | 17.6 | 18.0 | |
| 42A - 46 | " | 19.1 | 19.7 | 19.5 | 19.9 | 19.5 | 17.3 | 17.9 | 17.8 | 17.7 | 18.5 | 18.5 | 18.5 | |
| 12A - 46 | " | 20.8 | 19.8 | 19.6 | 19.9 | 20.0 | 19.4 | 18.9 | 19.8 | 19.4 | 18.9 | 19.3 | 19.1 | |
| 7A - 46 | " | 19.3 | 17.9 | 18.6 | 18.9 | 18.6 | 17.1 | 18.2 | 18.2 | 17.8 | 19.4 | 18.6 | 19.0 | |
| 125A - 46 | " | 18.7 | 18.1 | 18.7 | 19.0 | 18.6 | 17.3 | 17.1 | 18.1 | 17.5 | 18.7 | 18.9 | 18.8 | |
| 9A - 46 | " | 19.5 | 19.5 | 19.8 | 20.6 | 19.8 | 18.8 | 18.7 | 18.9 | 18.8 | 19.5 | 19.8 | 19.7 | |
| 96A - 46 | " | 18.8 | 19.1 | 19.7 | 20.1 | 19.4 | 18.2 | 18.1 | 18.8 | 18.4 | 20.5 | 20.5 | 20.5 | |
| Altitude means for coast type | | | | | | 19.3 | | | | 17.9 | | | 19.0 | 18.78 |
| 1A - 46 | Mountain | 16.3 | 16.4 | 18.9 | 18.6 | 17.5 | 14.6 | 14.5 | 15.0 | 14.7 | 15.8 | 15.5 | 15.6 | |
| 39A - 46 | " | 16.7 | 16.3 | 18.1 | 18.9 | 17.5 | 15.6 | 15.5 | 15.7 | 15.6 | 15.8 | 15.9 | 15.8 | |
| 106A - 46 | " | 17.2 | 17.2 | 18.8 | 19.1 | 18.1 | 16.5 | 16.5 | 16.8 | 16.6 | 16.9 | 17.2 | 17.1 | |
| 33A - 46 | " | 18.1 | 18.1 | 19.8 | 20.5 | 19.1 | 18.0 | 16.9 | 17.6 | 17.5 | 17.1 | 17.3 | 17.2 | |

Table 13. (Continued)

| Maize tested | | Mean number of nodes at different sites | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number | Type | Low altitude sites | | | | | Mid altitude sites | | | | High alt. sites | | | All alt. mean |
| | | 1 | 2 | 3 | 4 | Mean | 5 | 6 | 7 | Mean | 8 | 9 | Mean | |
| Altitude means for mountain types | | | | | | 18.1 | | | | 16.1 | | | 16.4 | 17.04 |
| 15A - 46 | Giant | 20.2 | 20.1 | 22.1 | 23.7 | 21.5 | 22.2 | 21.0 | 20.5 | 21.3 | 21.4 | 21.0 | 21.2 | |
| 17A - 46 | " | 21.8 | 21.5 | 23.2 | 24.2 | 22.7 | 22.5 | 22.4 | 22.0 | 22.4 | 22.0 | 21.9 | 22.0 | |
| 47A - 46 | " | 18.8 | 18.3 | 20.5 | 21.2 | 19.7 | 20.3 | 20.0 | 20.2 | 20.2 | 19.3 | 19.9 | 19.6 | |
| 138A - 46 | " | 20.5 | 19.7 | 21.1 | 26.3 | 21.9 | 23.2 | 25.7 | 24.3 | 24.4 | 22.4 | 21.9 | 22.2 | |
| 14A - 46 | " | 22.0 | 21.1 | 21.8 | 23.5 | 22.1 | 22.9 | 21.1 | 21.1 | 21.7 | 20.0 | 19.7 | 19.9 | |
| Altitude means for giant type | | | | | | 21.6 | | | | 22.0 | | | 20.9 | 21.59 |
| Altitude means for all types | | | | | | 18.0 | | | | 17.1 | | | 17.5 | 17.62 |

Table 14. Individual analysis of variance of the numbers of nodes of 25 entries of maize for each of the nine sites in Guatemala.

| Experiment | Entries d.f. | Entries M.S. | Error d.f. | Error M.S. | F* | C.V. % |
|---|---|---|---|---|---|---|
| | | | Low altitude | | | |
| 1 | 24 | 24.02 | 48 | .2342 | 102.56 | 2.62 |
| 2 | 24 | 25.61 | 48 | .1250 | 204.90 | 2.03 |
| 3 | 24 | 21.14 | 48 | .0308 | 302.00 | 1.46 |
| 4 | 24 | 31.59 | 48 | .1646 | 197.44 | 2.12 |
| | | | Mid altitude | | | |
| 5 | 24 | 35.20 | 48 | .4388 | 80.00 | 3.81 |
| 6 | 24 | 32.02 | 48 | .2925 | 110.41 | 3.18 |
| 7 | 24 | 23.99 | 48 | .1079 | 218.09 | 1.88 |
| | | | High altitude | | | |
| 8 | 24 | 21.95 | 48 | .0448 | 489.95 | 1.21 |
| 9 | 24 | 22.20 | 48 | .1825 | 123.33 | 2.44 |

* For all values of F, $P < 0.01$.

Table 15. Combined analysis of variance of the numbers of nodes of 25 entries of maize for nine sites in Guatemala.

| Source of variation | Degrees of freedom | | Mean squares |
|---|---|---|---|
| Altitudes | 2 | | 52.56 |
| Entries | 24 | | 220.10 |
| Between types | | 4 | 1,231.23 |
| Within types | | 20 | 17.87 |
| Altitudes x Entries | 48 | | 5.09 |
| Altitudes x Between types | | 8 | 16.90 |
| Altitudes x Within types | | 40 | 2.72 |
| Sites within altitudes | 6 | | 29.37 |
| Entries x Sites within altitudes | 144 | | 1.06 |
| Total | 224 | | 26.61 |

for any one Guatemalan type remained distinct from the numbers recorded for other types. There was, however, a similarity in the values of the Early Type and in those for the single-crosses grown from Iowa seed.

The constancy of this character was borne out by the individual analysis of variance. Table 14 shows the extremely low values of error mean square, the large F values and the very small coefficients of variation for each of the nine sites. Greatest variation in numbers of nodes occurred at Site 5 while Site 8 showed the least.

The combined analysis of variance showed that the greatest source of variation was that produced by the between type difference of the entries. The variations among entries within types were very slight. Altitudinal variation was considered attributable to the unexplained depression in values at mid altitude. The variation of this factor within entries at the sites within an altitude was almost negligible, as shown by the error mean square 1.06 (Table 15).

Arithmetical values were calculated for predicting time of anthesis in the field in Guatemala. For this purpose the mean value for days to anthesis of all entries was divided by the mean number of nodes for all entries. These quotients for the first plantings at low altitude Site 1 and mid altitude Site 5 were used to predict the time of anthesis for other plantings at the same altitudes. Thus the value 2.98 (rounded to 3) was used at low altitude and 4.99 (rounded to 5) was used at mid altitude. As an example, the mean node number of 17.1 recorded for entry 101A-46 at Site 5 was multiplied by the value of 5 to predict its expected day of anthesis at Site 6. The resultant value of 85.5 proved to be only 0.5 days in error of the actual time of 86 days recorded for

Table 16. Analysis of variance for linear regression of time of anthesis on node number, based on altitude means, for 25 entries of maize grown in Guatemala, together with the appropriate prediction equation.

| Variation due to | d.f. | M.S. | F* | Prediction equation |
|---|---|---|---|---|
| | | Low altitude | | |
| Regression | 1 | 1,489.84 | 49.5 | $\hat{Y} = 5.17 + 2.78X$ |
| Dev. from Reg. | 23 | 30.24 | | |
| | | Mid altitude | | |
| Regression | 1 | 5,439.21 | 166.7 | $\hat{Y} = 1.64 + 4.77X$ |
| Dev. from Reg. | 23 | 32.62 | | |
| | | High altitude | | |
| Regression | 1 | 5,660.83 | 87.0 | $\hat{Y} = 18.66 + 5.74X$ |
| Dev. from Reg. | 23 | 65.04 | | |

Site 6. Predictions at low altitude did not prove as accurate but were sufficiently so to be useful. That these simple values were not greatly in error was proven when the analysis for linear regression of time of anthesis on node number was completed on the data collected in Guatemala. This analysis is presented in Table 16.

With the use of the prediction equation it is possible to predict the date of anthesis of any sample collected. Thus at the mid altitude of 1,500 meters any collector could predict the time of anthesis of a single or multiple plant sample, or the progeny thereof. Multiply the node number of the single sample or mean node number of the multiple sample by 4.77 and add 1.64 to the sum. The value derived should closely approximate the date of anthesis of the sample if planted at that altitude. By interpolation or derivation similar prediction equations could be derived for any altitude desired. Equations of this kind should be of use to the breeder in planning his plantings for cross pollinations.

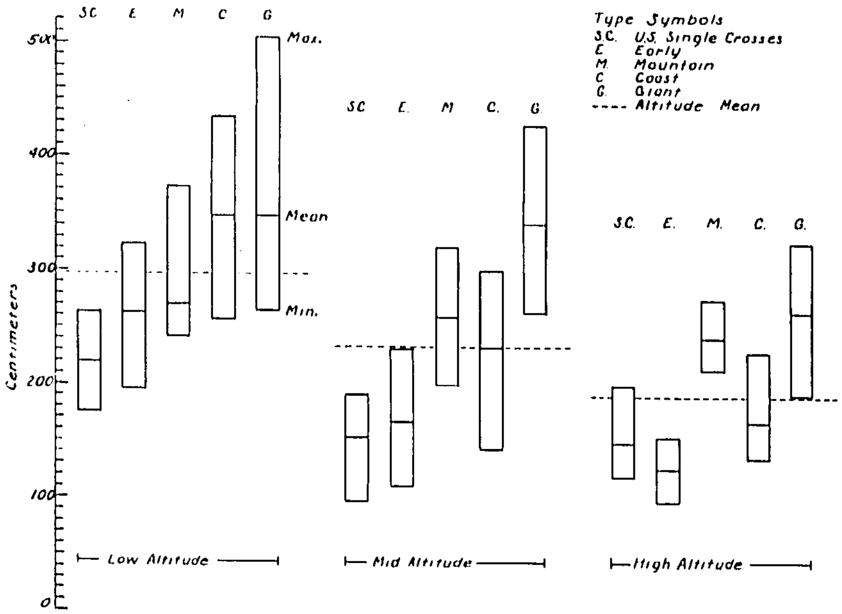
It will be noticed that the deviation from regression was quite similar at low and at mid altitudes. The greater deviation at high altitude is probably attributable to the differences in days to anthesis between Sites 8 and 9. These sites were located at 2,286 and 2,449 meters respectively with a resultant climatic difference. There was considerable difference between the two sites as to time of anthesis (Table 11) although other responses were quite similar.

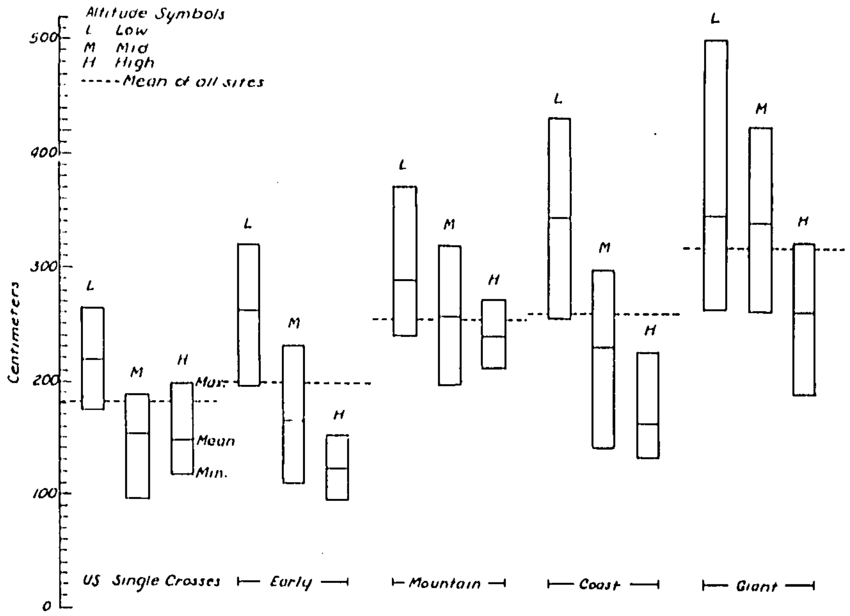
## Height

Height was one of the most indicative of the characters studied for

PLATE 40

Means and extremes of plant height of five maize types, grown at low, mid, and high altitudes in Guatemala, compared with the altitude mean for all types (A, above) and with the mean for all sites for each type (B, below).


SC
E
M
C
G
Max.
Mean
Min.
500
400
300
200
100
0
Centimeters
Type Symbols
SC. U.S. Single Crosses
E Early
M Mountain
C Coast
G Giant
---- Altitude Mean
Low Altitude
Mid Altitude
High Altitude


Altitude Symbols
L Low
M Mid
H High
-----Mean of all sites
500
400
300
200
100
0
Centimeters
Max.
Mean
Min.
US Single Crosses
Early
Mountain
Coast
Giant

growth response to climate. It was the character which most readily distinguished the type. As may be seen in Table 17 the height of the individual entries as well as the type groups of entries varied considerably from one altitude-climate to another. Plate 40 illustrates the interesting shifts in this character from one altitude to another. All of the types reached their greatest mean heights at low altitude. This was not always true of individual variants within the Giant and Mountain Types. In the Giant and Mountain Types this response often reached maximum at the expense of reproductive tissues. The U. S. single-crosses never reached the maximum, or mean, height which they attain in Iowa. However they never lost their morphological identity.

The individual analysis of variance (Table 17) for height at the nine sites showed by the low coefficients of variation that this growth response was quite uniform at any given site. Site 1 exhibited the greatest variation. The error mean squares were quite variable. Lodging among the Mountain and Giant Types at low altitude was partly responsible for this variability. These types responded abnormally at low altitude with very poor root development; root growth being insufficient to support top growth.

The combined analysis of variance brought out the fact that the principal sources of variation were attributable to altitude and between types differences among entries. There was also a quite noticeable interaction among altitudes x entries most of which proved to be due to within type differences. The error mean square was negligible considering the magnitude of the character values (Table 19).

Table 17. Heights of 25 entries of maize planted at nine sites at low, intermediate and high altitudes in Guatemala.

| Maize tested | | Mean height in centimeters at diffe | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Low altitude sites | | | | | Mid altitude sites | | | |
| Number | Type | 1 | 2 | 3 | 4 | Mean | 5 | 6 | 7 | Mea |
| 153 x WF9 | S. cross | 224.9 | 202.1 | 214.4 | 212.0 | 213.3 | 155.4 | 142.6 | 147.2 | 148 |
| 205 x 289 | " " | 249.4 | 235.9 | 234.1 | 233.1 | 238.1 | 162.5 | 166.1 | 167.3 | 165 |
| 205 x 234 | " " | 226.8 | 208.9 | 219.5 | 222.8 | 219.5 | 167.9 | 152.5 | 156.4 | 158 |
| M14 x WF9 | " " | 228.1 | 213.7 | 221.2 | 211.1 | 218.5 | 170.5 | 152.0 | 149.9 | 157 |
| M14 x Wis.22 | " " | 214.3 | 201.8 | 207.1 | 198.9 | 205.5 | 146.4 | 138.7 | 142.5 | 142 |
| Altitude means for U.S. single crosses | | | | | | 219.0 | | | | 154 |
| 30A - 46 | Early | 263.5 | 279.3 | 259.7 | 258.7 | 265.3 | 182.8 | 181.0 | 169.7 | 177 |
| 32A - 46 | " | 283.1 | 298.0 | 260.0 | 257.6 | 274.7 | 165.2 | 171.5 | 173.9 | 170 |
| 25 - 44 | " | 249.2 | 255.2 | 241.1 | 240.1 | 246.4 | 149.0 | 151.9 | 157.4 | 153 |
| Altitude means for early type | | | | | | 262.1 | | | | 167 |
| 101A - 46 | Coast | 324.4 | 376.8 | 373.2 | 342.6 | 354.2 | 238.6 | 240.6 | 240.9 | 240 |
| 13 - 44 | " | 316.4 | 333.8 | 323.2 | 322.0 | 323.8 | 197.1 | 202.9 | 195.8 | 198 |
| 42A - 46 | " | 370.2 | 357.3 | 368.0 | 361.5 | 364.2 | 254.1 | 241.5 | 244.5 | 246 |
| 12A - 46 | " | 375.7 | 395.7 | 387.8 | 385.9 | 386.3 | 275.3 | 264.7 | 269.4 | 269 |
| 7A - 46 | " | 333.9 | 289.5 | 298.5 | 295.4 | 304.3 | 211.6 | 210.3 | 224.2 | 215 |
| 125A - 46 | " | 339.1 | 338.4 | 327.4 | 327.5 | 333.1 | 190.8 | 216.9 | 196.1 | 201 |
| 9A - 46 | " | 351.7 | 361.5 | 357.1 | 356.9 | 356.8 | 247.9 | 239.1 | 241.1 | 242 |
| 96A - 46 | " | 331.3 | 351.5 | 351.5 | 348.6 | 345.7 | 246.3 | 239.8 | 247.6 | 244 |
| Altitude means for coast type | | | | | | 346.1 | | | | 232 |
| 1A - 46 | Mountain | 294.0 | 291.0 | 308.3 | ------ | 300.6 | 234.7 | 225.7 | 237.2 | 232 |
| 39A - 46 | " | 246.0 | 249.6 | 240.0 | ------ | 246.8 | 254.3 | 249.1 | 244.0 | 249 |
| 106A - 46 | " | 320.5 | 322.5 | ------ | 351.0 | 331.1 | 281.0 | 262.3 | 281.7 | 275 |
| 33A - 46 | " | 283.6 | 285.7 | 290.9 | 270.0 | 283.3 | 273.7 | 273.9 | 281.7 | 276 |
| Altitude means for mountain type | | | | | | 290.1 | | | | 258 |
| 15A - 46 | Giant | 280.8 | 288.5 | 286.4 | 395.1 | 313.6 | 338.9 | 325.8 | 337.6 | 334 |
| 17A - 46 | " | 367.1 | 356.8 | 393.8 | 447.0 | 395.4 | 377.9 | 361.1 | 377.3 | 372 |
| 47A - 46 | " | 300.9 | 310.7 | 304.4 | 377.0 | 314.7 | 288.1 | 305.9 | 296.9 | 296 |
| 138A - 46 | " | 307.0 | 303.0 | 320.5 | 487.8 | 359.8 | 374.3 | 370.1 | ------ | 372 |
| 14A - 46 | " | 420.0 | 366.5 | 407.0 | 384.6 | 385.8 | 355.2 | 328.6 | 344.9 | 342 |
| Altitude means for giant type | | | | | | 348.6 | | | | 341. |
| Altitude means for all types | | | | | | 298.0 | | | | 233 |

of 25 entries of maize planted at nine sites at
ermediate and high altitudes in Guatemala.

| | Mean height in centimeters at different sites | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Low altitude sites | | | | Mid altitude sites | | | | High altitude sites | | | All alt. mean |
| | 2 | 3 | 4 | Mean | 5 | 6 | 7 | Mean | 8 | 9 | Mean | |
| | 202.1 | 214.4 | 212.0 | 213.3 | 155.4 | 142.6 | 147.2 | 148.4 | 158.5 | 165.7 | 162.1 | |
| | 235.9 | 234.1 | 233.1 | 238.1 | 162.5 | 166.1 | 167.3 | 165.3 | 174.7 | 183.1 | 178.9 | |
| | 208.9 | 219.5 | 222.8 | 219.5 | 167.9 | 152.5 | 156.4 | 158.9 | 130.8 | 126.5 | 128.6 | |
| | 213.7 | 221.2 | 211.1 | 218.5 | 170.5 | 152.0 | 149.9 | 157.4 | 146.9 | 151.1 | 149.0 | |
| | 201.8 | 207.1 | 198.9 | 205.5 | 146.4 | 138.7 | 142.5 | 142.5 | 125.6 | 124.7 | 125.1 | |
| rosses | | | | 219.0 | | | | 154.5 | | | 148.8 | 181.9 |
| | 279.3 | 259.7 | 258.7 | 265.3 | 182.8 | 181.0 | 169.7 | 177.8 | 138.5 | 136.0 | 137.3 | |
| | 298.0 | 260.0 | 257.6 | 274.7 | 165.2 | 171.5 | 173.9 | 170.2 | 125.4 | 115.0 | 120.2 | |
| | 255.2 | 241.1 | 240.1 | 246.4 | 149.0 | 151.9 | 157.4 | 153.1 | 119.8 | 118.1 | 118.9 | |
| | | | | 262.1 | | | | 167.0 | | | 125.5 | 200.6 |
| | 376.8 | 373.2 | 342.6 | 354.2 | 238.6 | 240.6 | 240.9 | 240.0 | 155.9 | 157.4 | 156.8 | |
| | 333.8 | 323.2 | 322.0 | 323.8 | 197.1 | 202.9 | 195.8 | 198.6 | 151.9 | 151.5 | 151.7 | |
| | 357.3 | 368.0 | 361.5 | 364.2 | 254.1 | 241.5 | 244.5 | 246.7 | 189.8 | 189.8 | 189.8 | |
| | 395.7 | 387.8 | 385.9 | 386.3 | 275.3 | 264.7 | 269.4 | 269.8 | 176.1 | 186.5 | 181.3 | |
| | 289.5 | 298.5 | 295.4 | 304.3 | 211.6 | 210.3 | 224.2 | 215.4 | 192.7 | 199.7 | 196.2 | |
| | 338.4 | 327.4 | 327.5 | 333.1 | 190.8 | 216.9 | 196.1 | 201.3 | 156.1 | 144.8 | 150.5 | |
| | 361.5 | 357.1 | 356.9 | 356.8 | 247.9 | 239.1 | 241.1 | 242.7 | 143.2 | 148.1 | 145.7 | |
| | 351.5 | 351.5 | 348.6 | 345.7 | 246.3 | 239.8 | 247.6 | 244.6 | 155.0 | 154.7 | 154.8 | |
| | | | | 346.1 | | | | 232.4 | | | 165.9 | 268.1 |
| | 291.0 | 308.3 | ------ | 300.6 | 234.7 | 225.7 | 237.2 | 232.5 | 234.6 | 236.4 | 235.5 | |
| | 249.6 | 240.0 | ------ | 246.8 | 254.3 | 249.1 | 244.0 | 249.1 | 251.6 | 241.8 | 246.7 | |
| | 322.5 | ------ | 351.0 | 331.1 | 281.0 | 262.3 | 281.7 | 275.0 | 258.1 | 246.1 | 252.1 | |
| | 285.7 | 290.9 | 270.0 | 283.3 | 273.7 | 273.9 | 281.7 | 276.4 | 234.9 | 228.3 | 231.9 | |
| | | | | 290.1 | | | | 258.3 | | | 241.6 | 256.0 |
| | 288.5 | 286.4 | 395.1 | 313.6 | 338.9 | 325.8 | 337.6 | 334.1 | 282.2 | 290.6 | 286.4 | |
| | 356.8 | 393.8 | 447.0 | 395.4 | 377.9 | 361.1 | 377.3 | 372.1 | 268.7 | 271.1 | 269.9 | |
| | 310.7 | 304.4 | 377.0 | 314.7 | 288.1 | 305.9 | 296.9 | 296.9 | 248.0 | 240.1 | 244.0 | |
| | 303.0 | 320.5 | 487.8 | 359.8 | 374.3 | 370.1 | ------ | 372.2 | 287.1 | 289.3 | 288.2 | |
| | 366.5 | 407.0 | 384.6 | 385.8 | 355.2 | 328.6 | 344.9 | 342.9 | 227.6 | 227.4 | 227.5 | |
| | | | | 348.6 | | | | 341.6 | | | 263.2 | 320.4 |
| | | | | 298.0 | | | | 233.5 | | | 189.1 | 247.0 |

Table 18. Individual analysis of variance of the heights of 25 entries[1] of maize for each of the nine sites in Guatemala.

| Experiment | Entries d.f. | Entries M.S. | Error d.f. | Error M.S. | F* | C.V. % |
|---|---|---|---|---|---|---|
| | | | Low altitude | | | |
| 1 | 18 | 8,861.44 | 36 | 817.26 | 10.84 | 9.52 |
| 2 | 17 | 12,857.32 | 34 | 157.75 | 81.50 | 4.21 |
| 3 | 16 | 11,907.67 | 32 | 35.16 | 338.67 | 2.04 |
| 4 | 19 | 16,762.45 | 38 | 187.57 | 89.37 | 4.43 |
| | | | Mid altitude | | | |
| 5 | 24 | 15,038.92 | 48 | 146.62 | 102.57 | 4.75 |
| 6 | 24 | 14,109.11 | 48 | 71.98 | 196.01 | 3.66 |
| 7 | 23 | 13,464.23 | 46 | 51.47 | 261.59 | 3.13 |
| | | | High altitude | | | |
| 8 | 24 | 8,975.50 | 48 | 23.45 | 382.75 | 3.95 |
| 9 | 24 | 8,800.54 | 48 | 56.46 | 155.87 | 3.97 |

* For all values of F, $P < 0.01$.

[1] Missing values due to death or lodging.

Table 19. Combined analysis of variance of the heights of 25 entries of maize for nine sites in Guatemala.

| Source of variation | Degrees of freedom | | Mean squares |
|---|---|---|---|
| Altitudes | 2 | | 719,176.50 |
| Entries | 24 | | 83,259.21 |
| Between types | | 4 | 450,211.50 |
| Within types | | 20 | 9,868.75 |
| Altitudes x Entries | 48 | | 10,476.56 |
| Altitudes x Between types | | 8 | 5,899.87 |
| Altitudes x Within types | | 40 | 11,391.90 |
| Sites within altitudes | 6 | | 1,881.83 |
| Entries x Sites within altitudes | 140[1] | | 1,078.64 |
| Total | 220 | | 18,644.32 |

[1] Reduced by 4 for missing values.

## Mean Daily Increase in Height

It was not possible to secure individual growth curves for the plants on which measurements were taken. Therefore the next best alternative was adopted. The mean daily growth rate, a function of time of anthesis and height, was calculated for each plant. The mean values of these calculations are tabulated in Table 20. Plate 41 presents the mean and extremes of the calculated values.

Rates of growth for all entries were greatest at low altitude and were inversely proportional to altitude. At any given altitude the entries which made the greatest mean daily increase in height were those belonging to the type adapted to that altitude.

The abnormal growth responses resulted in very large coefficients of variation and error mean squares for the four low altitude sites (Table 21). Variation was almost entirely attributable to altitude.

## Leaf Area

The magnitude of the leaf area of each entry proved to be quite characteristic of the type to which that entry belonged. This is clearly presented in Table 23. Plate 42 shows that for all types except the Giant this response was greatest at low altitude and decreased as altitude increased. The Giant Type produced the largest leaves in its natural environment, i.e. mid altitude.

PLATE 41

Means and extremes of daily growth rate of five maize types, grown at low, mid, and high altitudes in Guatemala, compared with the altitude mean for all types (A, above) and with the mean of all sites for each type (B, below).

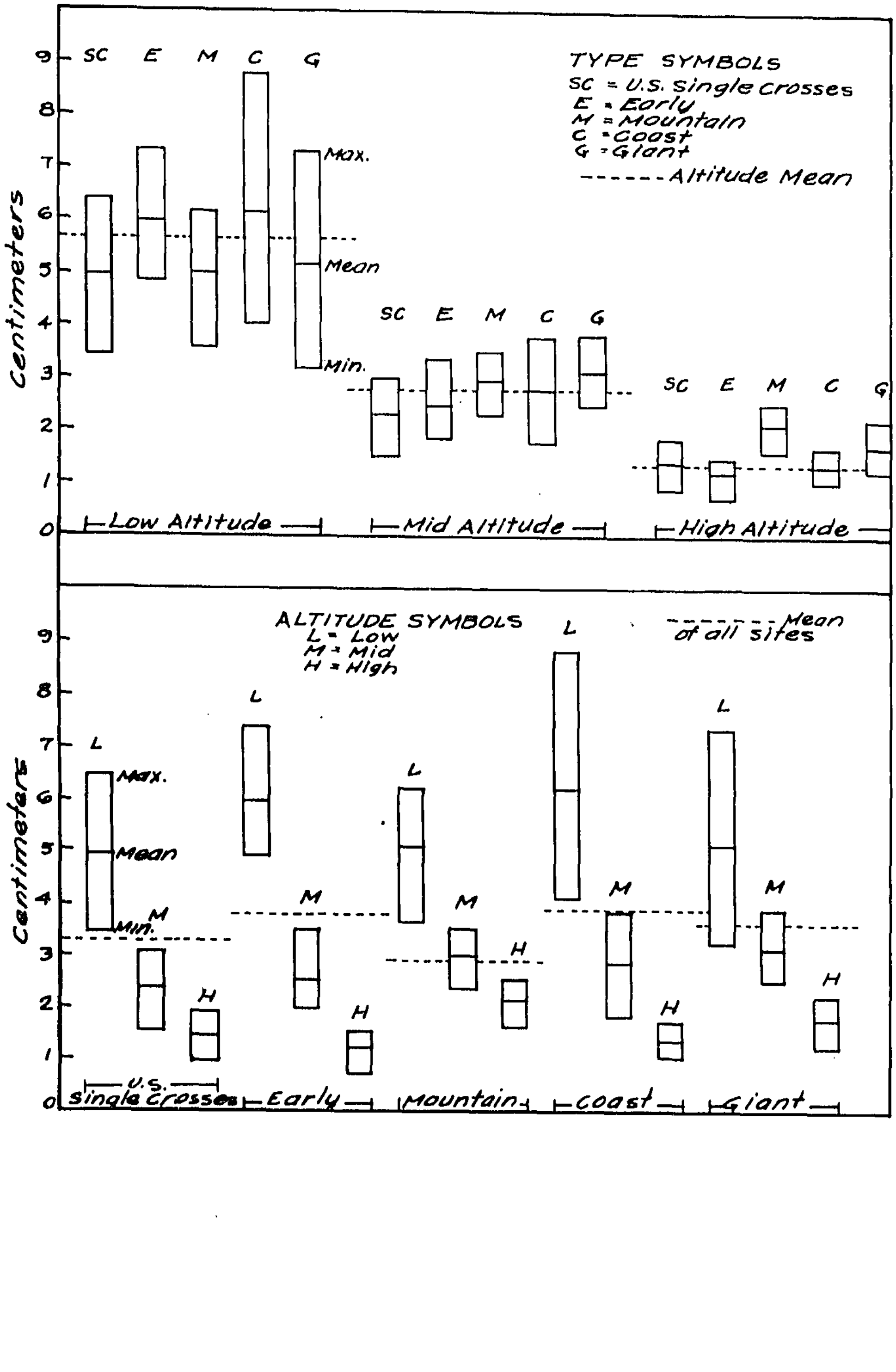

TYPE SYMBOLS
SC = U.S. single crosses
E = Early
M = Mountain
C = Coast
G = Giant
------ Altitude Mean
Centimeters
SC E M C G
Max.
Mean
Min.
Low Altitude
Mid Altitude
High Altitude
ALTITUDE SYMBOLS
L = Low
M = Mid
H = High
------ Mean of all sites
U.S. Single Crosses
Early
Mountain
Coast
Giant

Table 20. Mean daily increases in heights of 25 entries of maize planted at nine sites at low, intermediate and high altitudes in Guatemala.

| Maize tested | | Mean daily increase in height in centimeters at different sites | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Low altitude sites | | | | | Mid altitude sites | | | | High alt. sites | | | All alt. mean |
| Number | Type | 1 | 2 | 3 | 4 | Mean | 5 | 6 | 7 | Mean | 8 | 9 | Mean | |
| 153 x WF9 | S. cross | 5.84 | 4.29 | 5.12 | 5.30 | 5.14 | 2.54 | 2.26 | 2.29 | 2.36 | 1.65 | 1.53 | 1.59 | |
| 205 x 289 | " " | 6.08 | 5.05 | 5.32 | 5.17 | 5.40 | 2.38 | 2.37 | 2.39 | 2.38 | 1.78 | 1.74 | 1.76 | |
| 205 x 234 | " " | 4.93 | 4.26 | 4.98 | 5.43 | 4.90 | 2.56 | 2.24 | 2.23 | 2.34 | 1.32 | 1.04 | 1.18 | |
| M14 x WF9 | " " | 5.44 | 4.27 | 4.91 | 4.80 | 4.85 | 2.43 | 2.20 | 2.20 | 2.28 | 1.42 | 1.51 | 1.46 | |
| M14 x Wis.22 | " | 4.98 | 3.79 | 4.60 | 4.32 | 4.42 | 2.09 | 1.98 | 2.03 | 2.03 | 1.26 | 1.14 | 1.20 | |
| Altitude means for U.S. single crosses | | | | | | 4.94 | | | | 2.28 | | | 1.44 | 3.28 |
| 30A - 46 | Early | 6.42 | 5.93 | 6.04 | 5.75 | 6.04 | 2.64 | 2.62 | 2.53 | 2.60 | 1.41 | 1.29 | 1.35 | |
| 32A - 46 | " | 6.74 | 5.84 | 5.30 | 5.72 | 5.90 | 2.39 | 2.52 | 2.45 | 2.45 | 1.26 | .94 | 1.10 | |
| 25 - 44 | " | 6.38 | 5.62 | 6.03 | 5.71 | 5.94 | 2.45 | 2.49 | 2.45 | 2.46 | 1.27 | 1.14 | 1.20 | |
| Altitude means for early type | | | | | | 5.96 | | | | 2.50 | | | 1.22 | 3.71 |
| 101A - 46 | Coast | 7.05 | 5.71 | 6.78 | 6.11 | 6.41 | 2.74 | 2.86 | 3.02 | 2.87 | 1.37 | 1.18 | 1.27 | |
| 13 - 44 | " | 5.97 | 5.47 | 6.20 | 6.44 | 6.02 | 2.56 | 2.59 | 2.57 | 2.57 | 1.47 | 1.29 | 1.39 | |
| 42A - 46 | " | 7.71 | 5.85 | 7.36 | 7.23 | 7.04 | 3.14 | 2.94 | 3.06 | 3.05 | 1.64 | 1.50 | 1.57 | |
| 12A - 46 | " | 7.17 | 6.38 | 6.50 | 6.32 | 6.59 | 3.19 | 3.00 | 3.13 | 3.11 | 1.54 | 1.29 | 1.41 | |
| 7A - 46 | " | 6.68 | 4.98 | 5.52 | 5.67 | 5.72 | 2.72 | 2.69 | 2.87 | 2.76 | 1.64 | 1.53 | 1.59 | |
| 125A - 46 | " | 6.78 | 5.93 | 5.62 | 5.62 | 5.99 | 2.44 | 2.78 | 2.57 | 2.60 | 1.44 | 1.16 | 1.30 | |
| 9A - 46 | " | 6.38 | 5.73 | 5.95 | 6.15 | 6.05 | 3.02 | 2.84 | 2.90 | 2.92 | 1.24 | 1.12 | 1.18 | |
| 96A - 46 | " | 5.99 | 5.48 | 5.66 | 5.80 | 5.74 | 2.84 | 2.78 | 2.92 | 2.85 | 1.31 | 1.17 | 1.24 | |
| Altitude means for coast type | | | | | | 6.19 | | | | 2.84 | | | 1.37 | 4.00 |
| 1A - 46 | Mountain | 4.98 | 4.68 | 5.13 | —— | 5.01 | 2.82 | 2.85 | 2.90 | 2.86 | 2.37 | 2.18 | 2.27 | |
| 39A - 46 | " | 3.83 | 3.73 | 3.69 | —— | 3.76 | 2.82 | 3.03 | 2.94 | 2.93 | 2.44 | 2.15 | 2.30 | |
| 106A - 46 | " | 5.42 | 5.11 | —— | 5.75 | 5.43 | 3.11 | 3.12 | 3.24 | 3.16 | 2.27 | 2.00 | 2.14 | |
| 33A - 46 | " | 5.66 | 5.09 | 5.28 | 4.50 | 5.26 | 3.00 | 3.01 | 3.16 | 3.06 | 2.05 | 1.80 | 1.92 | |
| Altitude means for mountain type | | | | | | 5.03 | | | | 3.00 | | | 2.16 | 2.93 |

Table 20. (Continued)

| Maize tested | | Mean daily increase in height in centimeters at different sites | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number | Type | Low altitude sites | | | | | Mid altitude sites | | | | High alt. sites | | | All alt. mean |
| | | 1 | 2 | 3 | 4 | Mean | 5 | 6 | 7 | Mean | 8 | 9 | Mean | |
| 15A - 46 | Giant | 3.46 | 3.84 | 3.72 | 5.26 | 4.05 | 3.02 | 3.16 | 3.18 | 3.12 | 2.12 | 2.01 | 2.07 | |
| 17A - 46 | " | 6.04 | 4.76 | 5.62 | 6.78 | 5.87 | 3.40 | 3.50 | 3.59 | 3.49 | 1.99 | 1.84 | 1.92 | |
| 47A - 46 | " | 6.00 | 4.57 | 4.92 | 6.17 | 5.06 | 2.74 | 3.09 | 2.97 | 2.93 | 1.90 | 1.69 | 1.79 | |
| 138A - 46 | " | 3.84 | 4.26 | 4.57 | 7.11 | 4.96 | 2.89 | 2.89 | —— | 2.89 | 1.78 | 1.64 | 1.71 | |
| 14A - 46 | " | 7.24 | 5.46 | 5.81 | 6.10 | 6.08 | 3.26 | 3.29 | 3.45 | 3.33 | 1.62 | 1.44 | 1.53 | |
| Altitude means for giant type | | | | | | 5.17 | | | | 3.17 | | | 1.80 | 3.62 |
| Altitude means for all types | | | | | | 5.66 | | | | 2.78 | | | 1.58 | 3.62 |

Table 21. Individual analysis of variance of the mean daily growth rates of 25 entries[1] of maize for each of the nine sites in Guatemala.

| Experiment | Entries d.f. | Entries M.S. | Error d.f. | Error M.S. | F* | C.V. % |
|---|---|---|---|---|---|---|
| | | | Low altitude | | | |
| 1 | 18 | 278.78 | 36 | 7.4300 | 38.73 | 44.97 |
| 2 | 16 | 170.54 | 32 | 6.8900 | 24.75 | 50.02 |
| 3 | 16 | 153.82 | 32 | 2.4159 | 63.67 | 27.32 |
| 4 | 18 | 131.08 | 36 | 5.5978 | 41.03 | 23.42 |
| | | | Mid altitude | | | |
| 5 | 24 | .3134 | 48 | .0205 | 15.29 | 4.65 |
| 6 | 24 | .4106 | 48 | .0144 | 28.51 | 4.35 |
| 7 | 23 | .5137 | 46 | .0054 | 95.13 | 2.64 |
| | | | High altitude | | | |
| 8 | 24 | .4027 | 48 | .000769 | 523.66 | 1.67 |
| 9 | 24 | .3862 | 48 | .002354 | 160.92 | 3.26 |

* For all values of F, $P < 0.01$.

[1] Missing values due to death or lodging.

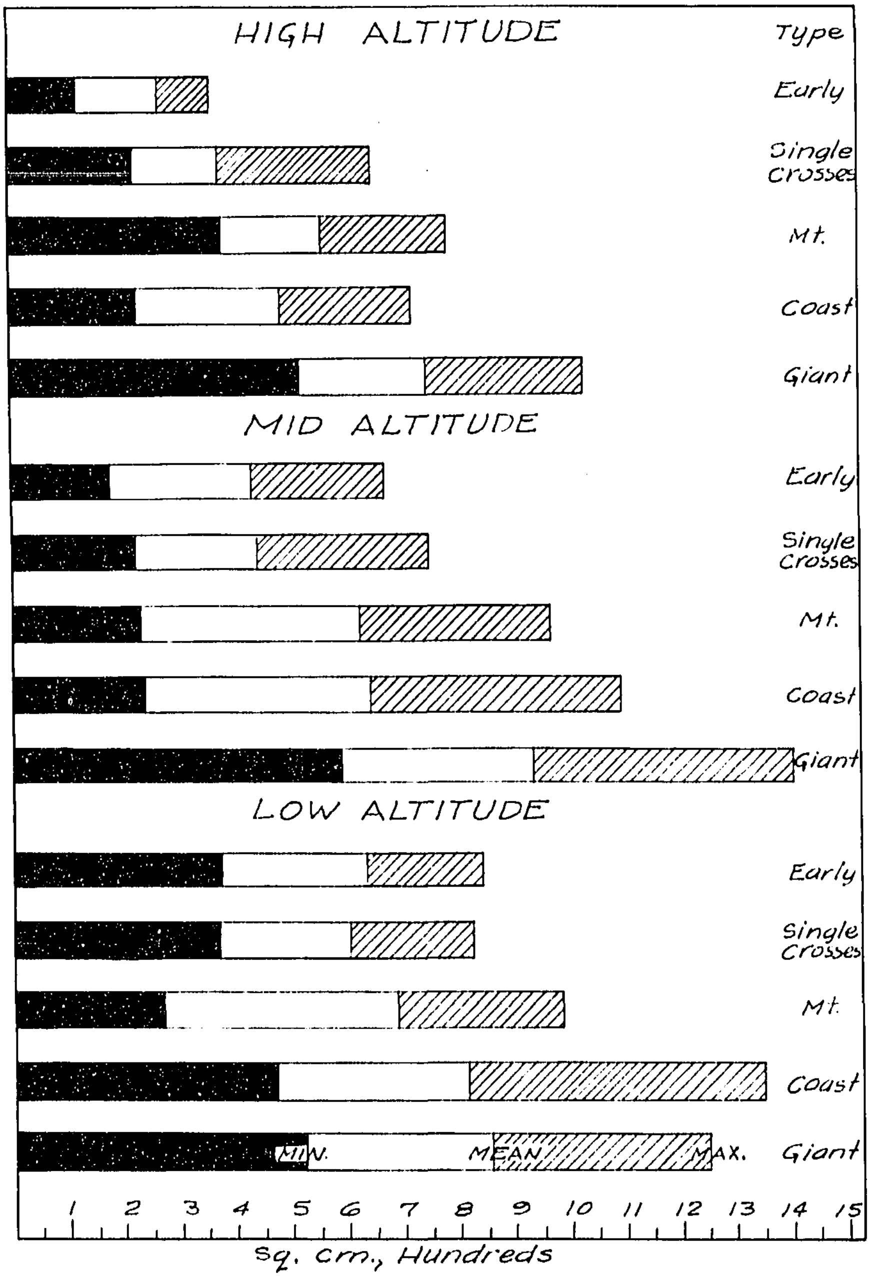
Table 22. Combined analysis of variance of the mean daily increases in heights of 25 entries of maize for nine sites in Guatemala.

| Source of variation | Degrees of freedom | | Mean squares |
|---|---|---|---|
| Altitudes | 2 | | 954.5960 |
| Entries | 24 | | 3.8049 |
| Between types | | 4 | 11.5240 |
| Within types | | 20 | 2.2601 |
| Altitudes x Entries | 48 | | 2.6738 |
| Altitudes x Between types | | 8 | 11.1111 |
| Altitudes x Within types | | 40 | 0.9863 |
| Sites within altitudes | 6 | | 4.9644 |
| Entries x Sites within altitudes | 140[1] | | .4009 |
| Total | 220 | | 9.7945 |

[1] Reduced by 4 for missing values.

PLATE 42

Mean and extreme leaf areas of five maize types grown at low, mid, and high altitudes in Guatemala.



HIGH ALTITUDE
Type
Early
Single Crosses
Mt.
Coast
Giant
MID ALTITUDE
Early
Single Crosses
Mt.
Coast
Giant
LOW ALTITUDE
Early
Single Crosses
Mt.
Coast
Giant
MIN.
MEAN
MAX.
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Sq. cm., Hundreds

Table 23. Leaf areas of 25 entries of maize planted at nine sites at low, intermediate and high altitudes in Guatemala.

| Maize tested | | Mean leaf area in square centimetersat di | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Low altitude sites | | | | | Mid altitude sites | | |
| Number | Type | 1 | 2 | 3 | 4 | Mean | 5 | 6 | 7 |
| 153 x WF9 | S. cross | 628.1 | 575.1 | 599.7 | 599.3 | 600.5 | 428.3 | 406.8 | 537.3 |
| 205 x 289 | " " | 667.0 | 664.6 | 611.1 | 627.0 | 642.4 | 356.2 | 480.4 | 527.2 |
| 205 x 234 | " " | 605.3 | 591.8 | 595.5 | 514.0 | 576.6 | 385.9 | 388.3 | 459.2 |
| M14 x WF9 | " " | 668.3 | 643.8 | 645.9 | 634.7 | 648.2 | 433.6 | 551.1 | 481.0 |
| M14 x Wis. 22 | " " | 578.0 | 539.7 | 560.1 | 526.3 | 551.0 | 359.5 | 438.7 | 410.6 |
| Altitude means for U.S. single crosses | | | | | | 603.8 | | | |
| 30A - 46 | Early | 627.5 | 688.6 | 665.8 | 664.1 | 661.5 | 380.8 | 470.7 | 557.9 |
| 32A - 46 | " | 641.3 | 669.6 | 649.6 | 626.7 | 646.8 | 379.7 | 474.3 | 493.0 |
| 25 - 44 | " | 611.5 | 627.7 | 617.7 | 537.4 | 598.6 | 337.4 | 384.2 | 462.3 |
| Altitude means for early type | | | | | | 635.6 | | | |
| 101A - 46 | Coast | 837.2 | 890.1 | 834.9 | 811.1 | 843.3 | 658.1 | 710.4 | 775.8 |
| 13 - 44 | " | 701.2 | 785.1 | 730.7 | 701.6 | 729.6 | 436.3 | 563.9 | 540.3 |
| 42A - 46 | " | 760.7 | 817.0 | 795.0 | 776.7 | 787.3 | 560.8 | 665.4 | 744.3 |
| 12A - 46 | " | 794.1 | 889.3 | 859.5 | 899.6 | 860.6 | 599.5 | 868.2 | 816.8 |
| 7A - 46 | " | 661.5 | 774.9 | 705.2 | 720.7 | 715.6 | 472.7 | 688.4 | 639.1 |
| 125A - 46 | " | 753.1 | 859.3 | 797.4 | 846.8 | 814.2 | 481.6 | 694.5 | 676.1 |
| 9A - 46 | " | 876.3 | 960.0 | 890.0 | 934.4 | 915.2 | 561.4 | 737.9 | 795.5 |
| 96A - 46 | " | 787.7 | 920.2 | 871.0 | 806.1 | 846.2 | 530.2 | 590.2 | 783.4 |
| Altitude means for coast type | | | | | | 814.0 | | | |
| 1A - 46 | Mountain | 734.5 | 723.6 | 628.9 | 601.9 | 672.2 | 475.3 | 584.5 | 636.9 |
| 39A - 46 | " | 728.5 | 742.7 | 682.5 | 614.5 | 692.0 | 556.0 | 580.5 | 615.3 |
| 106A - 46 | " | 816.5 | 814.3 | 643.5 | 630.7 | 726.2 | 617.5 | 742.5 | 639.0 |
| 33A - 46 | " | 724.7 | 733.9 | 647.5 | 621.9 | 682.0 | 625.5 | 720.9 | 738.7 |
| Altitude means for mountain type | | | | | | 693.1 | | | |
| 15A - 46 | Giant | 832.5 | 848.6 | 883.6 | 773.3 | 834.5 | 876.5 | 919.5 | 914.3 |
| 17A - 46 | " | 838.3 | 940.7 | 890.1 | 822.7 | 872.9 | 980.6 | 915.4 | 928.7 |
| 47A - 46 | " | 742.6 | 914.2 | 879.1 | 815.0 | 837.7 | 750.1 | 988.6 | 969.1 |
| 138A - 46 | " | 796.8 | 887.4 | 846.6 | 830.0 | 840.2 | 1,118.8 | 1,000.3 | 979.3 |
| 14A - 46 | " | 845.1 | 935.3 | 943.1 | 937.2 | 915.2 | 924.3 | 898.6 | 911.7 |
| Altitude means for giant type | | | | | | 860.0 | | | |
| Altitude means for all types | | | | | | 740.4 | | | |

ries of maize planted at nine sites at
d high altitudes in Guatemala.

| Mean leaf area in square centimetersat different sites | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ltitude sites | | | Mid altitude sites | | | | High alt. sites | | | All alt. Mean |
| 3 | 4 | Mean | 5 | 6 | 7 | Mean | 8 | 9 | Mean | |
| 599.7 | 599.3 | 600.5 | 428.3 | 406.8 | 537.3 | 457.4 | 466.6 | 457.4 | 462.0 | |
| 611.1 | 627.0 | 642.4 | 356.2 | 480.4 | 527.2 | 454.6 | 424.4 | 482.9 | 453.7 | |
| 595.5 | 514.0 | 576.6 | 385.9 | 388.3 | 459.2 | 411.1 | 277.6 | 278.1 | 277.9 | |
| 645.9 | 634.7 | 648.2 | 433.6 | 551.1 | 481.0 | 488.6 | 365.7 | 396.1 | 380.9 | |
| 560.1 | 526.3 | 551.0 | 359.5 | 438.7 | 410.6 | 402.9 | 339.3 | 351.7 | 345.5 | |
| | | 603.8 | | | | 442.9 | | | 384.0 | 501.8 |
| 665.8 | 664.1 | 661.5 | 380.8 | 470.7 | 557.9 | 469.8 | 310.8 | 304.2 | 307.5 | |
| 649.6 | 626.7 | 646.8 | 379.7 | 474.3 | 493.0 | 449.0 | 301.1 | 276.3 | 288.7 | |
| 617.7 | 537.4 | 598.6 | 337.4 | 384.2 | 462.3 | 394.6 | 255.4 | 195.6 | 225.5 | |
| | | 635.6 | | | | 437.8 | | | 273.9 | 489.3 |
| 834.9 | 811.1 | 843.3 | 658.1 | 710.4 | 775.8 | 714.7 | 487.4 | 487.3 | 487.0 | |
| 730.7 | 701.6 | 729.6 | 436.3 | 563.9 | 540.3 | 513.5 | 370.5 | 452.2 | 411.4 | |
| 795.0 | 776.7 | 787.3 | 560.8 | 665.4 | 744.3 | 656.8 | 573.5 | 539.8 | 556.7 | |
| 859.5 | 899.6 | 860.6 | 599.5 | 868.2 | 816.8 | 761.5 | 557.3 | 543.7 | 550.5 | |
| 705.2 | 720.7 | 715.6 | 472.7 | 688.4 | 639.1 | 600.1 | 581.2 | 563.3 | 572.2 | |
| 797.4 | 846.8 | 814.2 | 481.6 | 694.5 | 676.1 | 617.4 | 363.1 | 404.1 | 383.6 | |
| 890.0 | 934.4 | 915.2 | 561.4 | 737.9 | 795.5 | 698.3 | 480.8 | 445.1 | 462.9 | |
| 871.0 | 806.1 | 846.2 | 530.2 | 590.2 | 783.4 | 634.7 | 463.9 | 466.9 | 465.4 | |
| | | 814.0 | | | | 649.6 | | | 486.2 | 686.4 |
| 628.9 | 601.9 | 672.2 | 475.3 | 584.5 | 636.9 | 565.5 | 489.4 | 504.8 | 497.1 | |
| 682.5 | 614.5 | 692.0 | 556.0 | 580.5 | 615.3 | 583.9 | 557.3 | 597.5 | 577.4 | |
| 643.5 | 630.7 | 726.2 | 617.5 | 742.5 | 639.0 | 666.3 | 593.8 | 602.7 | 598.3 | |
| 647.5 | 621.9 | 682.0 | 625.5 | 720.9 | 738.7 | 695.0 | 577.2 | 574.7 | 576.0 | |
| | | 693.1 | | | | 627.7 | | | 562.2 | 642.2 |
| 883.6 | 773.3 | 834.5 | 876.5 | 919.5 | 914.3 | 903.4 | 749.0 | 759.8 | 754.4 | |
| 890.1 | 822.7 | 872.9 | 980.6 | 915.4 | 928.7 | 942.5 | 734.7 | 769.1 | 751.9 | |
| 879.1 | 815.0 | 837.7 | 750.1 | 988.6 | 969.1 | 902.6 | 758.8 | 789.9 | 774.4 | |
| 846.6 | 830.0 | 840.2 | 1,118.8 | 1,000.3 | 979.3 | 1,032.8 | 780.9 | 794.0 | 792.1 | |
| 943.1 | 937.2 | 915.2 | 924.3 | 898.6 | 911.7 | 911.5 | 714.1 | 665.9 | 690.0 | |
| | | 860.0 | | | | 938.6 | | | 752.5 | 862.4 |
| | | 740.4 | | | | 637.1 | | | 505.7 | 653.9 |

The individual analysis of variance (Table 24) brought out the fact that, although leaf area was quite variable from site to site, none of the coefficients of variation were larger than might have been expected for such a character.

There is room for criticism of the method used to measure leaf area. Leaf shapes were quite variable, the average leaf shape varied from type to type and the shape varied slightly with climate. However, the error mean square derived in the combined analysis of variance (Table 25) was remarkably small. It is clear that experimental error in the measurement of this response was not great. The principal sources of variation were shown to be attributable to altitude and between type differences. Sites within altitudes also contributed somewhat to the general sources of variation. All in all the area of the median leaf as an indicator of growth response proved much more reliable than was anticipated.

## Basal Area

Basal area exhibited considerable variability. The measurement of larger samples would have been preferable in the case of this character. However, the samples drawn indicate that the range of basal areas for any entry are indicative of the type of which that entry was a variant. This is especially true at low and high altitudes (Table 26). At mid altitude there was less variation from type to type. Plate 43 presents the comparative magnitude of the mean and extreme values for each of the types

Table 24. Individual analysis of variance of the leaf areas of 25 entries of maize for each of the nine sites in Guatemala.

| Experiment | Entries d.f. | Entries M.S. | Error d.f. | Error M.S. | F* | C.V. % |
|---|---|---|---|---|---|---|
| | | | Low altitude | | | |
| 1 | 24 | 24,259.23 | 48 | 1,749.84 | 13.86 | 5.68 |
| 2 | 24 | 47,487.44 | 48 | 2,238.26 | 21.22 | 6.09 |
| 3 | 24 | 41,638.04 | 48 | 581.61 | 71.59 | 3.25 |
| 4 | 24 | 49,117.17 | 48 | 2,201.47 | 22.31 | 6.20 |
| | | | Mid altitude | | | |
| 5 | 24 | 131,063.92 | 48 | 3,215.21 | 40.76 | 9.86 |
| 6 | 24 | 111,047.85 | 48 | 2,554.64 | 43.47 | 7.45 |
| 7 | 24 | 92,691.62 | 48 | 1,865.02 | 49.70 | 6.33 |
| | | | High altitude | | | |
| 8 | 24 | 78,497.20 | 48 | 398.38 | 197.04 | 4.00 |
| 9 | 24 | 79,897.73 | 48 | 997.01 | 80.14 | 6.00 |

* For all values of F, $P < 0.01$.

Table 25. Combined analysis of variance of the leaf areas of 25 entries of maize for nine sites in Guatemala.

| Source of variation | Degrees of freedom | | Mean squares |
|---|---|---|---|
| Altitudes | 2 | | 2,801,934 |
| Entries | 24 | | 6,195,694 |
| Between types | | 4 | 2,876,706 |
| Within types | | 20 | 48,142 |
| Altitudes x Entries | 48 | | 50,059 |
| Altitudes x Between types | | 8 | 159,510 |
| Altitudes x Within types | | 40 | 28,169 |
| Sites within altitudes | 6 | | 153,163 |
| Entries x Sites within altitudes | 144 | | 6,000 |
| Total | 224 | | 99,372 |

PLATE 43

Mean and extreme basal areas of five maize types grown at low, mid, and high altitudes in Guatemala.

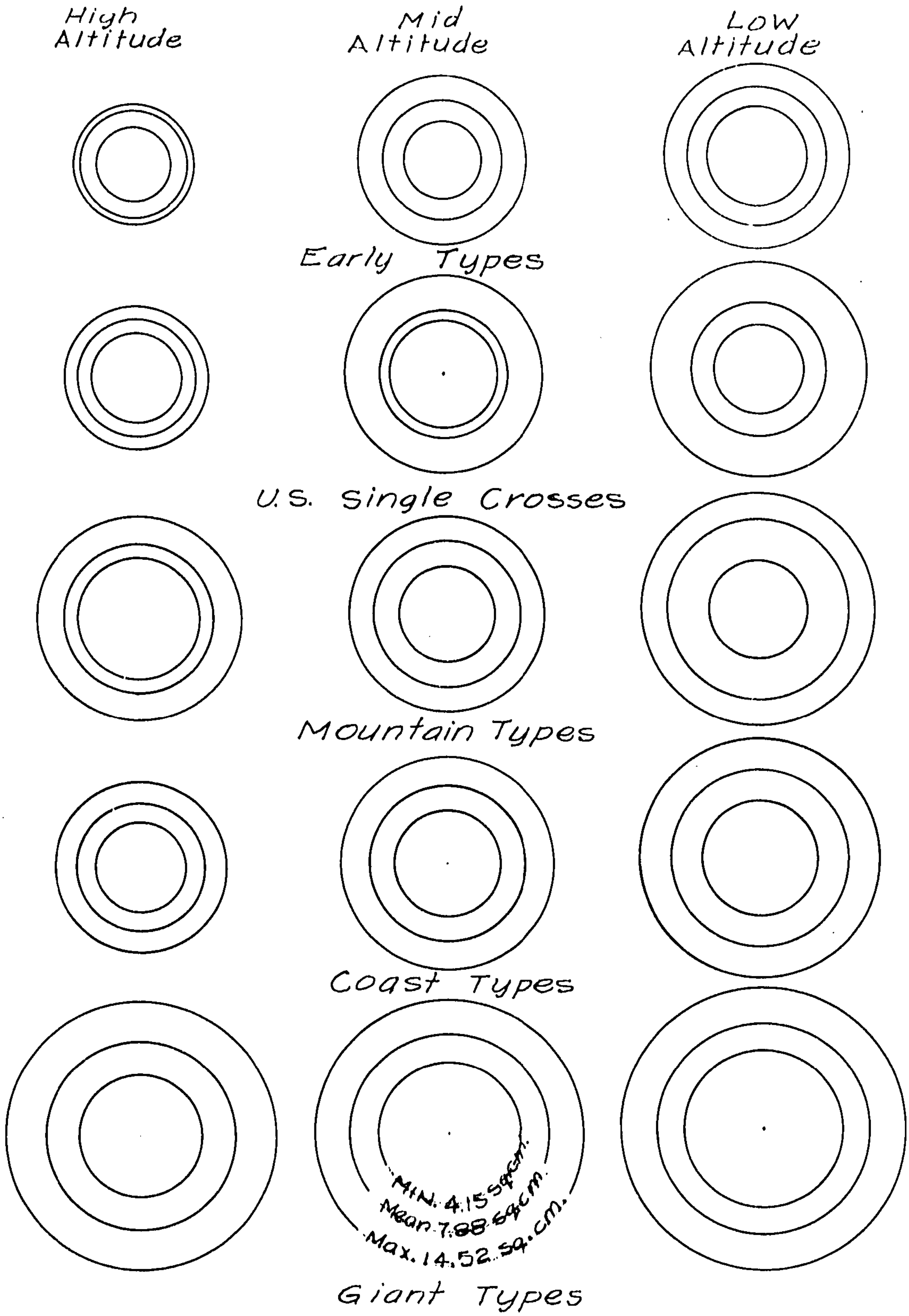

High Altitude
Mid Altitude
Low Altitude
Early Types
U.S. Single Crosses
Mountain Types
Coast Types
Min. 4.15 sq.cm.
Mean 7.88 sq.cm.
Max. 14.52 sq.cm.
Giant Types

Table 26. Basal area of 25 entries of maize planted at nine sites at low, intermediate and high altitudes in Guatemala.

| Maize tested | | Mean basal area in square centimeters at different sites | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Low altitude sites | | | | | Mid altitude sites | | | | High alt. sites | | | All alt. mean |
| Number | Type | 1 | 2 | 3 | 4 | Mean | 5 | 6 | 7 | Mean | 8 | 9 | Mean | |
| 153 x WF9 | S. cross | 4.64 | 2.64 | 2.99 | 3.44 | 3.43 | 4.04 | 1.89 | 2.15 | 2.69 | 3.08 | 2.83 | 2.96 | |
| 205 x 289 | " " | 4.97 | 3.87 | 3.59 | 3.44 | 3.97 | 3.73 | 2.31 | 2.66 | 2.90 | 3.35 | 3.44 | 3.40 | |
| 205 x 234 | " " | 4.90 | 3.75 | 3.95 | 4.03 | 4.16 | 4.49 | 2.30 | 2.32 | 3.03 | 2.53 | 1.89 | 2.21 | |
| M14 x WF9 | " " | 4.19 | 3.35 | 3.71 | 3.10 | 3.59 | 3.99 | 2.29 | 2.45 | 2.91 | 2.68 | 2.88 | 2.78 | |
| M14 x Wis.22 | " | 6.84 | 3.90 | 3.98 | 3.68 | 4.60 | 4.74 | 2.43 | 4.13 | 3.77 | 2.91 | 3.15 | 3.03 | |
| Altitude means for U.S. single crosses | | | | | | 3.95 | | | | 3.06 | | | 2.88 | 3.41 |
| 30A - 46 | Early | 4.42 | 3.82 | 3.95 | 3.70 | 3.97 | 4.39 | 2.66 | 3.51 | 3.52 | 2.51 | 2.72 | 2.62 | |
| 32A - 46 | " | 4.91 | 3.95 | 5.03 | 3.79 | 4.42 | 3.81 | 2.18 | 3.19 | 3.06 | 2.09 | 2.15 | 2.12 | |
| 25 - 44 | " | 3.94 | 3.99 | 2.99 | 2.88 | 3.45 | 3.11 | 1.80 | 2.30 | 2.40 | 1.62 | 1.58 | 1.60 | |
| Altitude means for early type | | | | | | 3.95 | | | | 2.99 | | | 2.11 | 3.22 |
| 101A - 46 | Coast | 8.50 | 7.56 | 7.89 | 7.67 | 7.91 | 5.40 | 4.37 | 3.44 | 4.40 | 3.05 | 3.33 | 3.19 | |
| 13 - 44 | " | 5.78 | 5.81 | 5.48 | 4.95 | 5.50 | 5.38 | 3.20 | 3.69 | 4.09 | 3.78 | 3.76 | 3.77 | |
| 42A - 46 | " | 5.92 | 7.01 | 5.94 | 5.69 | 6.14 | 5.28 | 3.45 | 5.10 | 4.61 | 4.31 | 4.05 | 4.18 | |
| 12A - 46 | " | 8.28 | 7.11 | 7.54 | 7.69 | 7.65 | 5.20 | 5.51 | 6.79 | 5.83 | 3.44 | 4.20 | 3.82 | |
| 7A - 46 | " | 5.97 | 4.37 | 4.61 | 4.45 | 4.85 | 4.69 | 3.97 | 3.78 | 4.15 | 2.98 | 3.33 | 3.16 | |
| 125A - 46 | " | 6.91 | 5.45 | 6.60 | 5.13 | 6.02 | 5.18 | 3.34 | 3.63 | 4.05 | 3.05 | 2.80 | 2.93 | |
| 9A - 46 | " | 7.85 | 6.40 | 8.05 | 7.42 | 7.43 | 5.44 | 4.35 | 6.87 | 5.56 | 3.45 | 3.88 | 3.67 | |
| 96A - 46 | " | 7.60 | 6.46 | 6.72 | 6.31 | 6.77 | 5.25 | 4.32 | 5.08 | 4.88 | 3.30 | 3.52 | 3.41 | |
| Altitude means for coast type | | | | | | 6.53 | | | | 4.70 | | | 3.52 | 5.25 |
| 1A - 46 | Mountain | 6.83 | 9.18 | 5.53 | 5.39 | 6.73 | 3.88 | 3.58 | 4.11 | 3.86 | 3.79 | 3.81 | 3.80 | |
| 39A - 46 | " | 7.16 | 7.21 | 6.26 | 6.21 | 6.71 | 3.72 | 3.50 | 3.58 | 3.60 | 3.83 | 3.73 | 3.78 | |
| 106A - 46 | " | 6.35 | 6.33 | 6.54 | 5.64 | 6.21 | 4.15 | 4.29 | 4.51 | 4.32 | 4.53 | 5.04 | 4.78 | |
| 33A - 46 | " | 7.44 | 7.54 | 6.26 | 5.79 | 6.76 | 4.07 | 4.98 | 5.80 | 4.95 | 4.73 | 4.63 | 4.68 | |

Table 26. (Continued)

| Maize tested | | Mean basal area in square centimeters at different sites | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number | Type | Low altitude sites | | | | | Mid altitude sites | | | | High alt. sites | | | All alt. mean |
| | | 1 | 2 | 3 | 4 | Mean | 5 | 6 | 7 | Mean | 8 | 9 | Mean | |
| Altitude means for mountain type | | | | | | 6.60 | | | | 4.18 | | | 4.26 | 5.28 |
| 15A - 46 | Giant | 10.57 | 7.64 | 8.18 | 6.99 | 8.35 | 6.36 | 7.48 | 8.90 | 7.35 | 8.05 | 7.48 | 7.76 | |
| 17A - 46 | " | 9.16 | 7.83 | 8.44 | 8.05 | 8.37 | 8.43 | 7.10 | 7.89 | 7.81 | 7.27 | 6.25 | 6.76 | |
| 47A - 46 | " | 9.66 | 8.88 | 8.86 | 7.13 | 8.63 | 6.37 | 8.11 | 8.46 | 7.65 | 7.06 | 7.48 | 7.27 | |
| 138A - 46 | " | 10.27 | 9.19 | 8.61 | 8.40 | 9.12 | 7.35 | 11.36 | 10.63 | 9.56 | 8.70 | 8.56 | 8.63 | |
| 14A - 46 | " | 10.16 | 7.84 | 8.82 | 8.10 | 8.73 | 6.58 | 5.95 | 8.55 | 7.02 | 7.36 | 5.73 | 6.55 | |
| Altitude means for giant type | | | | | | 8.64 | | | | 7.88 | | | 7.39 | 7.96 |
| Altitude means for all types | | | | | | 6.14 | | | | 4.72 | | | 4.12 | 5.19 |

at each of the altitudes. These life-size areas are presented in circular form rather than in elliptical because of ease of calculation. There was room for error in either calculation because neither takes into account the channel of the culm. However, the measurements presented are means of individual measurements meticulously made and calculated. They are therefor considered quite satisfactory and indicative of type and entry variation. Plate 43 illustrates that the Giant Type was the least affected by altitude-climate differences. The Early Type was the most variable in its responses to that control.

The individual analysis of variance yielded coefficients of variation that were quite variable from site to site. Table 27 shows that at Site 8 the variability of basal area was at its minimum for sites.

As was true with the other characters measured for growth response, altitude and type were found to be the chief factors controlling variation. This was clearly brought out by the combined analysis of variance (Table 28). The error mean square was comparatively large. The variation attributable to sites within altitudes was also quite noticeable.

There was a very high positive correlation between basal area and node number and between basal area and leaf area at all altitudes.

## Yield

Yield per plant was extremely variable at all sites and altitudes and within all types. The planting at Site 8 was destroyed by livestock before yields were secured. The Mountain Type produced only vegetative growth at low altitude. No ears were formed by any plant of this type

Table 27. Individual analysis of variance of the basal areas of 25 entries of maize for each of the nine sites in Guatemala.

| Experiment | Entries d.f. | Entries M.S. | Error d.f. | Error M.S. | F* | C.V. % |
|---|---|---|---|---|---|---|
| | | | Low altitude | | | |
| 1 | 24 | 12.5825 | 48 | .5629 | 22.35 | 10.57 |
| 2 | 24 | 11.3087 | 48 | .2813 | 40.20 | 8.13 |
| 3 | 24 | 11.0890 | 48 | .1257 | 88.22 | 5.88 |
| 4 | 24 | 9.3383 | 48 | .3644 | 25.63 | 10.28 |
| | | | Mid altitude | | | |
| 5 | 24 | 3.7100 | 48 | .3654 | 10.15 | 12.14 |
| 6 | 24 | 15.7709 | 48 | .3264 | 48.32 | 13.38 |
| 7 | 24 | 17.2309 | 48 | .1508 | 114.26 | 7.72 |
| | | | High altitude | | | |
| 8 | 24 | 10.8495 | 48 | .0210 | 516.64 | 3.39 |
| 9 | 24 | 10.1602 | 48 | .2228 | 45.60 | 11.52 |

* For all values of F, $P < 0.01$.

Table 28. Combined analysis of variance of the basal areas of 25 entries of maize for nine sites in Guatemala.

| Source of variation | Degrees of freedom | | Mean squares |
|---|---|---|---|
| Altitudes | 2 | | 244.7010 |
| Entries | 24 | | 86.5676 |
| Between types | | 4 | 478.5409 |
| Within types | | 20 | 8.1730 |
| Altitudes x Entries | 48 | | 3.7867 |
| Altitudes x Between types | | 8 | 11.8355 |
| Altitudes x Within types | | 40 | 2.1769 |
| Sites within altitudes | 6 | | 17.3972 |
| Entries x Sites within altitudes | 144 | | 1.5226 |
| Total | 224 | | 13.7161 |

at low altitude. The Giant Type also reacted very abnormally at low altitude producing very few ears and thus very low yields per plant generally. In every case the type best adapted to a given altitude produced the greatest per plant and per type yields. At high altitude the Early and Coast Types made poor growth with correspondingly low yields. These types set few seed although ear and silk growth was luxuriant and pollen plentiful. The Giant Type and the U. S. single-crosses made surprisingly good top and root growth but produced very little grain. These responses are depicted in Table 29 and Plate 44.

The individual analysis of variance in Table 30 shows the high coefficients of variation produced by the variability in the yield response. No combined analysis of variance was made.

## Correlation Coefficients of Plant Characters Measured for Growth Response

Correlation coefficients, based on altitude means, were calculated among five of the plant characters measured for growth responses. These were anthesis, node number, leaf area, basal area and height. These correlation coefficients are presented in Table 31. With few exceptions there were high to very high positive correlations among all of the characters included. None of the correlations was below the 0.01 probability level of .505. Tendency toward grouping along the axes was very slight. There was a definite relationship between altitude and the degree of correlation. With one exception the correlation coefficients were highest at mid altitude. In the case of anthesis x basal area the lowest correlation was shown at mid altitude. Two very variable characters, basal

PLATE 44

Mean and extreme yields of shelled grain per plant for each of the five maize types at three altitudes in Guatemala.

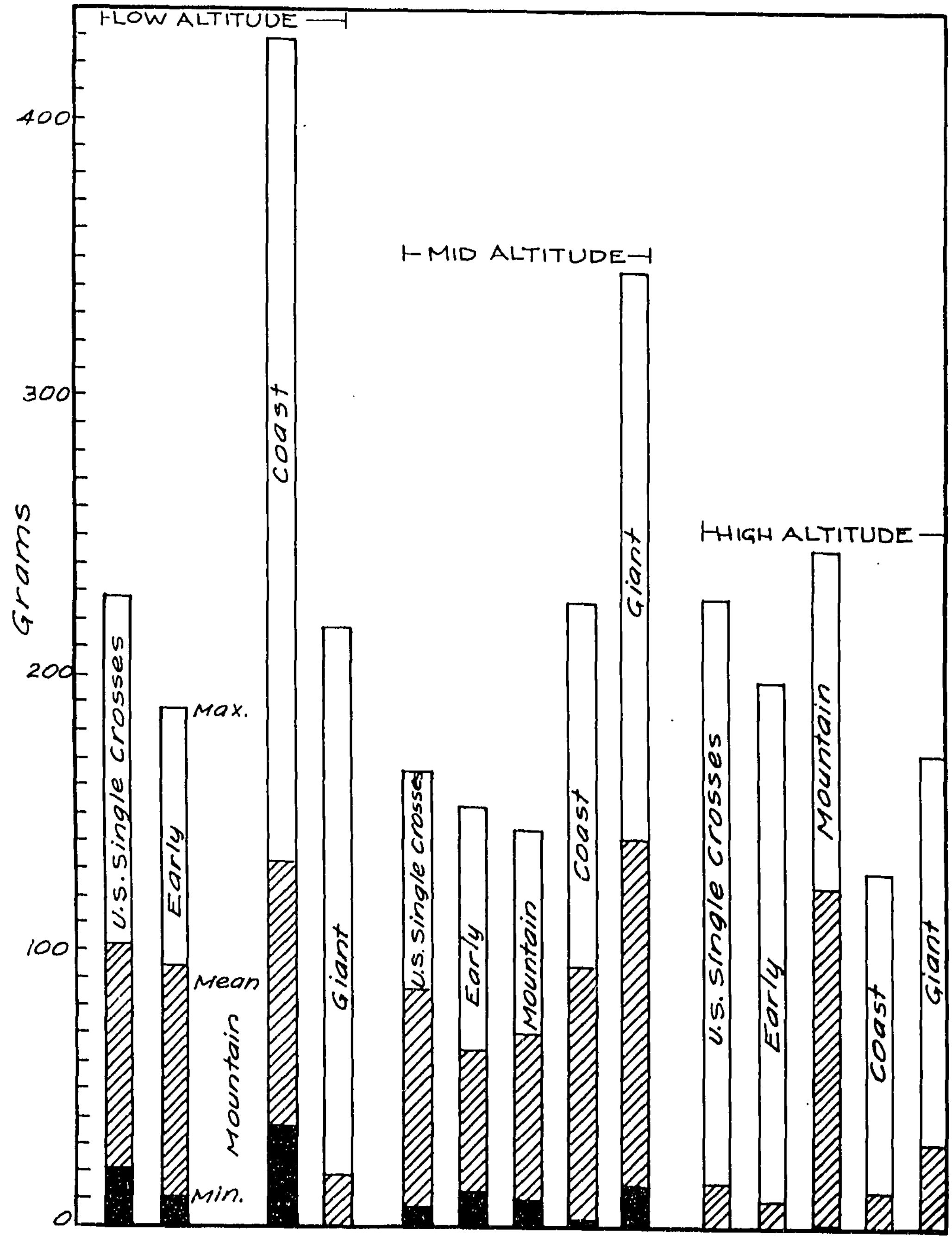

LOW ALTITUDE
MID ALTITUDE
HIGH ALTITUDE
Grams
400
300
200
100
0
U.S. Single Crosses
Early
Coast
Giant
U.S. Single Crosses
Early
Mountain
Coast
Giant
U.S. Single Crosses
Early
Mountain
Coast
Giant
Max.
Mean
Mountain
Min.

Table 29. Yields of 25 entries of maize planted at nine sites at low, intermediate and high altitudes in Guatemala.

| Maize tested | | Mean yield in grams per plant at | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Low altitude sites | | | | | Mid altitude site | | |
| Number | Type | 1 | 2 | 3 | 4 | Mean | 5 | 6 | 7 |
| 153 x WF9 | S. cross | 117.5 | 83.4 | 87.8 | 96.9 | 96.4 | 71.4 | 69.8 | 64.6 |
| 205 x 289 | " " | 149.3 | 101.1 | 104.4 | 115.8 | 117.6 | 114.1 | 105.8 | 66.4 |
| 205 x 234 | " " | 147.5 | 87.1 | 99.3 | 126.2 | 115.0 | 117.3 | 106.9 | 70.0 |
| M14 x WF9 | " " | 116.0 | 77.3 | 94.6 | 111.1 | 99.8 | 106.5 | 115.6 | 55.6 |
| M14 x Wis. 22 | " " | 92.9 | 89.2 | 91.5 | 60.3 | 83.5 | 87.6 | 94.1 | 52.2 |
| Altitude means for U.S. single crosses | | | | | | 102.5 | | | |
| 30A - 46 | Early | 143.7 | 109.2 | 93.9 | 79.7 | 106.6 | 99.8 | 66.1 | 30.6 |
| 32A - 46 | " | 88.4 | 99.0 | 93.6 | 91.0 | 93.0 | 93.2 | 63.0 | 63.2 |
| 25 - 44 | " | 128.5 | 60.6 | 78.3 | 46.2 | 78.4 | 84.8 | 41.9 | 31.4 |
| Altitude means for early type | | | | | | 94.4 | | | |
| 101A - 46 | Coast | 143.7 | 133.1 | 131.1 | 134.9 | 135.7 | 97.5 | 81.7 | 107.8 |
| 13 - 44 | " | 95.4 | 66.3 | 80.6 | 98.9 | 85.3 | 98.1 | 64.5 | 40.8 |
| 42A - 46 | " | 71.1 | 74.1 | 83.4 | 98.6 | 81.8 | 111.3 | 102.6 | 113.2 |
| 12A - 46 | " | 99.6 | 98.6 | 111.5 | 184.4 | 123.6 | 102.0 | 128.6 | 90.0 |
| 7A - 46 | " | 159.6 | 139.5 | 132.5 | 135.8 | 141.9 | 112.4 | 137.6 | 98.2 |
| 125A - 46 | " | 262.8 | 148.8 | 187.9 | 174.6 | 193.5 | 137.1 | 91.4 | 71.1 |
| 9A - 46 | " | 204.9 | 139.2 | 126.7 | 203.4 | 168.5 | 116.5 | 106.3 | 30.7 |
| 96A - 46 | " | 122.0 | 104.8 | 110.1 | 192.7 | 132.4 | 103.3 | 75.5 | 54.3 |
| Altitude means for coast type | | | | | | 132.8 | | | |
| 1A - 46 | Mountain | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 95.3 | 52.5 | 44.7 |
| 39A - 46 | " | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 94.5 | 63.5 | 43.5 |
| 106A - 46 | " | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 90.6 | 67.1 | 39.8 |
| 33A - 46 | " | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 105.9 | 75.6 | 72.0 |
| Altitude means for mountain type | | | | | | 0.0 | | | |
| 15A - 46 | Giant | 0.0 | 6.0 | 0.0 | 0.0 | 1.5 | 143.7 | 135.6 | 144.3 |
| 17A - 46 | " | 0.0 | 0.0 | 0.0 | 50.6 | 12.7 | 149.2 | 103.9 | 112.0 |
| 47A - 46 | " | 1.1 | 1.3 | 9.8 | 14.5 | 6.7 | 119.6 | 81.4 | 116.0 |
| 138A - 46 | " | 0.0 | 0.0 | 0.0 | 28.1 | 7.0 | 191.7 | 176.1 | —— |
| 14A - 46 | " | 2.1 | 0.0 | 1.1 | 77.5 | 20.2 | 169.9 | 175.7 | 156.2 |
| Altitude means for giant type | | | | | | 9.6 | | | |
| Altitude means for all types | | | | | | 76.2 | | | |

ntries of maize planted at nine sites at low,
nd high altitudes in Guatemala.

| Mean yield in grams per plant at different sites | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Low altitude sites | | | | Mid altitude sites | | | | High alt. sites | | | All alt. mean |
| 2 | 3 | 4 | Mean | 5 | 6 | 7 | Mean | 8 | 9 | Mean | |
| 83.4 | 87.8 | 96.9 | 96.4 | 71.4 | 69.8 | 64.6 | 68.6 | --- | 34.6 | 34.6 | |
| 101.1 | 104.4 | 115.8 | 117.6 | 114.1 | 105.8 | 66.4 | 95.5 | --- | 22.4 | 22.4 | |
| 87.1 | 99.3 | 126.2 | 115.0 | 117.3 | 106.9 | 70.0 | 98.1 | --- | 10.8 | 10.8 | |
| 77.3 | 94.6 | 111.1 | 99.8 | 106.5 | 115.6 | 55.6 | 92.6 | --- | 3.2 | 3.2 | |
| 89.2 | 91.5 | 60.3 | 83.5 | 87.6 | 94.1 | 52.2 | 78.0 | --- | 11.2 | 11.2 | |
| sses | | | 102.5 | | | | 86.5 | | | 16.5 | 85.75 |
| 109.2 | 93.9 | 79.7 | 106.6 | 99.8 | 66.1 | 30.6 | 65.5 | --- | 12.6 | 12.6 | |
| 99.0 | 93.6 | 91.0 | 93.0 | 93.2 | 63.0 | 63.2 | 73.2 | --- | 14.8 | 14.8 | |
| 60.6 | 78.3 | 46.2 | 78.4 | 84.8 | 41.9 | 31.4 | 52.7 | --- | 2.2 | 2.2 | |
| | | | 94.4 | | | | 63.8 | | | 9.9 | 71.51 |
| 133.1 | 131.1 | 134.9 | 135.7 | 97.5 | 81.7 | 107.8 | 95.6 | --- | 5.3 | 5.3 | |
| 66.3 | 80.6 | 98.9 | 85.3 | 98.1 | 64.5 | 40.8 | 67.8 | --- | 7.6 | 7.6 | |
| 74.1 | 83.4 | 98.6 | 81.8 | 111.3 | 102.6 | 113.2 | 109.0 | --- | 25.3 | 25.3 | |
| 98.6 | 111.5 | 184.4 | 123.6 | 102.0 | 128.6 | 90.0 | 106.9 | --- | 20.9 | 20.9 | |
| 139.5 | 132.5 | 135.8 | 141.9 | 112.4 | 137.6 | 98.2 | 116.1 | --- | 20.9 | 20.9 | |
| 148.8 | 187.9 | 174.6 | 193.5 | 137.1 | 91.4 | 71.1 | 99.9 | --- | 9.8 | 9.8 | |
| 139.2 | 126.7 | 203.4 | 168.5 | 116.5 | 106.3 | 30.7 | 84.5 | --- | 11.1 | 11.1 | |
| 104.8 | 110.1 | 192.7 | 132.4 | 103.3 | 75.5 | 54.3 | 77.7 | --- | 0.0 | 0.0 | |
| | | | 132.8 | | | | 94.7 | | | 12.6 | 103.51 |
| 0.0 | 0.0 | 0.0 | 0.0 | 95.3 | 52.5 | 44.7 | 64.2 | --- | 124.2 | 124.3 | |
| 0.0 | 0.0 | 0.0 | 0.0 | 94.5 | 63.5 | 43.5 | 67.2 | --- | 171.3 | 171.3 | |
| 0.0 | 0.0 | 0.0 | 0.0 | 90.6 | 67.1 | 39.8 | 65.8 | --- | 101.2 | 101.2 | |
| 0.0 | 0.0 | 0.0 | 0.0 | 105.9 | 75.6 | 72.0 | 84.5 | --- | 95.6 | 95.7 | |
| | | | 0.0 | | | | 70.4 | | | 123.1 | 41.80 |
| 6.0 | 0.0 | 0.0 | 1.5 | 143.7 | 135.6 | 144.3 | 141.2 | --- | 110.2 | 110.2 | |
| 0.0 | 0.0 | 50.6 | 12.7 | 149.2 | 103.9 | 112.0 | 121.7 | --- | 19.0 | 19.0 | |
| 1.3 | 9.8 | 14.5 | 6.7 | 119.6 | 81.4 | 116.0 | 105.7 | --- | 4.9 | 4.9 | |
| 0.0 | 0.0 | 28.1 | 7.0 | 191.7 | 176.1 | --- | 183.9 | --- | 0.0 | 0.0 | |
| 0.0 | 1.1 | 77.5 | 20.2 | 169.9 | 175.7 | 156.2 | 167.3 | --- | 23.7 | 23.7 | |
| | | | 9.6 | | | | 141.1 | | | 31.6 | 59.63 |
| | | | 76.2 | | | | 94.1 | | | 34.5 | 77.17 |

Table 30. Individual analysis of variance of the yields of 25 entries[1] of maize for each of the nine sites in Guatemala.

| Experiment | Entries d.f. | Entries M.S. | Error d.f. | Error M.S. | F* | C.V. % |
|---|---|---|---|---|---|---|
| | | | Low altitude | | | |
| 1 | 15 | 6,799.66 | 30 | 205.55 | 33.08 | 44.97 |
| 2 | 15 | 2,221.75 | 30 | 166.84 | 13.32 | 12.84 |
| 3 | 16 | 3,816.86 | 32 | 168.83 | 22.61 | 12.85 |
| 4 | 17 | 68,039.72 | 34 | 415.70 | 163.68 | 17.66 |
| | | | Mid altitude | | | |
| 5 | 24 | 2,256.30 | 48 | 216.13 | 10.43 | 13.08 |
| 6 | 24 | 3,678.96 | 48 | 261.16 | 14.09 | 16.85 |
| 7 | 23 | 3,691.55 | 46 | 71.43 | 51.68 | 11.61 |
| | | | High altitude | | | |
| 8 | Planting destroyed before maturity. | | | | | |
| 9 | 20 | 7,355.58 | 40 | 169.10 | 43.50 | 32.37 |

* For all values of F, $P < 0.01$.

[1] Missing values due to death or abnormal growth response.

Table 31. Correlation coefficients (r) based on altitude means among five plant characters on 25 entries of maize grown in Guatemala.

| Character | Alt. | Node number | Leaf area | Basal area | Height |
|---|---|---|---|---|---|
| | Low | .826 | .687 | .862 | .624 |
| Anthesis | Mid | .937 | .962 | .685 | .963 |
| | High | .889 | .813 | .875 | .566 |
| | Low | .909 | .613 | .797 | |
| Height | Mid | .936 | .967 | .952 | |
| | High | .515 | .728 | .748 | |
| | Low | .928 | .857 | | |
| Basal area | Mid | .955 | .959 | | |
| | High | .929 | .929 | | |
| | Low | .909 | | | |
| Leaf area | Mid | .971 | | | |
| | High | .781 | | | |

r of .505 occurs with P 0.01

area and leaf area produced some of the highest correlations. The only two correlation coefficients which approached the 0.01 probability level of .505 were height x node number and height x anthesis, both at high altitude.

Thus it was shown that the growth response of any one character was closely correlated with the response of all others. It was also shown that these characters respond as a group to changes in environment.

## General Observations of Responses

There were several responses that were not measured but which are worth noting at this point. It was found that some characters, often used in descriptions, were quite variable while others were constant when transplanted to environments different from natural habitats.

During the course of this investigation it was found that leaf position was very constant. Thus the reflexed leaves of the Mountain Type never varied regardless of the environment to which they were exposed.

Anthocyanin pigmentation was much more pronounced at high altitude than at low. Some entries which showed little or no pigmentation at low altitude showed definite coloring at high.

Tassel branching was extremely variable with changes in climate. The Mountain Entries, which are characterized by few tassel branches in their natural environment, branch profusely at low altitude and at high latitudes.

Root development of some types, especially the Mountain Type, was seriously curtailed by any downward change in altitude-climate.

The growth response of reproductive structures, especially female, was greatly influenced by changes in altitude-climate. The Mountain Type produced no ears at low altitude. The Giant Type showed a similar response. At high altitude there was an indication that the viability of the pollen of lowland types was lost or greatly reduced.

Many aberrations and abnormal responses such as failure to produce ears, excessive tassel branching, multiple ears, tassel seed, growth stimulation, excessive suckering, and lodging were exhibited by individual plants. The Coast Type was much freer from these abnormalities than any other type when removed from its natural environment.

There was extreme variation in endosperm characteristics in all of the types. Although there was a general tendency toward flinty endosperm in all types, flour, flint, and dent variants existed in each. There was no apparent relationship between endosperm characteristics and other morphological responses.

## Growth Responses in Greenhouse Conditions at Ames, Iowa

A planting of three plants of each of the twenty entries of Guatemalan corn was made in the north greenhouse at Iowa State College, Ames, Iowa. Spacing was identical with field plantings in Guatemala. The planting was made on February 18, 1948 when day-length conditions were similar to those prevailing in Guatemala. Air temperature was thermostatically controlled and moisture conditions were maintained at a high level. Soil and air temperature were recorded daily until completion of the growth period of Entry 138A-46. Light intensity was recorded at maximum daily. These records are as follows:

Air temperature, C° Mean min. 19.03 Mean 22.31 Mean max. 25.60

Soil temperature, C° Mean min. 19.02 Mean 20.12 Mean max. 21.07

Mean maximum light intensity, f.c. 8,210

Air temperature was slightly higher than at the mid altitude sites in Guatemala; soil temperature slightly lower. Light intensity was lower than any of the values recorded for growth periods in Guatemala except that for Site 1.

The data for this planting are presented in Table 32. The values for each character response represent the average for the three plants of each entry. None of the responses were greatly different than those recorded at the mid altitude sites near Antigua, Guatemala. It must be borne in mind that these greenhouse grown plants went through their periods of differentiation during the short days of February and early March.

## Growth Responses of Maize Field-planted at Ames, Iowa

A field planting of the 25 entries used in Guatemala was made at the Ash Avenue plots at Ames, Iowa on May 17, 1942. This planting was made in 5x5 triple lattice identical with spacing and other methods used in the plantings at the nine sites in Guatemala. The same measurements were made on all growth responses as were made in Guatemala. The site means for each entry are presented in Table 33. No data was taken on yield.

Table 32. Average growth responses of 3 plants of 20 entries of maize planted in the greenhouse at Ames, Iowa.

| Number | Type | No. days emergence to anthesis | Height | Daily increase in height | Leaf area | Basal area | No. of nodes |
|---|---|---|---|---|---|---|---|
| 30A - 46 | Early | 67 | 166.9 | 2.49 | 521.3 | 3.19 | 14.8 |
| 32A - 46 | " | 69 | 174.3 | 2.53 | 476.8 | 2.94 | 14.5 |
| 25 - 44 | " | 63 | 158.6 | 2.52 | 432.7 | 2.71 | 13.2 |
| 101A - 46 | Coast | 82 | 253.1 | 3.09 | 710.8 | 4.28 | 17.1 |
| 13 - 44 | " | 84 | 210.0 | 2.50 | 596.4 | 4.56 | 16.6 |
| 42A - 46 | " | 79 | 239.8 | 3.04 | 684.3 | 4.37 | 17.7 |
| 12A - 46 | " | 86 | 271.5 | 3.16 | 710.1 | 5.15 | 18.6 |
| 7A - 46 | " | 80 | 228.9 | 2.86 | 692.4 | 4.80 | 18.1 |
| 125A - 46 | " | 81 | 209.7 | 2.59 | 644.5 | 4.62 | 17.9 |
| 9A - 46 | " | 87 | 240.2 | 2.76 | 652.7 | 5.39 | 18.5 |
| 96A - 46 | " | 82 | 254.3 | 3.10 | 640.7 | 4.76 | 18.7 |
| 1A - 46 | Mountain | 81 | 218.7 | 2.70 | 584.3 | 3.98 | 16.2 |
| 39A - 46 | " | 81 | 241.3 | 2.98 | 610.2 | 4.02 | 16.5 |
| 106A - 46 | " | 86 | 264.5 | 3.08 | 582.7 | 4.30 | 17.1 |
| 33A - 46 | " | 90 | 257.3 | 2.86 | 611.9 | 4.68 | 17.3 |
| 15A - 46 | Giant | 106 | 347.1 | 3.27 | 961.5 | 8.10 | 20.6 |
| 17A - 46 | " | 110 | 386.8 | 3.52 | 950.4 | 7.93 | 23.1 |
| 47A - 46 | " | 103 | 309.8 | 3.01 | 937.2 | 8.61 | 21.2 |
| 138A - 46 | " | 126 | 394.4 | 3.13 | 984.8 | 10.32 | 25.9 |
| 14A - 46 | " | 110 | 326.1 | 2.96 | 927.6 | 7.61 | 20.9 |

Table 33. Mean growth responses of maize field-planted at Ames, Iowa.

| Number | Type | No. days emergence to anthesis | Height | Daily increase in height | Leaf area | Basal area | No. of nodes |
|---|---|---|---|---|---|---|---|
| 153 x WF9 | S. Cross | 60 | 246.7 | 4.13 | 878.3 | 6.51 | 17.9 |
| 205 x 289 | " | 56 | 270.3 | 4.83 | 739.6 | 5.56 | 17.8 |
| 205 x 234 | " | 55 | 261.0 | 4.74 | 784.5 | 6.70 | 18.1 |
| M14 x WF9 | " | 59 | 253.0 | 4.29 | 823.8 | 6.78 | 18.3 |
| M14 x Wis.22 | " | 61 | 246.1 | 4.03 | 912.4 | 7.48 | 18.1 |
| 30A - 46 | Early | 85 | 323.1 | 3.80 | 838.7 | 6.51 | 21.6 |
| 32A - 46 | " | 73 | 304.4 | 4.17 | 825.7 | 7.10 | 19.3 |
| 25 - 44 | " | 82 | 303.9 | 3.64 | 936.2 | 6.16 | 21.4 |
| 101A - 46 | Coast | 100 | 431.5 | 4.31 | 982.7 | 13.95 | 29.8 |
| 13 - 44 | " | 94 | 374.1 | 3.98 | 888.7 | 9.59 | 26.5 |
| 42A - 46 | " | 97 | 432.7 | 4.46 | 944.6 | 9.92 | 28.5 |
| 12A - 46 | " | 107 | 425.7 | 3.98 | 962.4 | 10.53 | 29.5 |
| 7A - 46 | " | 90 | 336.7 | 3.74 | 943.7 | 6.88 | 22.9 |
| 125A - 46 | " | 84 | 349.9 | 4.17 | 995.9 | 8.30 | 24.5 |
| 9A - 46 | " | 98 | 370.8 | 3.78 | 937.3 | 9.39 | 29.8 |
| 96A - 46 | " | 100 | 398.7 | 3.99 | 944.7 | 9.60 | 28.1 |
| 1A - 46 | Mountain | 73 | 332.9 | 4.56 | 936.6 | 8.75 | 22.4 |
| 39A - 46 | " | 107 | 345.5 | 3.23 | 895.5 | 8.43 | 23.5 |
| 106A - 46 | " | 106 | 389.1 | 3.67 | 940.1 | 10.40 | 24.1 |
| 33A - 46 | " | 111 | 373.5 | 3.36 | 801.2 | 11.20 | 27.5 |
| 15A - 46 | Giant | 119 | 423.5 | 3.56 | 1,030.8 | 15.39 | 28.8 |
| 17A - 46 | " | 119 | 471.4 | 3.96 | 991.3 | 15.65 | 32.6 |
| 47A - 46 | " | 111 | 433.7 | 3.91 | 931.3 | 15.30 | 29.7 |
| 138A - 46 | " | 125 | 480.5 | 3.84 | 1,052.7 | 15.82 | 31.3 |
| 14A - 46 | " | 116 | 462.7 | 3.97 | 1,004.5 | 14.12 | 30.7 |

The days to anthesis for the U. S. single-crosses, which were growing in home environment, were somewhat less than at mid altitude in Guatemala. In nearly all the other entries this response was greater than at Antigua. The two exceptions were Mountain Type Entry 1A-46 and Giant Type Entry 138A-46. Number 1A-46 came to anthesis abnormally early, produced no ears and most of the plants died. Root development of this entry was extremely poor as was true of the other variants of the Mountain Type. Entry 138A-46 came to anthesis only four days earlier than the mean for Antigua.

The response for height was greater, in every case but one, for each of the entries than at any site in Guatemala. The one exception was Entry 138A-46. The value for this entry at low altitude Site 4 was slightly greater than that recorded at Ames.

Mean daily increase in height, as recorded at Ames, was in all cases intermediate between the recordings for low and for mid altitude in Guatemala.

The values for leaf area were, for all entries greater than those recorded at any of the sites in Guatemala. This was also true for the basal area values recorded at Ames.

The numbers of nodes for all entries were greater, and in most cases considerably greater, than the numbers recorded at any site in Guatemala. At the nine sites in that country there was very little variation in this response regardless of altitude-climate.

## DISCUSSION

This study of the growth responses of maize transplants to different climates revealed that modifications, both morphological and physiological, occurred in all entries. These modifications were very slight from site to site within a given altitude-climate but were marked from one altitude-climate to another. There was a great difference between types in their range of adaptability. The Mountain Type (2,200-3,000 meters) was the least adaptable to altitude-climates outside its normal environment. The Coast Type (0-1,000 meters) was the most adaptable. The Giant Type (1,000-2,200 meters) and the Early Type (isolated variants at 500-1,500 meters) were intermediate in their adaptability. The U. S. single-crosses showed a remarkable range of adaptability. In all cases growth responses were most normal at the site within or most nearly approaching the natural range of climate of the entry or type in question. Limits of adaptability were demonstrated by abnormal physiological response i.e. failure to produce ears, lodging, failure to set seed, abnormal size, and aberrant inflorescence. Changes in root development were quite prominent in the Mountain and Giant Types at altitudes below their ranges.

Despite the changes in environment each type retained its character distinct from other types. This is nonconfirmatory to the work of Bonnier (7) who found that his transplants of wild perennials often took on the characteristics of adapted variants. The extent of modification in each type and in each variant was limited by inheritance. When the heritable limits of modification were exceeded death, aberrations or the failure to complete life processes resulted. Changes in dimensions and growth periods were the most prominent growth responses to climate. Heredity prevented the individual from losing its identity despite these growth changes. Modification was never localized in one character but the plant responded as a whole to climatic changes. The net result of the growth responses was modification — attributable to environment but limited by heredity.

The results of these climatic influences on maize transplants were not entirely in keeping with Kerner von Marilaun's (36) results with wild annuals. His annuals had fewer nodes at high altitude while in these studies there was no decrease in the number of nodes of maize with increase in altitude. The findings of this study, however, do confirm his findings of shorter internodes and higher pigmentation at high altitude.

Altitude, as the regulator of the climatic elements of temperature and light was the principal source of variation in the maize variants studied. Moisture relationships were at all times favorable to growth. Edaphic factors, neither chemical or physical, showed any indication of dominance over climate. Thus temperature, as controlled by altitude, was considered the dominant climatic factor responsible for variations in growth response. Soil temperature was considered as part of the general temperature relationship. These findings are in keeping with those of McCalla, Weir, and Neatby (52) who demonstrated that, in Canada, 69 to 90 per cent of the variability of growth in maize can be accounted for in the factors of temperature and sunlight. Temperature effects cannot be completely singled out from other elements of climate (65). However, the data here presented is in accord with Hanna's (30) finding that growth had a closer correlation with temperature than any other single climatic factor. Likewise, other investigators have shown (65, 42, 46, 52) that temperature is by far the most important element in relation to growth.

Most of the research on the effects of light intensity on growth responses has been carried on in laboratory conditions. Also, the bulk of this research has been performed in light intensity conditions much below those encountered in the field. Soil and air temperature have not usually been given due consideration in studies with light. Lundegårdh (45) found that conclusions drawn under laboratory conditions often lead to erroneous conclusions as to similar reactions in the field. To date no one has successfully separated the effects of light and temperature on growth in the field. No attempt was made to do so in this investigation.

It was found in this investigation that each type had its own optimum conditions of temperature and light. The application of any of the usual temperature indices to the maize of Guatemala was not feasible. The maximum, minimum, and mean temperatures for growth were distinct for each type. The Mountain Type made satisfactory growth at lower temperatures than any of the other types.

Root development was closely associated with temperature and light as indicated by its response under the different altitude-climates. However, neither the conclusions of Lubimenko (44) nor those of Rose (60), as to increased root development with increased light intensity, were applicable under the intensities recorded in this investigation. The Mountain Type showed extremely poor root development at low, fair at mid, and excellent at high altitudes. Development at low altitudes was so poor that few of the plant were able to develop sufficient root system to support top growth. This was also true for Mountain Type plants field-grown at Ames, Iowa. This fact limits the use of this type as an otherwise valuable source of germ plasm for cold resistance unless its variants are brought into hybrid combination. It is believed that the inherent inability of this type to adapt itself to increased temperature and decreased light intensity conditions are responsible for this root response.

The Giant Type also showed very poor root development at low altitude. At mid altitude this type produced excellent systems. At high altitude this type developed extensive root systems but other responses were abnormal. At Ames root development of this type was fair to good depending on the entry. The Coast Type, although developing its best root systems in its native environment, produced remarkably good systems in all of the altitude-climates of Guatemala as well as at Ames, Iowa. The Early Type developed good but not extensive root systems in all the altitude-climates of Guatemala. This type produced excellent systems at Ames. The root systems of the U. S. single-crosses in Guatemala were never sufficient to maintain a physiological balance in the plant. They were, however, sufficient to permit the use of these entries as male parents in breeding work at low altitude and as either male or female parents at mid altitude. At high altitude the root systems of these single-crosses were greatly improved.

These observations on root development led to the opinion that this response was dependent on the interrelationship of soil-air temperature and light intensity plus the inherent limits of adaptability of the type to these climatic elements. It was acknowledged that root development was very closely related to some, if not all, of the plant growth responses measured.

There are several points of difference between the findings of other workers and the data collected in this study. This was especially true of the leaf areas found in the growth response measurements. The results did not confirm Lubimenko's (44) conclusion that leaf area was greatest at moderate light intensities and lessened with extremes. This was true of the Giant Type in Guatemala. The other types all produced greatest leaf area at low altitude and least leaf area at high altitude. Neither were the conclusions of Rose (60) entirely applicable to the findings of this investigation. He concluded that optimum light intensity for a plant was that at which the greatest leaf area developed. This was true with the Coast and Giant Types in Guatemala; was partly true applied to the Early Type; but was nonconfirmatory when applied to the Mountain Type and U. S. single-crosses. At Ames every entry reached magnitudes of leaf area greater than those recorded in Guatemala. At this site all growth responses for the Guatemalan variants were other than those exhibited in their natural environments. The single-crosses were, of course, considered under normal environmental conditions. The mean maximum light intensity for the growth period at this site was 8,194 foot candles. This value was less than that of all sites in Guatemala except Site 1.

Greatest mean heights in Guatemala were exhibited at low altitude. However, the mean heights for every entry were greatest at Ames, Iowa. It has been shown by others that temperature is the principal factor controlling this response (46, 30, 52). The data of this study tends to confirm the findings of others that greatest growth occurs in the higher temperature ranges; other factors being favorable.

The mean daily increase, a function of height and time of anthesis, was most rapid in the high, even temperatures of the low altitude sites in Guatemala. These temperatures approached the optimum growth temperatures for maize as recorded by Lehenbauer (42) and McDougal (46). Although growth was most rapid at this altitude it was abnormal in the Mountain and Giant Types.

Basal area was found to be inversely proportional to altitude and thus to light intensity. This does not agree with the work of Popp (57) on soybeans. He concluded that stem diameter was directly proportional to light intensity. However, the greatest intensity that he used was 4,285 foot candles. In these studies with maize, the greatest mean basal areas of culms were produced at Ames, Iowa.

Kuleshov's (37) theory that leaf number could be used in prognosticating the length of the vegetative period was considered in this investigation. Unfortunately he offered no method or statistical approach to the matter. In this work it was deemed more accurate to use actual node counts in place of number of leaves. Maturity being a rather approximate factor it was decided to use the value of the days from emergence to anthesis. Likewise this period was of more value to the maize studies of the Center. Not only do these results confirm Kuleshov's findings but statistical evidence of their validity is presented. Also an accurate calculation and prediction equation is offered. This method can be applied to maturity. Kuleshov mentions the use of longitudinally sectioned seedlings for determining earliness or lateness of a variety. He also suggests that recommendations as to regions for planting could be made on the basis of these determinations. The data presented do not entirely confirm his findings.

The prediction equations developed in this investigation are applicable to use on seedlings. However, there are several points of caution to be adopted. Sample numbers of seedlings of any collection can be grown through the period of differentiation under field or laboratory conditions. These seedlings can be sectioned longitudinally, the number of nodes determined, and dates of anthesis or maturity predicted for any site for which such equations have been developed. From the value derived it can be ascertained whether the growing period of the planting site is sufficiently long for the sample in question to reach anthesis or maturity. However, from the data presented, it is evident that the worker must have knowledge as to the inherent adaptability of the sample to the environment in which it is to be planted. One could very satisfactorily calculate the prediction equation for a high altitude maize to be planted at low altitude. The effort, however, would be useless if the adaptability of that type were not known. This type produces no ears at low altitude and often succumbs before anthesis. Thus the worker must have some knowledge of his collection samples before applying prediction equations for breeding work.

Until more information is available this method of prediction is of unknown value at the higher latitudes of maize production. It must be remembered that low latitude climates are known for their uniformity. At these latitudes maize is grown during the months of the year when growth conditions are seldom limiting. It would probably be found that the prediction equations would frequently prove inaccurate at high latitudes due to the annual differences between growth seasons. These year to year differences might also result in lower coefficients of correlation than were derived in Guatemala.

More information will be necessary before any conclusions of statistical value can be drawn as to the growth responses demonstrated by the field-plantings at Ames. However, a few observations can be made with security. The greenhouse planting showed that by duplicating the temperature and day length conditions of Guatemala, small scale studies can be made at high latitudes. Light quality and quantity conditions due to glass were present but the results obtained demonstrated that they caused no interference with life processes. However, any breeding program of consequence must be carried on at the low latitudes. The evidence demonstrates that northern maize can be used in field plots in the tropics successfully. Tropical maize cannot be used in the northern states with any predictable degree of success except where introduced in hybrid combination.

Field-plantings at Ames have demonstrated the fallacy of describing maize from plants grown in high latitude climates. The excessive values recorded in the field plantings at Ames illustrated this quite clearly. Two notable cases of failure to recognize this fact have been found in the literature. Kuleshov (37) based much of his description of Central and South American maize on plantings made at Sukhum, U.S.S.R. It is believed that for this reason the values for leaf numbers which he recorded are in excess of values which would be found in climates to which his variants were adapted. This is also true of some of his other measurements. Likewise the illustration which Bonafous (6) presented in support of his description of Zea hirta, a Mountain Type variant, shows strong indications of abnormality. His illustration depicts a plant with three ears which, as illustrated, is a rarity in the natural environment of that type. This response is a common one for this type when planted in high latitude climates. His plant was grown in Lyons, France.

Ample evidence is presented that growth responses at the mid altitude sites was such that the variants of all types were able to complete life processes. At these sites near Antigua, Guatemala, individual plant performance for all types was sufficiently good that breeding and other work could be carried on with any type. The coefficients of correlation presented in Table 31 show strong evidence that growth response in this altitude-climate was a unified response of all characters. At this altitude only one correlation coefficient, that of basal area x anthesis, was lower than those calculated for other altitudes. This would indicate that factors of climate interfering with growth response were at a minimum. It was demonstrated that highland maize variants transplanted to lowland sites did not respond normally to climatic influences. Likewise, lowland variants when transplanted to high altitude climates did not show normal responses. These imperfections in response and the dominance of some responses over others are reflected in the comparatively lower correlation coefficients at low and high altitude. Calculations of coefficients of correlation among plant characters as influenced by different climates might be used as an indication of unity of growth response and inherent ability to complete life processes in a given climate. This together with the prediction equation already presented should serve as useful tools to the student of influences of tropical climates on growth response of plants.

The statistical analyses of variance of the data collected show that there was a difference among types. The tables of means show that the types could be separated on the basis of these differences. Variation between types is prominent but within type variation among entries is comparatively small as shown by the combined analyses of variance. The statistical evidence together with the descriptive and illustrative data presented furnish evidence that the maize of Guatemala can be grouped into four assemblages of variants. This confirms Melhus' (54) classification of the maize of Guatemala into four groups viz: Early, Coast, Mountain, and Giant. It is known that these four groupings apply generally to all maize variants of Central America. The data show that these four groups are distinct morphologically and physiologically which are in keeping with Turesson's (74) findings that certain physiological and morphological characters are associated with certain habitat factors. The possibility that one or more other minor climatological types might exist is not overlooked.

## SUMMARY

This study of the influence of climate on the growth and development of maize in Guatemala was performed with the use of twenty maize variants collected in Guatemala and five from the corn belt of the United States. The Guatemalan entries were samples drawn from open pollinated populations and the U. S. entries were drawn from single-crosses produced at Kanawha in north central Iowa. Nine site plantings were employed in varied climates within three altitude ranges in Guatemala and one site planting was employed at Ames, Iowa. A small greenhouse planting was also used at Ames. The elements of climate were recorded throughout the growth period of each variant at each site. The influence of different climates on maize transplants was determined by the influence of the elements of climate on specific characters. The variants were separated into types on the basis of their response in the different climates.

Measurement of the growth responses of numbers of each variant in the several site climates confirmed Melhus' (54) grouping of the maize of Guatemala into four heritably distinct assemblages of variants, here called types, viz: Early, Coast, Giant, and Mountain.

Despite morphological and physiological modifications each type retained its inherent identity, distinct from other types, regardless of the climatic conditions to which it was subjected.

The morphological and physiological characteristics of each type were peculiar to that type and could be used in the positive placement

of any variant into its proper type assemblage.

The ability of any type to adapt itself to any or various climates was fixed by heredity and varied from the same function in other types. Likewise, the range and limits of adaptability of a given type were dependent upon these same restrictions placed upon it by heredity.

Climatological modifications of hereditary characters varied with each type. These modifications were similar for the individual variants within a given type. The range of modification of each character varied considerably from type to type. Some characters such as leaf position and pubescence were unaffected by changes in environment. Modification of growth responses due to climatic changes was always unanimous and never the response of a single character.

The calculation of the regression of days to anthesis on node number yielded an equation that could be used for the prediction of the approximate date of anthesis of any entry, any type, or the progeny of any individual plant. This prediction equation was useful in determining dates of planting for hybridization and in determining dates for the recording of data.

There was a high positive coefficient of correlation among the growth responses of all characters measured viz: anthesis, node number, height, leaf area, and basal area. Coefficients of correlations were highest at mid altitude in all cases but one.

Temperature and light were found to be the two elements of climate largely responsible for the variations in growth responses.

At no time did edaphic factors show any indication of being dominant over the elements of climate.

The investigation demonstrated that maize adapted to a low altitude climate could be transplanted to a high altitude climate with less physiological and morphological modification than vice versa.

Growth was most normal and yields highest at the sites within or nearest to the native habitat range of the entry or type.

All indications were that maize native to a high latitude climate may be transplanted to a low latitude climate with less physiological and morphological modification than vice versa.

The mid altitude sites were the only ones in which all types were able to complete their life cycles successfully.

# LITERATURE CITED

1. Adams, J. The effect on certain plants of altering the daily period light. Ann. Bot. 37: 75-94. 1923.

2. Aikman, J. M., Eisele, H. F. and Bair, R. A. Relation of corn yields to rate of growth and available soil moisture. U.S.D.A. Bur. Agr. Econ., Research on relationships of weather to crop yields. Papers relating to objectives and progress of crop-weather research. 1938.

3. Anderson, E. and Cutler, H. C. Races of Zea mays I. Their recognition and classification. Ann. Mo. Bot. Garden 29: 69-88. 1942.

4. Ashby, Eric. The interaction of factors in the growth of Lemna. III The interrelationship of duration and intensity of light. Ann. Bot. 43: 333-354. 1924.

5. Bair, R. A. Climatological measurements for use in the prediction of maize yield. Ecology 23: 79-88. 1942.

6. Bonafous, M. Note sur une nouvelle espece de maïs. Ann. Sci. Nat. 17: 156-158. 1829.

7. Bonnier, G. Cultures experimentales dans les Alpes et dans les Pyrenees. Rev. Gen. de Bot. 2: 513-546. 1890.

8. ________. Recherches experimentales sur l'adaptation des plantes an climat alpin. Ann. Sci. Nat., Botanique, 7, 20: 217-358. 1895.

9. ________. Nouvelles observations sur les cultures experimentales a diverses altitudes. Rev. Gen. de Bot. 32: 305-326. 1920.

10. Bukasov, S. M. Khlebnye zernovye rasteniia (kukuruza, khuautli, kinoa) (Chap. II of his Vozdelyvaemye rasteniia Meksiki, Gvatemaly i Kolumbii.)(The cultivated plants of Mexico, Guatemala and Colombia, Chap. II: Cereals. A. Maize.)(p. 491: English summary.) Trudy Prikl. Bot., Genet., i Selek., (Bul. Appl. Bot., Genet., and Plant Breeding), Prilozhemi 47: 109-116. 1930.

11. Christie, W. and Grau, H. H. Die Einwirkung verschiedener Klimaverhälisse auf reine Linien von Hafer und Gerste. Hereditas 8: 207-228. 1926.

12. Clausen, J., Keck, D. D. and Hiesey, W. M. Experimental studies on the nature of species I. Effect of varied environments on western North American Plants. Carnegie Inst. of Wash. Pub. No. 520. 1940.

13. Cofino, P. G. Antigua, Guatemala. Meteorological data from Finca Retana. Private communication. 1948.

14. Collins, G. N. New-place effect in maize. Jour. Agr. Res. 12: 231-243. 1918.

15. ________. The tropical varieties of maize. Jour. Hered. 9: 147-154. 1918.

16. Compañia Agricola de Guatemala. Alotenango rainfall reports by month. Tiquisate, Guatemala. Unpublished. 1947.

17. ________. Monthly meteorological reports. Tiquisate, Guatemala. Unpublished. 1947.

18. ________. Solola Farm rainfall reports, by month. Tiquisate, Guatemala. Unpublished. 1947.

19. Cox, Gertrude M., Eckhardt, R. E. and Cochran, W. G. The analysis of lattice and triple lattice experiments in corn varietal tests. Iowa Agr. Exp. Sta. Res. Bul. 281. 1940.

20. Davis, F. E. and Pallesen, J. E. Effect of the amount and distribution of rainfall and evaporation during the growing season on yields of corn and spring wheat. Jour. Agr. Res. 60: 1-23. 1940.

21. De Leon, H. F., Director. Anales No. 20, Observatorio de Occidente, Quetzaltenango, Guatemala. Unpublished. 1947.

22. Dorno, Carl. Physik der sonnen-und himmelsstrahlung. Friedr. Viewig und Sohn, Braunschweig. 1919.

23. Eisele, H. F. Leaf area and growth rate of corn plants. Iowa State Col. Jour. Sci. 9: 521-526. 1935.

24. Evans, M. W. Relation of latitude to certain phases of the growth of timothy. Amer. Jour. Bot. 26: 212-218. 1939.

25. Goodding, F. H. and Kiesselbach, T. A. The adaptation of corn to upland and bottom land soils. Jour. Amer. Soc. Agron. 23: 928-937. 1931.

26. Gourley, J. H. The effects of shading on some horticultural plants. Proc. Amer. Soc. Hort. Sci. 17: 256-260. 1920.

27. ________ and Nightingale, G. T. The effects of shading some horticultural plants. New Hampshire Agr. Exp. Sta. Tech. Bul. 18: 1-22. 1921.

28. Gregor, J. W. Experiments on the genetics of wild populations. Jour. Genet. 22: 15-25. 1930.

29. Hall, H. M. Heredity and environment as illustrated by transplant experiments. Scientific Monthly 35: 289-302. 1932.

30. Hanna, W. F. Growth of corn and sunflowers in relation to climatic conditions. Bot. Gaz. 78: 200-214. 1924.

31. Hoffman, Elise. Der ausbruck optimalen Lichtgenusses imm Blattbau der Pflanze. Bot. Arch. 18: 288-295. 1927.

32. Ito, Kenji and Furukawa, Daiji. Regional adaptation of corn varieties with respect to the number of leaves on the main stem and their systematical classification in Manchoukuo and the neighboring countries. Japanese with English summary. Manchoukuo Agr. Exp. Sta. Res. Bul. 32. 1940.

33. Jones, D. F. and Huntington, E. The adaptation of corn to climate. Jour. Amer. Soc. Agron. 27: 261-270. 1935.

34. Kelsey, Vera and Osborne, L. D. Four keys to Guatemala. Funk and Wagnalls, New York. 1939.

35. Kempton, J. H. Jala maize; a giant variety from Mexico. Jour. Hered. 15: 337-344. 1924.

36. Kerner von Marilaun, A. Pflanzenleben. 2: 489-507. Bibliographischen Instituts, Leipzig. 1891.

37. Kuleshov, N. N. Chislo list' ev kak pokazatel' dliny vegetalsionnogo perioda u kukuruzy. (Number of leaves as an index of the duration of growth of maize.) Trudy Prikl. Bot., Genet., i Selek., (Bul. Appl. Bot., Genet., and Plant Breeding.) 27, 1: 477-488. 1931.

38. ________. Kukuruza Miksiki; Gvatemaly, Kuby, Panamy i Kolumbii. (p. 492-501. English summary, The maize of Mexico, Guatemala, Cuba, Panama and Colombia.). Trudy Prikl. Bot., Genet., i Selek. (Bul. Appl. Bot., Genet., and Plant Breeding.) Prilozhenie 47: 117-141. 1930.

39. ________. The world's diversity of phenotypes of maize. Jour. Amer. Soc. Agron. 25: 688-700. 1933.

40. Le Clerc, J. A. and Yoder, P. A. Tri-local soil exchange experiments with wheat. 8th Internatl. Cong. Appl. Chem. Orig. Commun. 26: 137-150. 1912.

41. Lees, J. H. Altitudes in Iowa. Iowa Geol. Survey. Ann. Rep. 32 (1926): 365-549, map. 1927.

42. Lehenbauer, P. A. The growth of maize seedlings in relation to temperature. Physiol. Res. 1: 247-288. 1914.

43. Loomis, W. E. Daily growth of maize. Amer. Jour. Bot. 21: 1-6. 1934.

44. Lubimenko, W. Production de la substance seche et de la chlorophylle chez les vegetaux superieuro aux differentes intensites luminenses. Ann. Sci. Nat. Botanique. 9, 7: 321-415. 1908.

45. Lundegårdh, Henrik. Klima und Boden in ihrer Wirkung auf das Pflanzenleben. Jena. 1925.

46. MacDougal, D. T. Growth of wheat (Triticum) and corn (Zea). Carnegie Inst. of Wash. Yearbook 16: 85-87. 1917.

47. ________. The reaction of plants to new habitats. Ecology 2: 1-20. 1921.

48. Manglesdorf, P. C. Corn varieties in Texas; their regional and seasonal adaptation. Texas Agr. Exp. Sta. Bul. 397. 1929.

49. ________ and Cameron, J. W. Western Guatemala a secondary center of origin of cultivated maize varieties. Bot. Museum Leaflets, Harvard Univ. 10: 217-252. 1942.

50. Marsden-Jones, E. M. and Turril, W. B. Reports on the transplant experiments of the British Ecological Society at Potterne, Wilts. Jour. Ecol. 16: 186; 18: 352-378; 21: 268-293; 23: 443-469; 26: 359-389. 1927-1938.

51. Marvin, C. F. Psychrometer tables for obtaining vapor pressure, relative humidity and temperature of the dew point from readings of the wet- and dry-bulb thermometers. U. S. Dept. of Commerce. Weather Bur. Bul. 235. 1941.

52. McCalla, A. G., Weir, J. R. and Neatby, K. W. Effect of temperature and sunlight on the rate of elongation of stems of maize and gladiolus. Canadian Jour. Res. C., 17: 388-409. 1939.

53. McClelland, F. H. Studies of the photoperiodism of some economic plants. Jour. Agr. Res. 37: 603-628. 1928.

54. Melhus, I. E. Annual report of the Director; Iowa State College-Guatemala Tropical Res. Center. Unpublished. 1947.

55. ________, Semeniuk, G. and Wallin, J. R. The influence of climate on the distribution of corn in Guatemala. (Abstract). Amer. Jour. Bot. 33: 825. 1946.

56. Pittier, H. Ensayo sobre las plantas usuales de Costa Rica. The McQueen Press, Washington. 1908.

57. Popp, H. W. Effects of light intensity upon soy beans. Bot. Gaz. 82: 306-319. 1926.

58. Raunkiaer, C. The life forms of plants and statistical plant geography. London. 1934.

59. Rojas, U. Elementos de botanica general. 2: 441. Tipografia Nacional, Guatemala. 1926.

60. Rosé, E. Energie assimilatrice chez les plantes cultivees sous differentes eclairement. Ann. Sci. Nat. Botanique. 9, 17: 1-110. 1913.

61. Salas, E. G. Tiquisate, Guatemala. Meteorological data. Private communication. 1948.

62. Sapper, Carl. Über die geologische bedentung der tropischen Vegetations-form in Mittlamerica und Sudmexico. Alexander Ledelmann, Leipzig. 1900.

63. ________. Climatology of Central America. A translation from the German of Klimakunde von Mittleamerika, Handbuck der Klimatologie, edited by W. Koppen and R. Geiger. Vol. 2, Part H. Berlin 1932. Translated by the U. S. Army Air Corps Weather Service. n.d. (Mimeographed.)

64. Sayre, J. D. Variability of certain characters in corn. Ohio Agr. Exp. Sta. Bul. 516: 36. 1933.

65. Sellick, N. P. Maize and meteorology. Rhodesia Agr. Jour. 27: 962-969. 1930.

66. Shirley, H. L. Influence of light intensity and light quality upon the growth of plants. Amer. Jour. Bot. 16: 354-390. 1929.

67. ________. The effects of light intensity on seed plants, in Duggar, B. M. Biological effects of radiation Vol. 2. McGraw-Hill, New York. 1936.

68. Sprague, H. B. The adaptation of corn to climate. (Notes) Jour. Amer. Soc. Agron. 27: 680-681. 1935.

69. ________, Farris, N. F., Colby, W. G. and Curtis, N. Corn varieties for grain, fodder, and silage. N. J. Agr. Exp. Sta. Bul. 537. 1932.

70. Stapledon, R. G. Cocksfoot grass (*Dactylis glomerata* L.) ecotypes in relation to the biotic factor. Jour. Ecol. 16: 71-104. 1928.

71. Stringfield, G. H. and Salter, R. M. Differential responses of corn varieties to fertility levels and to seasons. Jour. Agr. Res. 49: 991-1000. 1934.

72. Sturtevant, E. L. Notes on maize. Bul. Forr. Bot. Club 21: 319-343, 503-523. 1894.

73. ________. Varieties of corn. U. S. Dept. Agr. Off. Exp. Sta. Bul. 57: 1-108. 1899.

74. Turesson, Göte. The species and the variety as ecological units. Hereditas 3:100-112. 1922.

75. ________. The genotypical response of the plant species to the habitat. Hereditas 3: 211-350. 1922.

76. ________. The plant species in relation to habitat and climate. Hereditas 6: 147-236. 1925.

77. ________. The selective effect of climate upon the plant species. Hereditas 14: 99-152. 1930.

78. Urrutia, C. E., Director. Anales No. 20, Observatorio Nacional Meteorologico y Sismologico, Guatemala City, Guatemala. 1947. (Mimeographed)

79. ________. Observatorio Nacional, Guatemala City, Guatemala. Meteorological data. Private communication. 1948.

80. Went, T. W. Effects of light on stem and leaf growth. Amer. Jour. Bot. 28: 83-95. 1941.

81. Wolfe, T. K. A mathematical inquiry into the influence of the amount of rainfall on the yield of corn. Jour. Amer. Soc. Agron. 17: 356-362. 1925.

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