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RACES OF MAIZE IN BRAZIL AND OTHER EASTERN SOUTH AMERICAN COUNTRIES

F. G. Brieger
J. T. A. Gurgel
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ACKNOWLEDGMENTS

The studies of indigenous races of maize were started in Piracicaba, Brazil, in 1937, as one of the first research projects of the then new Department of Genetics of the University of Piracicaba. For several years, however, these studies could not be intensified for lack of funds, indispensable for organizing any large-scale collecting activities. The plan established by the Committee on Preservation of Indigenous Strains of Maize of the National Academy of Sciences — National Research Council in Washington, which included the establishment of three main Centers for collecting and study, one in Mexico, another in Colombia, and the third in Piracicaba, allowed the long-hoped-for expansion of the work. During the years 1953–55 resources were available for collecting, and during 1956–58 for studying, this material. Additional contributions were obtained from the Brazilian National Research Council in Rio de Janeiro. The gift of a station wagon and grants from the Rockefeller Foundation also helped considerably.

Under the program of the National Academy of Sciences — National Research Council the total area of Latin America was divided into three regions, of which the third including Argentina, Brazil, eastern Bolivia, Paraguay, Uruguay, Surinam, and the Guianas was made the responsibility of the Center at Piracicaba.

The collecting activities present considerable difficulty in this area. An inspection of the maize offered on the local markets of small towns does not give any information about the maize grown on farms around these towns in Argentina or Brazil, since in both countries maize rarely is sold on the spot, the commerce being in the hands of commercial intermediary agents. Thus in these regions excursions must be organized to individual farms, or the collection must be organized through government agencies and county agents. It is our pleasure to thank here especially Dr. Vallega, of the Instituto de Fitotecnia at Castelar, and Dr. Kugler, of the Experiment Station at Pergamiño in Argentina, the late Dr. A. Boerger and Dr. G. Fisher of the Instituto "La Fitotechnico

Estanzuela," Uruguay, Drs. Breitenbach, José R. Ramires, and Rogelio Vargas Morel in Asunción, Paraguay, Dr. M. Cardenas of the Universidad Mayor de San Simon, Cochabamba, Bolivia, Drs. Edmundo Heidrich and Leo Fett in the State of Rio Grande do Sul, Dr. Afonso Veiga of the Federal Extension Service in the State of St. Catarina, Drs. Glauco Pinto Viégas of the Instituto Agronomica, José Andrade Sobrinho of the Extension Service, Raul Drumond Goncalves of the Instituto Biológico, all in the State of São Paulo, and many other colleagues and friends, for the valuable help given to our staff members who mainly did the collecting, Drs. J. T. A. Gurgel, W. E. Kerr, E. Paterniani, and A. Blumenschein.

In the central and northern parts of Brazil there are only two ways to collect maize samples from the Indian population: either to organize expeditions or to receive samples from organizations which are in direct contact with the tribes, and we thank Dr. E. Galvão, of the Brazilian Service of Indian Protection, Sr. Vilas Boas of the Foundation Brazil-Central, and members of the Franciscan, Jesuit, and Salesian Missions, all of whom helped us greatly.

In the Amazon area, Dr. W. E. Kerr had considerable help from Dr. Felisberto de Camargo, and in the Guianas from Dr. M. Lohier of the Musee de Cayenne and Dr. D. Geyskes of the Department of General Affairs in Surinam.

In spite of these efforts, our collections cannot yet be considered as complete, but all collecting activity had to stop in 1955 for lack of funds. Though we believe that little has been overlooked in the southern area, we obtained only a limited number of samples from the central and eastern part of the Amazon Basin, and these were received before the program became fully established. Thus they were not as fully analyzed as now seems desirable. There may still be very interesting examples of rather primitive maize in existence in the Amazon and Orinoco Basins, where the Indians are rather scattered and where maize is no longer the main subsistence crop.

Before the program of the Centers was established, some collections were made in Colombia, mainly with the help of Dr. Eduardo Chavarriaga and our former students, Drs. Alberto Gon-

calez and Ernesto Villegas, and of the archaeologist Dr. Reichel-Dolmatoff. The knowledge of these Colombian races, and especially those of the Magdalena plains in the north and of the St. Martha Mountains, contributed greatly to our understanding of questions of the general distribution of corn races in South America. However, the study of this material was given up as soon as the Colombian Maize Center of the Rockefeller Foundation started its work. We thank Drs. Wellhausen, Grant, and Grobman, of the Mexican, Colombian, and Peruvian Maize Centers, for their permission to inspect and study some of their collections.

Samples given to us upon request by Dr. Grant from the Colombian Center established the link between Chilean and Argentinian maize races of the Calchaqui type. We found also that the races of northwestern Argentina, high up in the Andes, belong to the Bolivian group of races and agree at least in part with material received with the help of Dr. M. Cardenas, both some fifteen years ago and again during the recent collecting trip of Dr. Gurgel (1957) under a grant from the Brazilian National Research Council.

We also want to thank here all those who helped us during the many years when the work was in progress and when we were compiling the final manuscript: Mr. João Zaldoval, José Penteado Maia, Alcides Perón and Miss Erica Spruck (recording and typing), Mr. Sebastião Coelho Fischer (photography), Mr. Adalberto Gorga and Oswaldo Peres (calculations), Mr. Walter Benedicto Bortolazzo (drawings), Mr. Antonio Gosser (in charge of field work), José Broglio (seed storing). Two of our students, Mr. Roland Vencovsky and Elliot Watanabe Kitajima, helped considerably in carrying out the final statistical analysis and in preparing the tables for this paper.

The authors are grateful to the Committee on Preservation of Indigenous Strains of Maize and to members of the staff of the Agricultural Board of the National Academy of Sciences — National Research Council for editing and preparing the manuscript for publication.

RACES OF MAIZE IN BRAZIL AND OTHER EASTERN SOUTH AMERICAN COUNTRIES

F. G. Brieger,[1] J. T. A. Gurgel, E. Paterniani, A. Blumenschein, and M. R. Alleoni

INTRODUCTION

From the beginning, the aim of our studies was not limited to describing or cataloguing the existing indigenous races of maize in South America, but included as well information about the origin and the history of indigenous races in this important American area. This is, however, not the only reason for including in this publication the results of studies on these questions of origin, carried out with South American material. Such studies have become in fact indispensable, since Wellhausen *et al* (1952) in their studies on the Mexican races, the first modern publication on the subject, considered the origin of each race, and since the descriptions have always been mixed in the literature with recent theories on the origin of maize, mainly following either E. Anderson or P. Mangelsdorf.

Before starting the discussion, one general consideration is necessary. Since facts are often lacking, they have been frequently replaced by assumptions or by working hypotheses, sometimes set up on weak foundations. The considerable value of this method is shown by an extensive literature, containing many new facts discovered in the attempts to prove or to find a sound foundation for a speculative working hypothesis. On the other hand, it is not considered justifiable to attempt, as is sometimes done, to save an hypothesis, even if no proof is found, by adding others to it, building up an impressive but extremely fragile structure.

We believe it is necessary to use from time to time the opposite method: strong criticism, based on facts only, even if one has to admit the existence of a large area where our knowledge is still

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very limited. Sound progress depends, we believe, upon a good combination of speculative argumentation and decisive criticism. The knowledge accumulated by the numerous studies of indigenous maize races now allows, and even requires, a critical revision of many working hypotheses on the origin of maize and its races.

This report represents a summary of work which has been going on over a period of more than twenty years. We cannot include, of course, a full description of all the facts gathered, nor would it be worth while to describe phases of the work which have become superfluous in the course of progress, which has been very considerable during this same period. However, a summary of facts bearing on the origin of maize appears indispensable for understanding the relations between maize races and will be given before going on to the description of the races.

THE BASIC NATURE OF MAIZE AND ITS ORIGIN

If one goes over the literature, beginning with St. Hilaire (1829) and coming up to the present, it becomes evident that we can distinguish two phases in the studies on the origin of maize: one ending around the middle thirties, when Weatherwax (1935) and Mangelsdorf and Reeves (1939) published extensive literature reviews, and the other starting with the latter of these two publications. In the first phase little importance was given to indigenous races, which then were almost completely unknown, and it is remarkable with what ease an older hypothesis was replaced by a new one, without too much conclusive evidence for or against either one. The most important progress in the second phase is, we believe, due mainly to the importance given to the still existing indigenous races, which, owing to the conservatism of Indian agricultural tribes, represent still different historical phases of the evolution of maize.

THE TIME OF ORIGIN OF MAIZE

The only safe method for timing the origin of a cultivated plant is through correct dating of archaeological remains. Historical data of any other sort are of no value, since the development of any kind of art, including writing, can only have started after a highly developed agriculture had become established and thus whatever reference we may find, even in old literature, should be considered as unfounded assumption, made by the respective authors and based only on hearsay or tradition, except as showing that maize was in existence as a crop plant.

Exact dating of relics has become possible only very recently, after the discovery that the content of radioactive C_{14} may be used for this purpose. Only three samples have so far been dated by this method, all from marginal areas. We now know that maize, not too different from present-day races, already existed in northeastern Mexico and New Mexico around 3,000 B.C. and 2,500 B.C. (Mangelsdorf and Smith 1949, Mangelsdorf, McNeish, and Galinat 1956). On the coast of Peru, maize appeared much later, around 900 B.C. (Bird 1949), which is not surprising, since this crop plant had to pass first over the Andes from east to west and thus had to undergo a number of adaptive changes before reaching the coastal area of the Pacific Ocean.

There is no information as to how old maize may have been in the tropical areas of Central and South America nor in the Andes of Peru and Bolivia. How primitive maize really was at this period, some 5,000 years ago, also remains an open question. We know from the study of the existing indigenous races that—to use terms suggested by Wellhausen *et al* (1952)—"ancient races, pre-Columbian races, prehistoric races, and modern incipient races" do coexist even now. Thus if archaeological relics apparently contain forms which seem very primitive, this does not prove that, at the same time and in the same or in another area, more highly developed races may not have also been in existence. Thus the age of about 5,000 years represents so far only a minimum estimate, and we must allow at least another few thousand years for the initial changes of a wild grass into something similar to domesticated maize.

In this respect it is of interest to refer to a special feature of plant breeding by the American Indians which differs considerably from old or modern plant breeding in the Old World. Nearly all American crop plants show clearly that breeding was carried out not only for practical purposes, but also for esthetic ones, resulting in the production of a very wide range of forms and colors in seeds (maize, peanuts, beans, etc.), fruits (cucurbits), roots and rhizomes (cassava, etc.).

Furthermore, we may assume that, more than 5,000 years ago, the Indian plant breeder must have already known something of basic breeding technique.

We agree fully with such authors as Kempton (1937), Weatherwax (1942), and others in considering the Indian on the whole as a quite efficient plant breeder. He has in fact obtained and highly improved many crops which are today of considerable importance, such as maize, cassava, potato, peanut, pineapple, tobacco, while the more "civilized" man of the last few thousand years has not added one new crop plant of basic value. The same of course is true of the prehistoric Old World breeder who domesticated wheat and all other small grain cereals. We cannot agree with Wellhausen *et al* (1957) who claims that "the principal forces which have been involved in the evolution of maize under domestication are the same forces which operate in nature: mutation, random genetic drift, natural selection and hybridization. Man by his activities has accelerated some or all of these forces. There is little evidence, at least in early stages of culture, that he consciously added to them." Under domestication, especially in the initial stages, man must have contributed quite considerably by intentionally annulling as much as possible the effects of natural selection which, if free to act, would give considerable advantage to any mutations or changes in gene frequency, favorable under natural conditions and thus contrary to the proper process of domestication itself. But even the secondary role, which is attributed to the Indian "in preserving and perpetuating them (*i.e.* races of maize) and perhaps through rigid selection improving their uniformity to some extent," requires a considerable skill, if one remembers not only that maize is a cross-fertilized crop, suffering rapidly from inbreeding in small populations, but that this process of "preservation" has been carried out and maintained successfully and constantly through many hundreds or even thousands of years. It seems certain that most indigenous races existed at least before the entry of the white man into the Americas.

The main conclusions which we feel it is safe to draw from these discussions are (a) that maize as a domesticated crop did exist in the Americas at least around 3,000 B.C. and (b) that its improvement through the formation of races by the indigenous plant breeder has been going on ever since and was started certainly before that time by rather efficient breeders.

THE PLACE OF ORIGIN OF MAIZE

The place of origin of maize is another field where decisive data are almost completely absent and where all authors have relied more or less on speculation or hypothesis to interpret facts or supposed facts.

DeCandolle (1884), who it seems was the first to study the question of the place of origin of cultivated plants, suggested four methods: (a) *Historical evidence,* which cannot be of any use in our case, since in the Americas written records of the pre-Columbian period are practically nonexistent, and whatever may have been written afterwards can have been based only on hearsay. (b) *Linguistic evidence,* which seems hardly useful in spite of attempts made in this direction. The crop plant we call "maize," using a variation of a name employed by the Aruak Indians of the Caribbean area, is called "corn" in most of North America, thus using a very old name for a very new crop, while in various regions in northern Europe the same name is applied to rye or wheat. Brazil follows the Portuguese custom of using the name "milho," derived from the name for the Old World cereal, millet (Sorghum or Panicum). The use of names such as maize, corn, or milho shows that agricultural people may accept new names, together with a new crop, from others or that they may use their own old names and transfer them to new crops. The same occurred possibly among the Indians. We may mention among many names the following: "Sara" in the Peruvian-Bolivian Andes, "Avatí" (or Abatí) of the southeastern Guaraní, "Nhara" of the Caingang Indians, and many other more complicated names used by other Indian tribes. (c) *Archaeological evidence* has only been useful so far in showing that maize already existed at a certain time and a certain place, but does not allow any general conclusions beyond this, *i.e.*, with regard to where maize first came into existence, because there are no relicts in tropical or subtropical wet areas.

Thus we must use DeCandolle's fourth method and try to find (d) *botanical evidence* to solve the question of the most probable region of origin of maize.

From a general estimate of the physiological behavior of the plant under cultivation, one may conclude that this cereal must be of tropical or subtropical origin, since it tolerates almost any amount of heat but not of cold; that it must have come from open country, since it requires direct sunlight and not shade; neither drought resistant nor supporting wet soils, it is, however, adapted to a change of seasons, with a rapid growth until maturity in order to finish its cycle in less than a year. Thus we may conclude that the ancestor of maize belonged to a tropical grassland flora, but vegetations of the type required are so frequent in middle altitudes from Guatemala to southern Brazil that these ecological requirements do not help to place the origin of the hypothetical wild ancestor from which domestication started.

The distribution of the known wild relatives of maize also does not help very much. After Ascherson (1880) recognized *Euchlaena* as a near relative of maize and Harshberger (1893), (1896) considered *Euchlaena* or teosinte as one parent which, after crossing with some unknown grass, gave origin to maize, it was thought that the Central American area, where *Euchlaena* still occurs in the wild, should be considered as the place of origin. But the theory of *Euchlaena* as the parent of maize has been abandoned by all authors concerned. With regard to the distribution of the ten species of *Tripsacum*, we know that this again covers practically the whole area from southern Mexico to the eastern Bolivian lowlands (Cutler and Anderson 1941). Thus this line of approach does not yield results either.

There has always been a tendency to link the origin of maize with those regions where a higher civilization later developed, *i.e.*, either in the Guatemalan-Mexican area or in the highlands of Perú-Bolivia. Such ideas apparently gained more weight after Vavilov (1926) formulated them in a more modern form, as part of his theory of the existence of collective centers of origin of cultivated plants. The validity of Vavilov's hypothesis, even for the so-called centers of origin and domestication in the Old World, has become quite doubtful, and it is certainly not valid in the Americas.

The attempt has been made to draw conclusions from the actual distribution of types or races of maize. Brieger (1950 a and b) tried to reconstruct "routes of migration" which, if converging to some common region, would justify consideration of this region as the place of origin. But the more complete knowledge that we have today about maize races no longer justifies such hypothetical reconstructions. Mangelsdorf in several publications (Mangelsdorf and Cameron (1942), Mangelsdorf (1945)) thought it possible to distinguish two basic types of corn races: those of "pure maize" and those of maize contaminated by *Euchlaena,* without giving a clear definition of what may be one or the other. At first (1942) they thought that "pure maize" was the so-called "Andean maize," but as we know now and shall see later in this paper, there is nothing which one could call "the" Andean type of maize. Later Mangelsdorf (1945) considered as "pure maize" the offspring of a cross between Guaraní maize and pod corn. It should, however, be remembered that pod corn may be any race or variety of maize which incidentally carries the dominant Tu factor, and the nature of the particular pod corn used was not stated by the author. Furthermore, there are several races of Guaraní maize as will be shown later, and again we do not know to which of these the author wanted to refer. In any case, all Guaraní maize is lowland maize, and thus quite in contrast with the "Andean" races formerly considered as "pure" maize.

In his paper, Mangelsdorf (1945) tried, however, to distinguish "pure" and "contaminated" maize on the basis of ear structure, *i.e.,* taking into consideration the relative position of the kernels in different rows. He attributes to "pure" maize a "whorled-random" arrangement of the kernels, and to maize with supposed Tripsacum or teosinte infiltration a "spiral systematic" arrangement. Brieger (manuscript) carried out a detailed study of ear morphology in South American races and showed that one must first analyze the position within the alveolus, and then the relative position of the kernel pairs in neighboring ranks. Within the alveolus, the two kernels may be at the same level and a line connecting their bases would be at right angles to the axis of the cob ("horizontal arrangement"), or this line may have an "oblique" position with regard to the cob axis. Frequently, both positions occur on the same ear, with not too frequent changes, but in extreme cases two quite different ear structures may result if we also take into consideration all the ranks of alveoli on an ear. With an oblique arrangement within alveoli and a lack of space on the cob surface, the oblique arrangements within alveoli may coincide in all ranks, forming ascending spirals all around the ear. These spirals may be much more conspicuous than the longitudinal kernel rows. This "oblique-spiral" arrangement can be found in a number of races such as the round-seeded *Guaraní Pop corn,* several races from the Amazon Basin (Caraja, Emerilhon), some *Altiplano* types from Humahuaca, *Brachytic Pop corn,* all illustrated below, but also in other races such as *Chococeno Pointed Pop corn,* described by Roberts *et al* (1957). They are generally considered as rather primitive and they may correspond, at least in part, to an early level of domestication, in which the aboriginal breeder has succeeded in increasing row numbers but not yet in increasing the surface space of the cob. The other extreme is found when a "horizontal" arrangement within alveoli coincides with ample space on the cob surface. This may result in a "horizontal-whorled" arrangement which, however, is rather rare but can be found in the *Cuzco Large Grain,* which has only four ranks of kernels, and in the *Interlocked Soft Corn* of the lowlands, as shown in Figure 1 and which was first described by Cutler (1946). The latter is especially interesting since Brieger now believes that the interlocking of neighboring alveoli corresponds to an early phase in domestication, representing another solution of the problem of accommodating more kernels on an ear, in regular rows, without a sufficient increase of cob surface. In an interlocked ear a doubling of row numbers can be accommodated on ears twice as long as normal but without alteration of the cob diameter. However, one must not forget that the majority of the South American races, and probably of all corn races, show an intermediate situation as illustrated for *Guaraní Soft Corn* in Figure 2. Brieger assumes that all these types, including the two extremes, *i.e.,* the "oblique-spiral" and the "horizontal-whorled" arrangements, are the result of the difficulties in accommodating an increasing number of rows

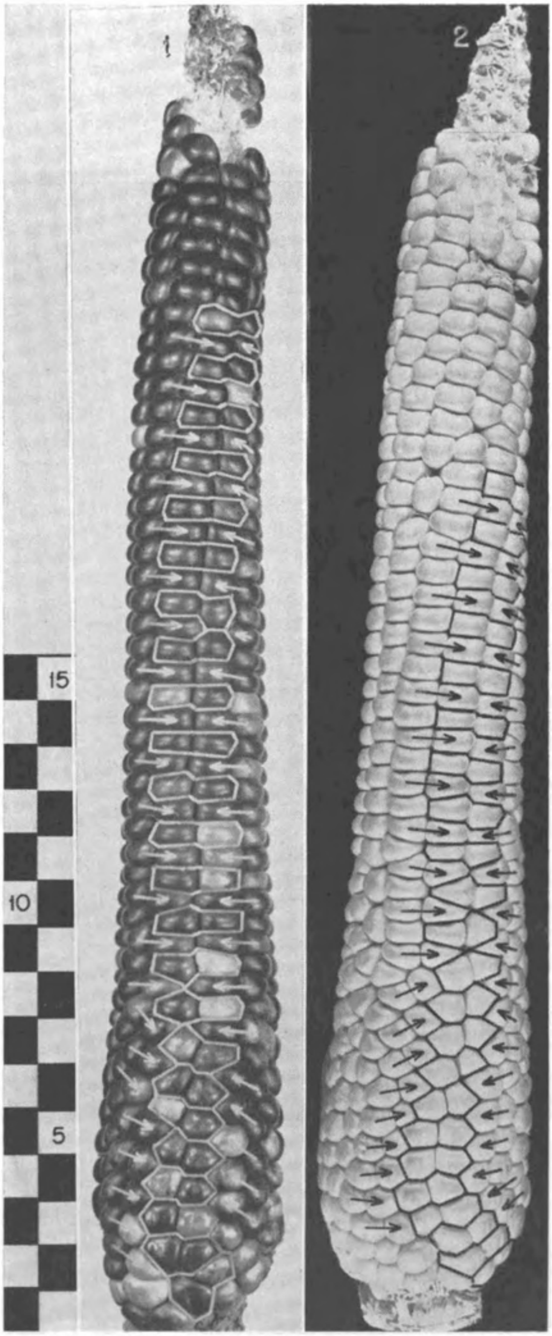

FIG. 1. Two ears of Interlocked Soft Corn, showing the development of interlocking between alveoli (pairs of sister spikelets). The ear on the left (1) with a "spiral-oblique" arrangement in the butt and a "whorled-horizontal" one in the rest of the ear. The ear on the right (2) with a "spiral-oblique" arrangement throughout.

(*Centimeter scale is used on all photographs.*)

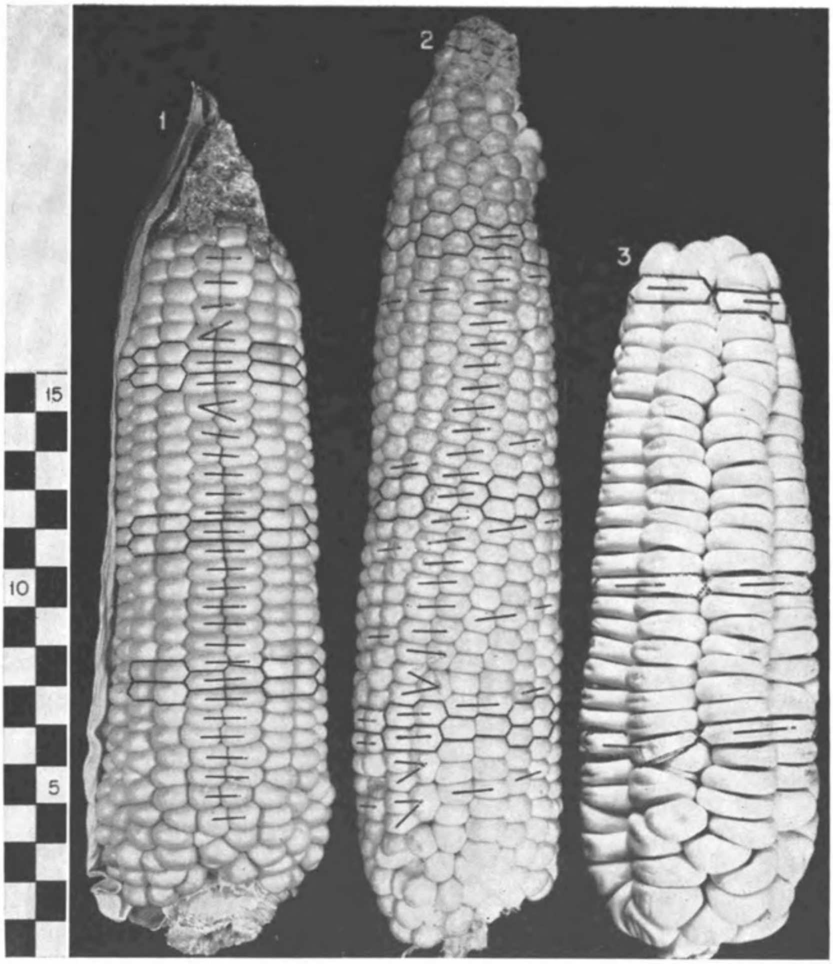

FIG. 2. Two ears of Guaraní Soft Corn, *Avatí Morotí* (1 and 2) and of Large Grain Cuzco Corn (3). In (1) an ear with "horizontal" position of sister spikelets and a near "whorled" arrangement; in (2) an ear with a "spiral oblique" arrangement between and within spikelets; (3) an ear with a "whorled-horizontal" arrangement within and between spikelets.

on the cob surface. We must thus conclude that there is so far no clear definition allowing us to distinguish "pure" and "contaminated" maize races.

We may finally try to obtain some information from the distribution of corn races. The origin of maize "contaminated" by teosinte must have been in Guatemala or southern Mexico, but it is also assumed that this contaminated variety scattered widely and may now occur both north and south of the original area of contamination. On the other hand, "pure maize," whatever it may be, must be restricted to some region outside Guatemala to which "contaminated maize" may have also scattered. Thus the distribution becomes confused when we study maize races in general, and this makes it difficult, if not impossible, to prove the hypothesis of the existence of these two types of maize.

Migration has been recently considered as one very important factor in the origin of races of maize, by bringing some races into contact and allowing their interbreeding from which new races may result. Such hypotheses are extensively used by Wellhausen *et al* (1957) for the origin of Guatemalan races, and by Roberts *et al* (1957) for the Colombian races. We shall also use this principle in the present publication, but some precautions are required and first a basic question should be raised: Can maize races really migrate easily anywhere or are there barriers, making such migrations difficult or even impossible? In other words, has the principle of migration and interbreeding not been used to an excessive degree?

It seems justifiable to ask if there are not climatic or ecological barriers against migration of maize races over too wide distances. Unfortunately not too much has been mentioned so far about such barriers in the enormous area between Mexico and Argentina, except that there are differences in altitude and latitude. However, interesting information was obtained by studies which we carried out during recent years with members of a completely different family, the orchids. Orchid seeds are very small and light and are scattered and disseminated widely by the wind. Thus if they do not grow anywhere, this must be due mainly to the fact that there are climatic barriers which impede the establishment of seedlings outside the normal climatic range of the parent species.

Since most orchids are epiphytes, they offer the additional advantage of being independent of soil conditions. The first results obtained in our studies are reproduced in the map shown in

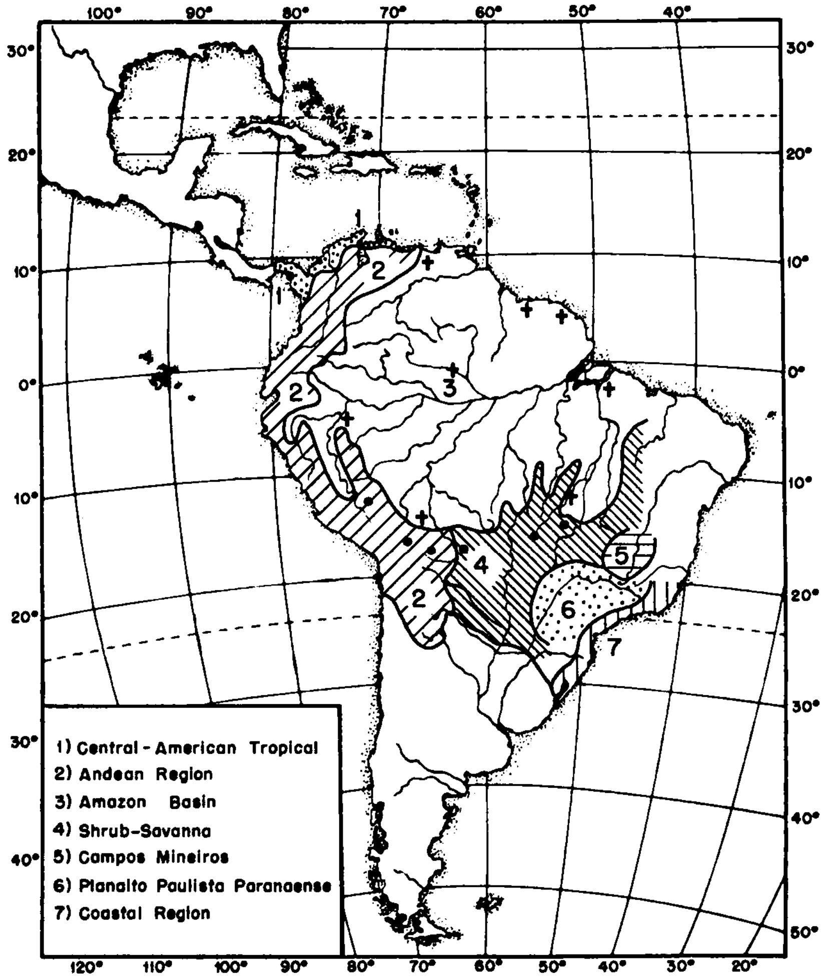

FIG. 3. Phyto-geographic map of South America showing the main climatic regions as indicated by the distribution of orchids.

Figure 3. By comparing, more or less accidentally, the distribution of maize races and of wild orchids in South America, a number of coincidences were found which cannot be considered as accidental. Starting with the Andean region (zone 2) in the west, a

change occurs, as far as orchids are concerned, at about 1,800 to 2,000 meters altitude on the eastern slopes. At the same level, highland maize reaches its lower limit and lowland races appear. The tropical flora of the Amazon Basin (zone 3) occurs north of an irregular line running from west to east, depending in its details on the course of the rivers, with the drier forests and savannas of Matto Grosso (Bolivia-Brazil) and of Goias (Brazil) (zone 4) to the south. But this line, separating orchid species, is also of great importance for maize. North of the line we find the *Interlocked Soft Corn,* and south of it the *Guaraní Soft Corn.* At about the southern limit of tropical orchids, in the area of the Pilcomayo River, the *Guaraní Soft Corn* becomes mainly replaced by the *Calchaqui White Flint.* Further west we come to the Plateau (Planalto) of the Brazilian States of São Paulo and Paraná (zone 6) and this again is also a special region of maize, where the main indigenous race is the *Caingang White Dent Corn.*

There seems to be some difference in the strength of these barriers, and some may be overcome while others seem absolute. But in any case, if a race of maize passes for some reason beyond the limit of the range of its adaptive area, it can do so apparently only by infiltrating into races native and already adapted to the new ecological-climatic region. Hardly any such transgression of barriers occurred on the eastern slopes of the Andes, as we shall see later in more detail, while infiltration apparently was easier in the lowlands. Among the lowland races, *Calchaqui White Flint* has been quite active by infiltrating towards the north. The resulting infiltration seems of rather recent date, possibly of the time of the large Jesuit missions in Paraguay and neighboring areas, and we may assume that the Jesuits, and not the Indians, were responsible. Synthetic races will be described later which show the infiltration of *Calchaqui Flint* even into the Andean High Valley races, into the *Guaraní Soft Corn* and the *Interlocked Corn,* the latter two being of the tropical lowlands. In all three cases the resulting synthetics are quite different from each other, depending on the other parent race and also on the amount of *Calchaqui* genes which may have successfully infiltrated the new synthetic race. It is thus shown that the *Calchaqui Flint* has migrated and infiltrated, covering a distance of the order of about 10 degrees of latitude and a difference of about 1,000 meters in altitude.

The migration and infiltration of Colombian races into Central America and Mexico (Wellhausen *et al* 1952, Wellhausen *et al* 1957, Roberts *et al* 1957) seems also quite probable, since this requires again only the covering of a distance of some 10 degrees of latitude.

These cases are cited in order to show that migration and infiltration may occur, even beyond climatic barriers.

The often accepted migration of "Andean races," *i.e.*, of highland races from Peru or Bolivia, to Central America and Mexico at some prehistoric time is something quite different. These races must have passed through many different regions to carry out such a migration, over a distance of the order of 40 degrees latitude, and should therefore have formed successfully and in a chain a number of new synthetics, all in prehistoric time, before Central America was finally reached and teosinte infiltration may have started, around (perhaps) 1,000 B.C. It is a complicating factor for this hypothesis that in the Colombian area hardly any races or residues of races of the Peruvian-Bolivian region are maintained even in the form of some synthetic races, as we know from our own collections in this area and from the material described by Roberts *et al* (1957). It seems to us more likely that some of the so-called "Andean races" are relics of quite an old period and were maintained in Peru and Bolivia mainly because of their value as highly adapted races in an extreme climate. We may further suppose that, in this old period, there must have existed other and similar races elsewhere, following some general pattern of geographical distribution. The old and supposedly basic races in Mexico, Guatemala, and Peru-Bolivia thus may not be directly related, or derived one from the others, but may have only belonged to the same stratum in domestication, a point to which we shall come back later.

In a discussion of distribution and possible migrations of races, which may serve as an indicator of the probable center of origin of this cereal, one important distinction seems very necessary. For a very long period, the whole history in the Americas has followed one pattern, determined by the customs and possibilities of migration of the Indians, and this pattern became completely altered over large areas with the appearance of the white man. The new phase after the conquest, *i.e.*, during the last 450 years, caused a complete breakdown of structure of the Indian populations in Central America, in the Andes, and in parts of the South American lowlands and reached rather deep inland from the coasts. The white settler gave preference to types of maize often quite different from those used previously by the Indians in the same region, and he used this crop exclusively as a field crop and not for ceremonial purposes, though it seems that the influence of the Indians hardly ever became completely obliterated. Furthermore there was a complete change both in means and in routes of transportation. This situation becomes very evident if one studies carefully the races described from Mexico (Wellhausen *et al,* 1952), Guatemala (Wellhausen *et al,* 1957), or Colombia (Roberts *et al,* 1957). The results of these changes can be rather clearly seen in material which we obtained when collecting maize in northern Colombia in 1945, where the territory of the "Sierra de St. Martha" still represents a fairly untouched indigenous area and where Dr. Reichel-Dolmatoff helped us in getting samples from two tribes, the Chimilo and Motilones. Thus from this general region we had at our disposal four types of samples: (a) those collected around Barranquilla, (b) from settlers ("colonos") on the margin of the Rio Sevilla, St. Martha, and finally (c) and (d) those of the two above-mentioned Indian tribes

Around Barranquilla (a), and consequently on sale in its market, there are the usual types of maize of the hot lowlands described by Roberts *et al* (1957), among which three belong certainly to the complex of races of South American lowland Indians: *Negrito, Cariaco,* and *Yellow Soft Dent* (Fig. 4). With regard to the last, Roberts, who calls it "*Maize Harinoso Dentado,*" believes that it may represent a rather recent infiltration from a dent coming from Central America. Some such infiltrations are quite evident in the "hard" or flinty dents such as the race mentioned below under the name of Yucal, while the soft Cariaco Dent seems to us quite different. Near St. Martha zone (b), there are in cultivation at least five races or types of maize (Fig. 5), *Negrito, Cariaco,* "Cuba," *i.e.*, orange tropical flint, *Colorado* which seems to us a product of

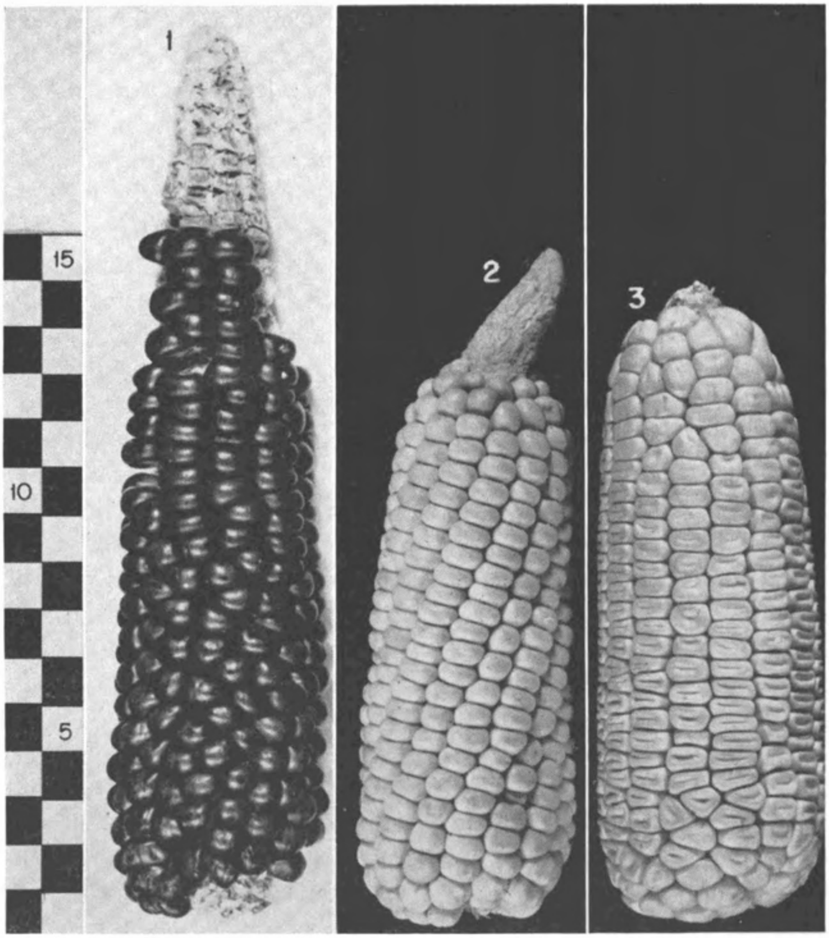

FIG. 4. Indigenous races from the farms around Barranquilla in northern Colombia. 1: Negrito, a semi-flint race with black aleurone. 2: Cariaco, a floury race with yellow-orange aleurone. 3: Cariaco Indentado, a soft dent with yellow aleurone.

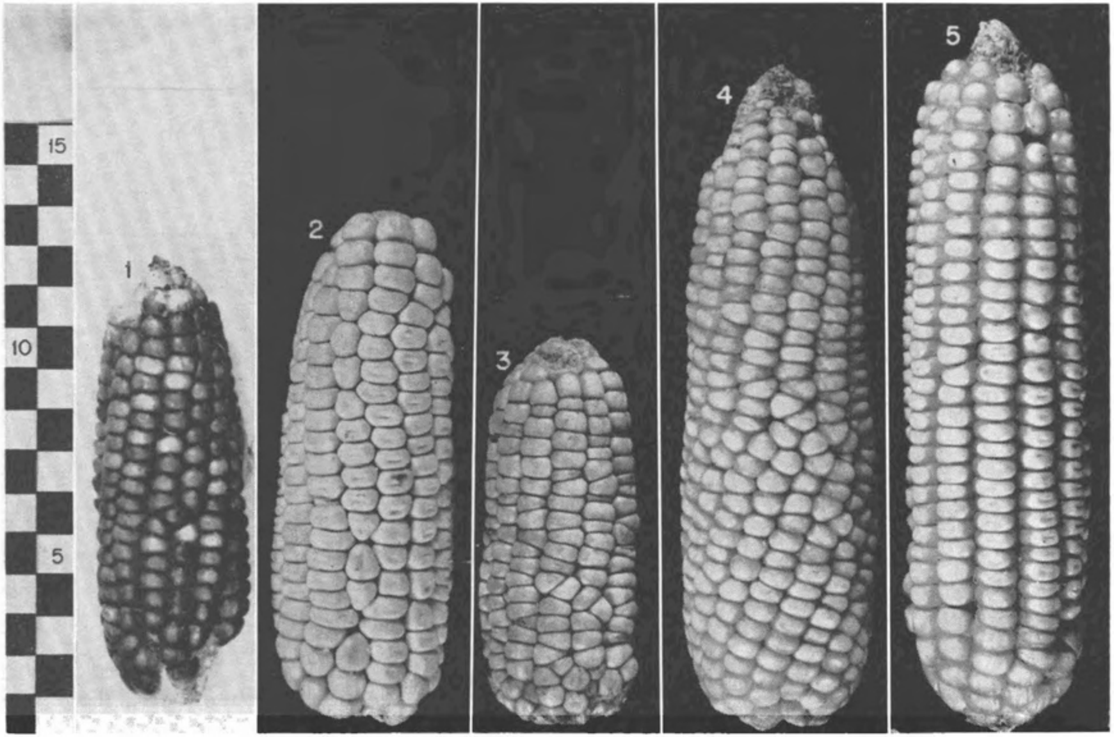

FIG. 5. Races of maize grown by settlers in the region on the Rio Sevilla; St. Martha (northern Colombia) 1: Negrito, the same race as in Fig. 4,*1*. 2: Cariaco, the same race as in Fig. 4,*2*. 3: Colorado, probably a synthetic between Cariaco and Cuba. 4: Cuba, the characteristic Caribbean Flint with yellow endosperm. 5: Yucal, a white hard dent, probably related to Central American Dent.

infiltration of *Cuba* into *Cariaco,* and finally Yucal, a very hard white flint, which certainly came from Central America. In the samples from the Chimilo Indians (c), the situation changes (Fig. 6). There are again of course *Negrito* and *Cariaco,* the former under the name *Gri-ritzó* and the other called *Moro* and subdivided into at least two different subraces, one with large ears and kernels, the real *Moro,* and the other with small ears and kernels, called *Moro Maripú* both with the typical soft starch and yellow aleurone. Then we have again the orange tropical flint, under the name of *Pu-lam-pó* and finally an intermediate type called Kro-pé, which seems very similar to the *Colorado* from St. Martha and which we consider to be a mixture of Cariaco and Cuba. Finally we come to the Motilones (d) and here the situation changes considerably (Fig. 7), since now even the infiltration of the tropical orange flints (Caribbean Flints or "Cuba") disappears, while new types appear which are typical of South America lowlands. There is *Aréyak* (Negrito), Kneétya (*Cariaco*) and a race called Kayansiwesák, which seems intermediate between the other two but has colored pericarp and harder endosperm and may be similar to the race called by Roberts (1957) *Güira.* Then there are three more races of soft dent corn, which are quite different from Central American or Mexican dents: *Mesosápa* with small flat kernels, and *Tanúyka,* with large and rounder kernels, and finally *Ksumsé,* a very interesting soft dent, with pointed kernels in slightly conical ears (Fig. 8). The two first-mentioned types of dent, both with flattened kernels, could very well be synthetics between Cariaco and the Pointed Dent, all four races having soft kernels.

If we compare the extremes of this series, Barranquilla with ordinary cultivated races and only two typical indigenous races of the area, *Negrito* and *Cariaco,* and the Motilones with none of the ordinary cultivated races but with several soft dent types and the peculiar Pointed Dent, we can see how far mutual infiltration may go. The farmers have accepted and maintained the two main races of soft maize, *Negrito* and *Cariaco,* which are cultivated both by settlers and by Indians over a very wide area of northern Colombia and western Venezuela. Some Indians have accepted the hard flints of the Caribbean areas, which may have been brought in after conquest or may have penetrated into the area

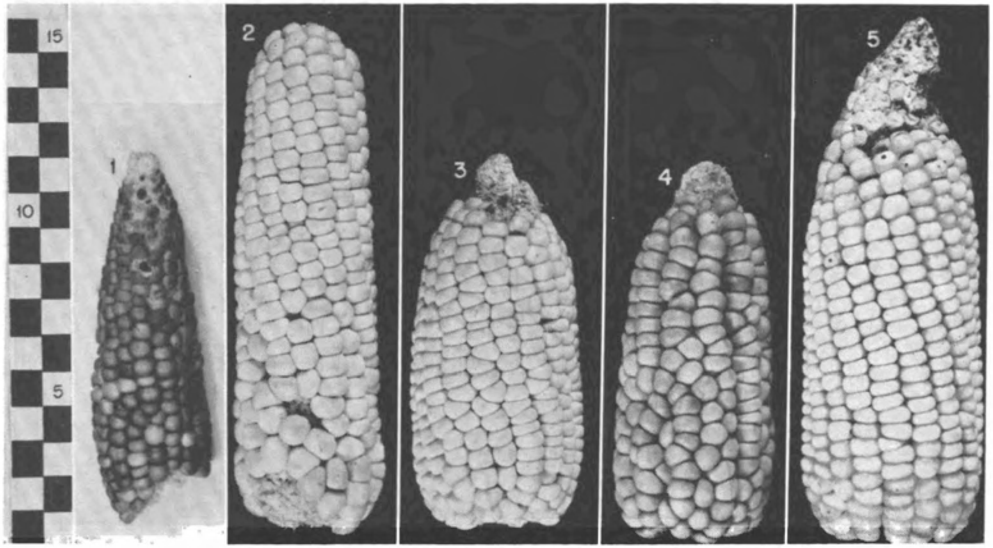

FIG. 6. Races cultivated by the Chimilo Indians in the Sierra de St. Martha, northern Colombia. 1: Gri-ritzo, identical with Negrito in Fig. 4,*1* and 5,*1*. 2: Moro, identical with Cariaco in Fig. 4,*2* and 5,*2* with large ears and kernels. 3: Moro-Maripu, a smaller type of Cariaco. 4: Kropé, identical with Colorado in Fig. 5,*3*.–5: Pu-Lam-po, identical with Cuba in Fig. 5,*4*.

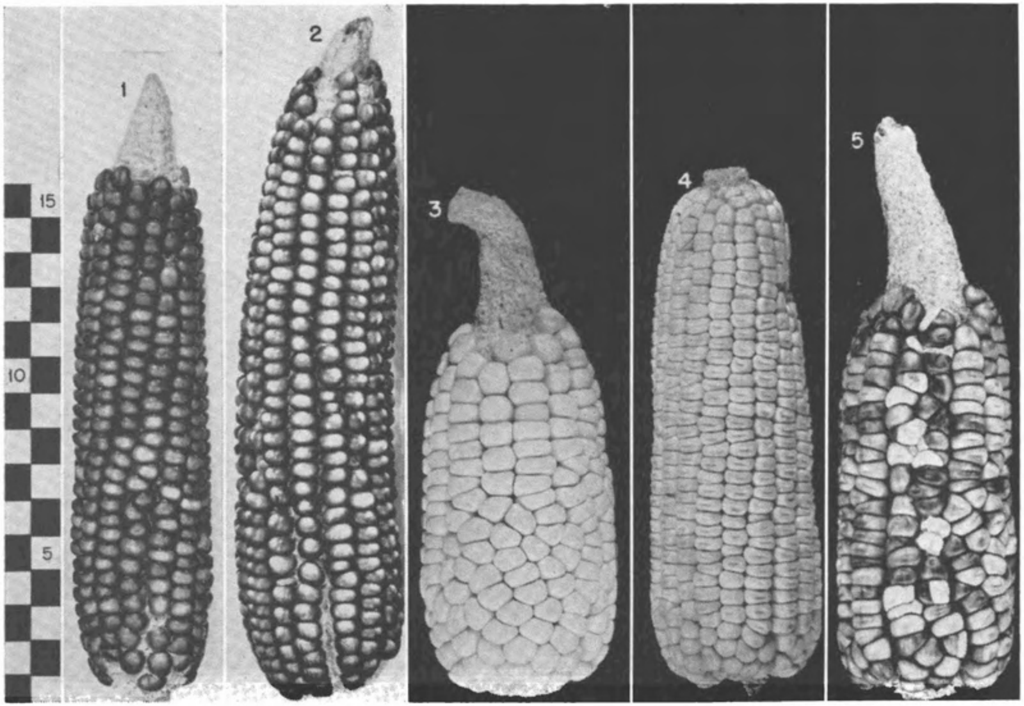

FIG. 7. Races of maize grown by the Motilones Indians, in the Sierra de St. Martha, in northern Colombia. 1: Areyak, identical with Negrito in Fig. 4,*1* and 5,*1*. 2: Kayanse-Wesek, similar to the former but with hard endosperm, perhaps identical with Güirua (*Roberts et al.* 1957). 3: Kneetya, identical with Cariaco in Fig. 4,*2* and 5,*2*. 4: Mesosapa, a soft dent with small kernels, generally yellow. 5: Tanuyaka, a soft dent with larger kernels, white or black.

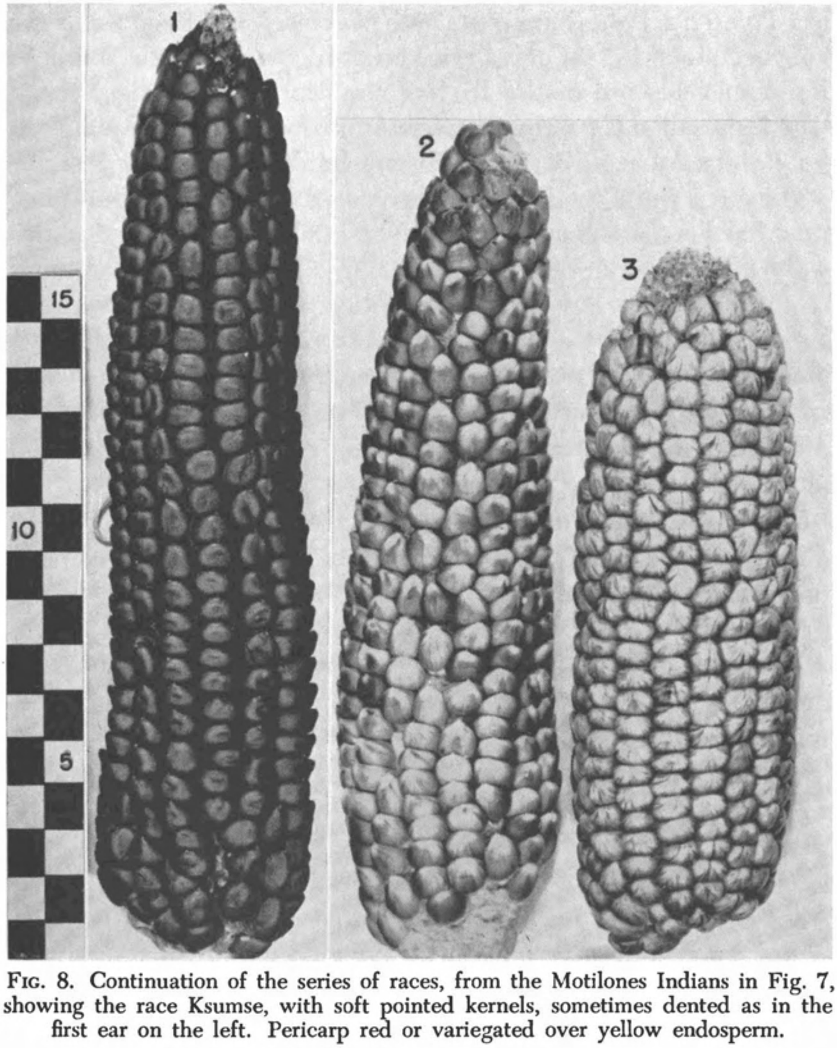

FIG. 8. Continuation of the series of races, from the Motilones Indians in Fig. 7, showing the race Ksumse, with soft pointed kernels, sometimes dented as in the first ear on the left. Pericarp red or variegated over yellow endosperm.

before this time, at the end of its migration up and around the Atlantic coast from Argentina and southern Brazil where this race probably originated. Only one tribe has not yet accepted anything from the outside, but kept alive a very special type of maize, the *Soft Pointed Dent.* Representatives of relatives of this same type have been found so far only in two other regions of South America: the main field corn of the High Valleys in Bolivia and northern Argentina called *Capia* or *Chechys,* and a race from the Carajá, in the eastern Amazon Basin. Both will be described later.

Thus it is quite evident that the old pattern of distribution of races has become almost obliterated in this area by the activities of the white man during the last 400 to 500 years. In most parts of South America, however, the situation is much more favorable. In the high Andes of Peru and Colombia, probably in consequence of the extreme climatic adaptation required, and in the lowlands east of the Andes, because the white man has not yet penetrated sufficiently, the old pre-Columbian pattern has apparently changed but little.

This discussion of the little that we really know about the migration of races of maize shows (a) that this has probably been quite limited in distances, probably not exceeding about 10 degrees of latitude, and (b) that lack of climatic adaptation represented and still represents the most efficient barrier. Furthermore, migrations may have gone back and forth with changing directions and since this process has been going on for at least 5,000 years, there is no hope of still finding signs of any prehistoric or even pre-Columbian routes of migration pointing to the hypothetical center of origin of races or of maize as such. This method of detecting the place of origin fails us also.

Sea transport has played only a limited role. There is only one region where this may have been possible within the Americas, from Peru and Guayaquil to Mexico, since only the Indians from the former area are known to have been able to travel successfully over the seas, while elsewhere there has been at the most a limited coastal travel. It may be expected that some Mexican races might have been imported by this process, and in fact some, such as *Harinoso de Ocho,* sweet corn, etc. (Wellhausen *et al* 1952) have their counterparts in the Inca area, while they do not exist in the intermediate Central America or Colombian region.

Sea travel has brought maize also to the Old World. The description of Eurasian races of maize is still rather incomplete (Stonor and Anderson 1949, Anderson and Brown 1953, Suto and Yoshida 1952–53). The last named authors distinguished five groups of races, two of them clearly of American origin—one derived from the Northeastern Little Flint and the other from the Caribbean Flints. The third type is called "European," and in fact it would be astonishing if in several hundred years no new races would have appeared in Europe. The difficulties start with the remaining two types, called the "Aegean" and the "Persian." These names are in a way misleading, and care should be taken that in the Old World no such confusion may eventually develop as followed the rather indiscriminate use of the term "Andean." Further confusion may come from the use of the term "pure maize" for the last two groups of Eurasian races, since, as we have seen above, not even in the Americas is it quite clear what the authors mean by this term. In any case the Aegean and Persian types are said to occur in back areas from Asia Minor to Assam and are generally not found in the more densely cultivated coastal areas.

Some questions raised by the study of this material have been cleared somewhat, since most authors (Mangelsdorf and Oliver 1951, Weatherwax 1955, Randolph 1955, Suto and Yoshida 1952–53) seem to agree that maize is of American origin, and doubt remains only as to the time when it may have come to Asia, whether before or after Columbus. Hard Flint maize certainly will stand sea transport better than any dent or flour corn, but this alone does not explain the preferential distribution of the two flint types, which occurred and still occur in the eastern coastal areas of North and South America. Unfortunately the coast areas were always the first ones to be colonized, and we cannot say what other races may have existed on all the American coasts before Columbus. It is quite possible or even probable that races similar to the "*Persian*" or "*Aegean*" types existed in coastal areas of America, and were taken on by ship crews and then shipped to Asia. We shall come back to this point when discussing the Amazonean races, while the problem of the peculiar distribution of races in the Old World must be left to the specialists of that region.

Finally, it may be expected that the study of the distribution of special genes or gene complexes may lead to conclusions about routes of migration (Mangelsdorf and Reeves 1939). In order to test this possibility, one cannot rely on a phenotypic analysis only, for instance assuming from the absence of anthocyanin in the aleurone the presence of any specific genic inhibitor. For this purpose, we started a special analysis including races from Mexico and Colombia, representatives of the *Interlocked Soft Corn,* the *Guaraní Soft Corn, Calchaqui Flint,* and *Caingang White Dent.* Since we found that direct crosses to tester did not give clear Mendelian segregations, all the material was first crossed to the Colombian race *Negrito,* giving in F_2 a random distribution of the elements of the modifier complexes from *Negrito,* favoring intense black aleurone, and those of the other races, favoring absence of anthocyanin. A small part of the data has been published (Taboria 1956). Brieger (unpublished) has found that in all cases, and for each character, several genes are generally involved. Thus the contrast black or red against colorless aleurone is controlled by two factor pairs (9:7 ratio) and rarely by one or three (3:1 or 27:37 ratios). Brown (yellow, orange, bronze, or nearly red) aleurone color is caused by one or two dominant factors (3:1 or 15:1 ratios) and yellow endosperms gave mostly the 3:1 ratio, but sometimes a 15:1 ratio and even a 63:1 ratio. Since thus in each individual race its phenotype is guaranteed by genes in more than one locus, it seems hardly probable that these genes may follow any distributional pattern.

The waxy gene has attracted special interest, since Collins (1918) first described this type from Asia and it was thought that it was something quite special and limited to Asia. Later, Brieger and Andrés found it in maize from Argentina. We know now from studies by Kita-jima (1958) that it occurs quite frequently in several races in southern Brazil and Paraguay.

In conclusion, we must admit that there is no conclusive evidence indicating where maize may have entered into domestication, or even where and how it migrated to cover finally the whole American area. Expanding maize cultivation is a process which has been going on for too long a time to leave any clear historic picture.

THE MODE OF ORIGIN OF MAIZE

Nearly all authors apparently now agree (Mangelsdorf 1945, Weatherwax 1955) that *Zea* and *Tripsacum* are good genera which developed independently long before domestication started, while the discussion regarding *Euchlaena* is still controversial. That all three genera are very near relatives becomes quite evident if we use Bonnet's method (1940, 1948, 1953) and study growing points. Brieger (1952a) has shown that these are essentially alike in all three genera, especially if we limit the comparison of two ranked inflorescences.

For over a hundred years, pod corn has played an important role in these discussions; in fact ever since St. Hilaire, after receiving material of this kind of corn from Brazil (1829) concluded that this was wild maize. His early reason was that pod corn showed one character of a wild grass, lost by all other types of maize: the complete cover of the kernels by their glumes. Mangelsdorf (1945, 1948) and Brieger (1945a, 1945b, 1952), have tried to determine the range of phenotypic effects which this dominant gene may have, and it is evident that it is extremely variable in its action. One may almost describe it rather as a "developer" gene, which allows different modifier complexes to show their effects. All South American pod corn which we have studied so far, about ten samples in all, were heterozygous pod corn and their descendants, whether *Tu Tu* homozygotes or *Tu tu* heterozygotes, showed only special features in ear, *i.e.*, in length of glumes, the size of the kernels and the degree of sterility, while in the tassel the changes were limited at the most to variation in glume length. The more extreme changes in the tassel appeared only after outcrossing to non-tunicate material, and selection yielded then in our material, as occurred also in Mangelsdorf's studies, tassels with a very high number (up to 400) mature kernels, from female or hermaphroditic flowers. Brieger (1952) has shown in such material that the *Tu* allele, combined with some modifier complexes, may even produce characters known from other grass tribes, but not present in the *Andropogeneae* or *Maydeae*, such as hermaphroditic flowers or spikelets with more than two flowers (maximum so far, three fertile female flowers and two sterile ones). Thus the question arises whether the *Tu* factor really brings about the reappearance of old "wild type characters" of the unknown wild maize ancestor, or whether it is simply a gene which acts very early in ontological development and thus can undo many inhibitory steps acquired in the phylogenetical evolution of grasses in general and of maize especially, or in other words, devolving possibilities inherent to all grasses and which do not necessarily represent any special features of the hypothetical wild maize. These results reduce considerably the value of the *Tu* factor as a possible "wild type relict gene."

The *Tu* allele is never found in any special race, but only as an addition to other races, quite frequently to ordinary field corn, which gives the impression that one is dealing with rather recent mutation. Pod corn is only cultivated as such by one specialized group of Indians (Cutler, 1945). We received some seeds of such material from Dr. Cárdenas, and it again did not belong to any special race.

We believe one can no longer accept either the *Tu* allele or other alleles of this locus as anything like a "wild relict gene." But the *Tu* factor has a considerable value, since it may show what change may be brought about in maize structure. After having found that the *Tu* allele has such a very wide range of phenotypic activity in maize, Brieger (1944) decided to replace a large part of the modifier factors, which may have been assembled in maize under domestication, by those of a wild grass such as teosinte. In the descendants of crosses between heterozygous pod corn and teosinte, segregates were selected which showed neither characters of domesticated maize nor those of teosinte, and one of the more extreme types is illustrated in Figure 9, 1 to 3. It had two ranks of paired spikelets, one being sessile and the other pedicelled. The kernels were protected by long and pointed stiff glumes. Perhaps the most remarkable feature was that the seeds, with their glume cover, shattered and became easily separated from the rachis. The ear looked much more like some rye or other grass than a segregate derived from maize. By combining a special mutant gene having very strong and early effects on the

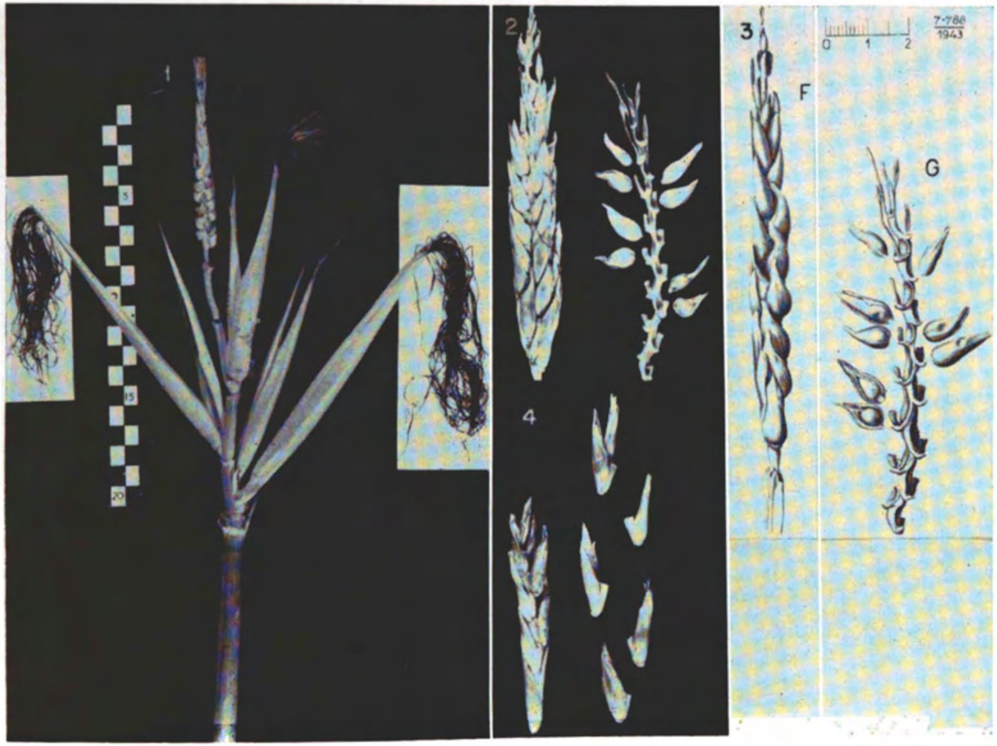

FIG. 9. Genetical reconstitution of a possible "wild ancestor" of maize, represented by a descendant in later generations of the cross (maize x teosinte) and after selecting for character combinations not present in either maize or teosinte.

growing point with a completely new set of modifiers, something as unexpected may come out of modern maize as the segregate illustrated.

Thus we must admit that the tunicate allele is a very important mutant gene but there is no conclusive evidence for considering it as a "wild type relict gene" of maize.

THE ORIGIN OF THE TYPES OF MAIZE

Farmers, and later scientists, have always distinguished four basic types of maize: popcorn, flint, floury, and dent. The differences between these four types are multifactorial, even in the case of floury maize, though sometimes the so-called "floury" factor in the 10th chromosome seems to have a stronger action than other genes, which act more like modifier factors. It is also a general rule that descendants of any cross between representatives of the same type do not segregate, while those between members of different types, of course, do segregate. This means that on the whole all representatives belonging to the same type have identical genes for the type characters.

It seems that all authors agree, though no real proof is available, that the popcorn races are the most primitive ones, and that the popcorn type should correspond to the first and lowest level of domestication. This conclusion is based on the fact that popcorn has still some "wild type" characters, such as very small kernels, very hard endosperm, and often very sharp and curved points at the tip of the kernel. Furthermore, it is not very productive, in terms of yield per unit area, and has a limited utility value. It not only yields little starch, but would require hard stones for milling and very hard work to do it. It can really be eaten only as roasted or popped kernels.

Flint corn may represent the second stage in domestication, the difference between pop and flint corn being mainly one of size, and consequently also of a certain proportional increase in the volume of the inner core, containing soft endosperm within the hard shell.

Soft or floury corn, which we may consider as the third stage of domestication, is evidently of very high value to the Indian. Not only can it be easily ground, but it is also easily cooked into a soft mash after soaking for a day in water.

The advantage of dent corn, which some consider as the most highly developed type, is not easily seen, especially since its value for animal feeding was of no importance to the Indian, who had no domesticated animals in big herds to be fed.

The dent type, whether really the most modern or not, shows by its irregular distribution that its origin must have occurred in several places independently. A connection may have existed between the dent corns of Central America and Mexico and some others from northern Colombia and western Venezuela, though the Mexican dents are mainly "hard" dents, with horny starch in the cup which is formed by the base and parts of the sides of the kernel. But *Cariaco Dent* from northern Colombia certainly belongs to the South American "soft" dent group. It may or may not be related to other types of the Amazon Basin. As far as pointed dents are concerned, we may assume that they occupied at some time a larger distribution than today, and they may have played a role in the origin of the Andean pointed dent *Capia* or *Chechys* or even of *Cuzco Large* grain. But the *Caingang White Soft Dent* is certainly completely isolated. Thus there are in existence today at least four dent groups: (a) the hard dents of Mexico and Central America, which have been distributed in modern times all over the world; (b) *Cariaco Soft Dent,* somewhat similar but not at all related to (c) *Caingang White Soft Dent,* and finally (d) the *Pointed Dents.*

Furthermore, one finds a slight tendency for denting in almost all races of flour corn, and we started a few years ago a strong selection and inbreeding (sibbing) program in Guaraní Soft Corn, obtaining after three to four generations a perfect *Yellow Soft Dent,* very similar to the *Cariaco Dent* from northern Colombia. Consequently we assume that one or a few mutations were responsible for the obtaining of a new type with dented kernels, but that the necessary genes were and still are present in the nondented races of soft corn in a random fashion. Only if and when the Indian breeder started to select, would and could he obtain a good soft dent race, but why he started selecting in this direction is still unknown.

We may generalize and conclude: It is quite possible that the genes necessary for the change from one type to the other may have been present, as not yet selected parts of the genetic reserve, before a new selective trend started. This trend may then have been started independently at different times and places.

We may furthermore assume that the four main types of maize really represent four successive stages in the domestication of corn, appearing in a sequence at least with regard to the periods in which each type attained its maximum distribution and acceptance, and also its maximum diversification.

The differences within popcorns, and even within pointed and round popcorn, seem to indicate that there must have been at some time a great number of popcorn races, and those that continue to exist today may be relicts of a long past period. Actually, the known variation in popcorn leads to the distinguishing of four groups, owing to the alternative pairs of characters: pointed against round kernels, straight salient rows against tightly packed ears, generally a spiral arrangement of the kernels, and less pronounced longitudinal rows (Brieger (in manuscript)). Those races which we still find in existence give what we may call a typical "relict pattern" of geographic distribution. If this interpretation should be correct, it would seem rather useless to imagine very close and special connections between all still existing pointed popcorns on the one hand, such as *Palomero Toluqueño* from Mexico, *Imbricado* from Boyaca (Colombia), *Pisincho* or Andean *Pisankalla,* and *Pointed Pipoca* from the Guaraní Indians, and on the other hand the very small round popcorn races such as *Chocoseño* from the northwestern lowlands of Colombia, some of the Peruvian popcorns (local Spanish name "*Confite,*" Indian name *Pisankalla, Pisincho,* etc.), the Pipcoa Redonda of the Guaraní, and finally the somewhat larger *Nal-tel* of Mexico-Guatemala and *Pira* of Colombia. They are, we suppose, the few remaining relicts of a long-past "popcorn period."

How and when the selection for larger kernels was started and the flint corn phase begun is completely unknown, and also whether this occurred only at one time and one place. As shown by Brieger (1949b, 1950b), the flint races occupy today mainly marginal areas, along the Atlantic Coast from Canada to Argentina, along the northern and southern climatic limits, and at the altitude limits in the High Valleys of the Andes and the savannas of Colombia.

There is also nothing known about the time and place of origin of the soft corn races. They occur now within the margin of the flint races, sometimes mixed with them, and are known to be the main Indian field corn in this western area.

Finally, as we pointed out before, the dent races show an irregular distribution similar to the popcorn races, but we must assume that this is the consequence of quite a different cause and that we are dealing with a rather new development which occurred independently in several places. Thus there has not yet been time enough to attain a generalized pattern of distribution (Brieger 1950a) like that of the flints or flour corn.

We must conclude again, however, that no indication could be found which allows any safe decision regarding the place of origin of maize itself or of any of the four main types of this cereal.

THE ORIGIN OF MAIZE RACES

It is as difficult to define in general terms what we understand by the name "race" as it is to define what we call a "species," though in both cases the material shows quite clearly that races and species exist and are breeding units or biological units. In both cases, we have the fact that races and species, each in its way, are characterized by complexes of characters, essentially alike in all members of any given one of these units, and that they can maintain themselves during many generations and do not easily mix with other races or species, *i.e.*, at least not sufficiently easily to lose their identity.

We may define as a race any group of populations having a sufficient number of distinctive characters in common, maintaining itself through panmictic reproduction within populations, and occupying definite areas.

There is still another parallel between races and species: we cannot limit ourselves to one category only, but must admit in addition at least one higher and one lower category, the species group or the collective species above and the subspecies or variety below the species level, and in the same way racial groups and subraces.

A "racial group" is formed by a number of races which have some decisive characters in common. These common characters are generally kernel characters such as size, color, endosperm texture, etc., and we shall speak later about the racial group of the *Guaraní Soft Corn races,* of the *Orange Flint races,* etc. The reason for the existence of such racial groups is the tendency on the part of the Indians to breed for definite kernel characters, while at the same time a certain diversity of adaptive characters such as earliness, adaptation to climatic ranges, etc., was maintained. It is also quite possible that, while selection was carried out for some characters, other and possibly quite unimportant traits, such as conical or cylindrical ear shape, high or medium row number, etc., were simultaneously selected for, either by accident or by correlation.

Subraces, just as subspecies, differ from a main type in detail only, and there are for instance a number of subraces in the race *Capia* from the southern High Valleys of the Andes, differing mainly in kernel color, and an almost identical range in subraces, differing mainly in color, exists also in *Large Grain Cuzco Corn.*

A difficult question is the explanation of the maintenance of racial characters through many generations, and certainly during more than 500 years, *i.e.,* since the time of Columbus. In some cases, differences in flowering time may act as the isolating factor, as mentioned below for the Guaraní races *Avati Moroti* and *Morotí Mitá,* but such an isolating mechanism does not occur in general.

Supergametophyte factors, allowing crossing between the members within one race carrying the *Ga* allele, can protect only one race against several others if the latter contain the *ga* allele, but it does not represent a general isolating mechanism.

But isolating mechanisms must exist. Of the many examples which show this and which we have seen, we may mention the *Large Grain Cuzco Corn,* of which we found a number of subraces cultivated side by side in the Urubamba Valley near Cuzco, and an identical situation was observed in the Humahuaca Valley for the race *Capia.* In both cases there are subraces with white or yellow endosperm, with or without pericarp or aleurone color, with mottled, or with light pericarp color on white endosperm. It is interesting to note that, both in *Capia* and in *Cuzco Large Grain,* the range and the distinction between subraces are almost identical. Seeds of such material, from ears taken out of the cribs, bred on the whole true to type, with little or no contamination apparent.

Probably the most important question is that of the origin of races. There are evidently two ways by which a new race may be created: (a) by the slow and constant selection of mutant genes and their favorable modifier complexes, a process during which other characters may also become fixed, without direct selection in their favor but through selection with correlation, and (b) by a similar selection following hybridization. In recent descriptions of corn races, the latter explanation has been much more in evidence than the former.

It seems that Wellhausen (1952) was the first to use the concept of synthetic races on a fairly large scale in explaining the origin of Mexican races of corn. Since then, others have adopted his method without further study. We consider it necessary, however, first to discuss the method used to identify putative parent races, before eventually using the principles of the method for determining putative parent races. Wellhausen evidently starts from the well known fact that varietal or racial crosses in maize yield an F_1 which, in a general way, is intermediate between the parents used. Next it is postulated that any synthetic must correspond to an F_1, and consequently should be essentially half-way between the parent races. It must be emphasized that the first postulate (intermediate nature of F_1 hybrids) is proved by many experiments, but the second (intermediate nature of synthetics) has, as far as we know, no experimental basis whatsoever. The method, however, starts from both these two contentions and it has become a practice to select as the two putative parents two other races which differ in about the same degree but in opposite direction from the race, to be explained as their synthetic. It is of course evident, since hybrids are intermediate, that hybrids obtained after thus selecting the putative parents must be intermediate between the latter. Since the putative parents were selected especially to differ equally in opposite directions from the supposed synthetic race, there is really no possibility of any differences between the F_1 hybrids and the supposed synthetic race. The argumentation and the so-called "proof" present a perfect circle in reasoning. If we were to change the working hypothesis and, for example, suppose that the synthetic "must" be nearer to one parent than to the other, a backcross of F_1 to this parent would easily furnish a "proof" for this new hypothesis.

To avoid misunderstanding, we want to state that there cannot be any doubt that many races are synthetics, resulting from crosses between at least two other races, and this was probably first understood by Anderson and Brown (1952a, 1952b) when studying the origin of Corn Belt Dent. The extension of this principle by Wellhausen (1952) to indigenous races was and remains of very great importance. What are really under discussion are methods to identify a race as a synthetic and to identify its probable parents. Before accepting Wellhausen's method, it must first be shown that synthetics "must" always be and in fact are in the middle between the parent races, and we started a special study for this purpose.

Material which may be useful for such studies was identified in the following way:

First we started from races which looked rather unusual for the areas in which they were found. For instance, the Caingang Indians, in southern Brazil, cultivate even today in most of their reservations one type of maize: *Caingang White Dent,* but in one reservation another type was also found: *Ivaí Amarello,* a soft corn with yellow aleurone, which is something quite unusual in the Caingang area. Furthermore, the many tribes of the southwestern Guaraní Indians grow several races of *Yellow Soft Corn,* and nothing but representatives of this racial group were obtained from Indians not yet touched by civilization. However, in Paraguay, this yellow soft maize appeared together with a very hard white flint, called *Cristal* or sometimes Perola, which also represents something unusual, this time for the Guaraní area.

The next question was, then, whether anything was known about the occurrence of *Yellow Soft Corn* in neighboring areas of the Caingang, and then it was noted that these neighbors are the Guaraní. Similarly, when asking if a white flint occurred near the

Guaraní area, one remembers immediately the *Calchaqui White Flint,* just south of the Guaraní area.

Thus, in the first case the assumption was justified that the Caingang adopted at Ivaí some Guaraní race, and that in turn the Guaraní adopted some Calchaqui race. This, then, justified a more detailed study to determine whether *Ivaí Amarello* of the Caingang was identical with or possibly derived from *Guaraní Soft Corn,* or whether *Cristal* was identical with, or derived from *Calchaqui White Flint.*

A similar situation exists with regard to the *Cristal* or "Perola" in the area of the *Interlocked Soft Corn* of eastern Bolivia, the only area where such "Perola" was observed together with *Interlocked Soft Corn.* Again one would think about the possibility of an infiltration of *Calchaqui White Flint.* A similar situation exists with regard to two races, *Morocho* and *Bola Blanca,* in the Humahuaca High Valley

A different situation led us to study the relations between two other races, *Capia Blanco* and *Amarillo de Ocho,* both from Humahuaca, since here in fact a number of intermediates were found, showing that some interbreeding and infiltration is going on.

In the material thus selected, we are able to identify the most probable parent races by other evidence and not because they seemed to be equally different, though in opposite directions, from the supposed synthetic.

Thus two types of observation were involved in the argument: (a) the occurrence of races which seem on the whole strange to the area where they actually occur, and (b) the occurrence of races with somewhat similar characters in other not too distant areas.

Ivaí Amarello looks in a way intermediate between the two races considered as probable parents, *Calchaqui White Flint* and *Avatí Morotí Mitá,* as one may judge from the aspect of the area in Figure 10, though the kernels are in size, texture, and especially in color, almost identical with *Avatí Morotí.* The more detailed comparisons of ear, tassel, and plant characters are given in Table 1, and in Figures 11 to 13. There are at least three main possibilities which might be expected *a priori* and which, in fact, were encountered:

(a) The synthetic is more or less halfway between the two par-

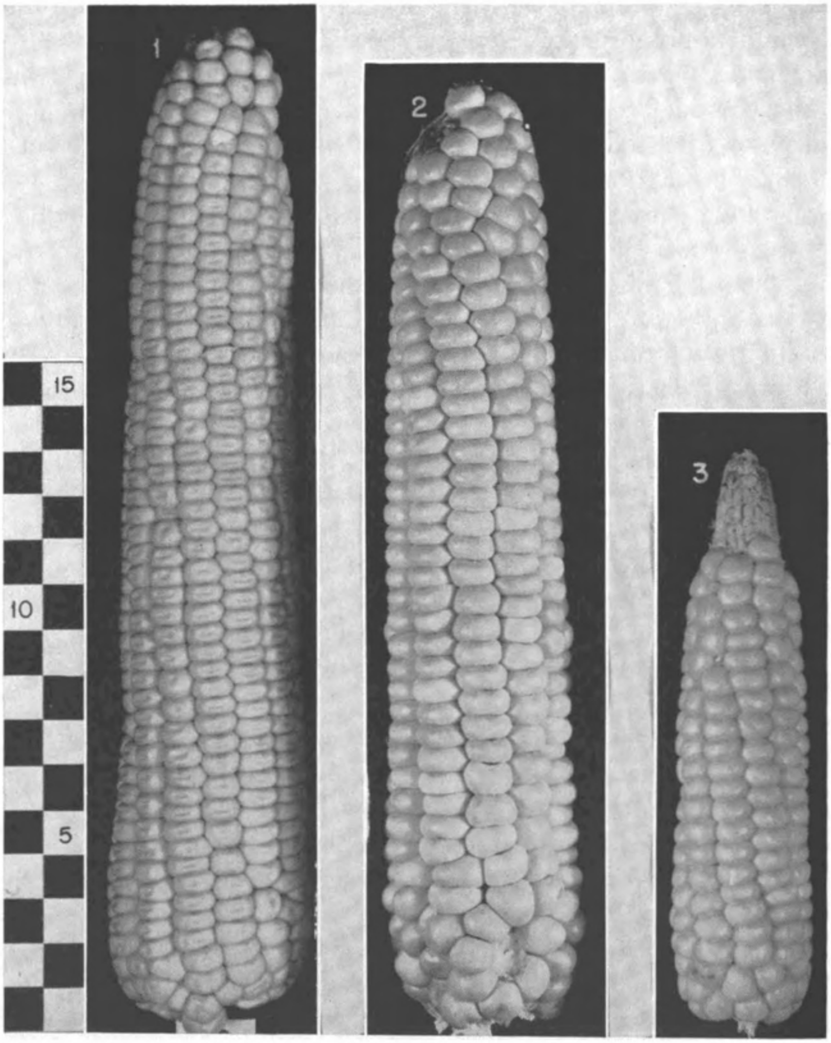

FIG. 10. *Ivaí Amarello* (2) is considered as a synthetic between *Avatí Morotí Mitá* (3), a Guaraní Soft Corn race with yellow aleurone and *Caingang White Dent* (1).

ents, and then a nearly straight line should appear in the schematical drawing. This is the case for eight measurements of the ear (Fig. 11, left), for the length of the sheath of the last leaf, covering the last internode of the stem below the tassel (Fig. 12, right) and for the number of leaves above and below the ear on the main stalk of the plant (Fig. 13, right), or in other words for eight ear characters out of twelve, for one tassel character out of nine, and for two plant characters out of five, or for ten characters out of twenty-six, less than half of the contrasts studied.

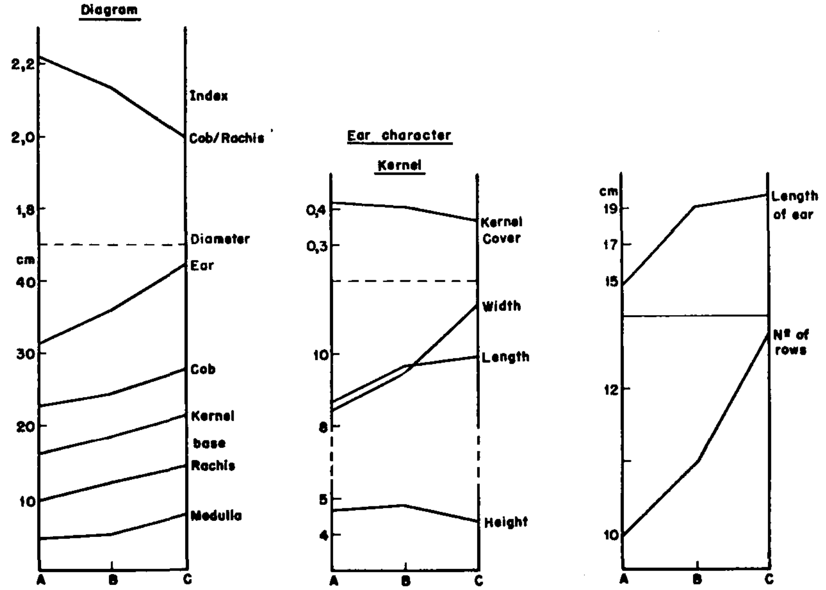

FIG. 11. Comparison between Ivaí Amarello (B) and its putative parents: *Avatí Morotí* (A) and *Caingang Dent Ivaí* (C).

(b) The synthetic may be almost equal to one of its parents, though this does not mean that this parent is dominant in the sense this term is generally used in genetics. It may mean that one parent had a greater chance to contribute genes than the other, and this should of course be in general the parent in whose area the synthetic was formed.

There are now two ear characters, with a prevalence of *Caingang Dent* (kernel length and ear length) and of Avatí in two characters (kernel height or depth) and kernel cover index (Fig. 11). In the tassel, we find prevalence of the Caingang parent in one character (number of branches of 1° order) and of Avatí in another character (length of last internode) (Fig. 11). In the plant, Caingang finally prevails in two characters, plant height and ear height/plant height index (Fig. 13). Thus we have Caingang prevailing in five characters and Avatí prevailing in two characters.

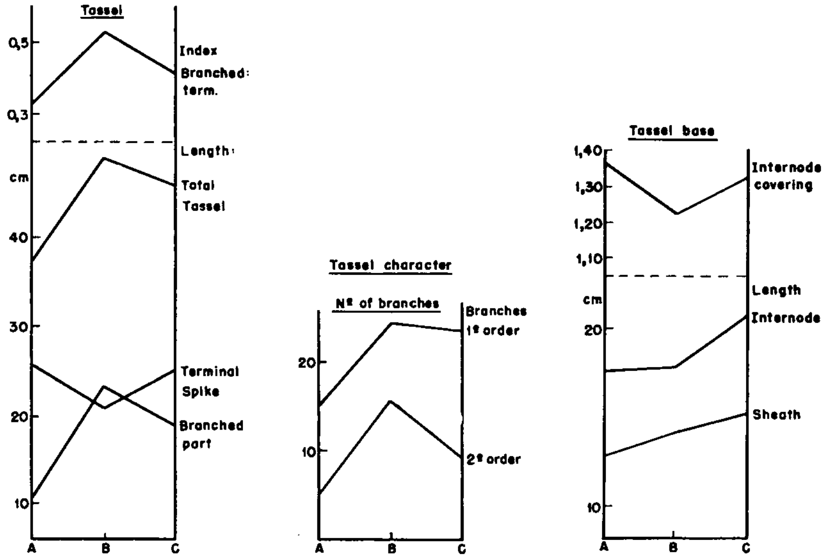

FIG. 12. Comparison between Ivaí Amarello (B) and its putative parents *Avatí Mitá* (A) and *Caingang White Dent* (C).

(c) The synthetic may go beyond the limits of either parent, owing to a favorable combination of complementary genes from either parent, giving new combinations not present in either parent. This occurred in no instance in the ear, but did occur in six tassel characters (length of all parts, the index branched part/terminal spike, the number of branches of 2° order, and regarding the index of internode covering) (Fig. 12). In the plant there is only one such case, ear height, which required, however, a special

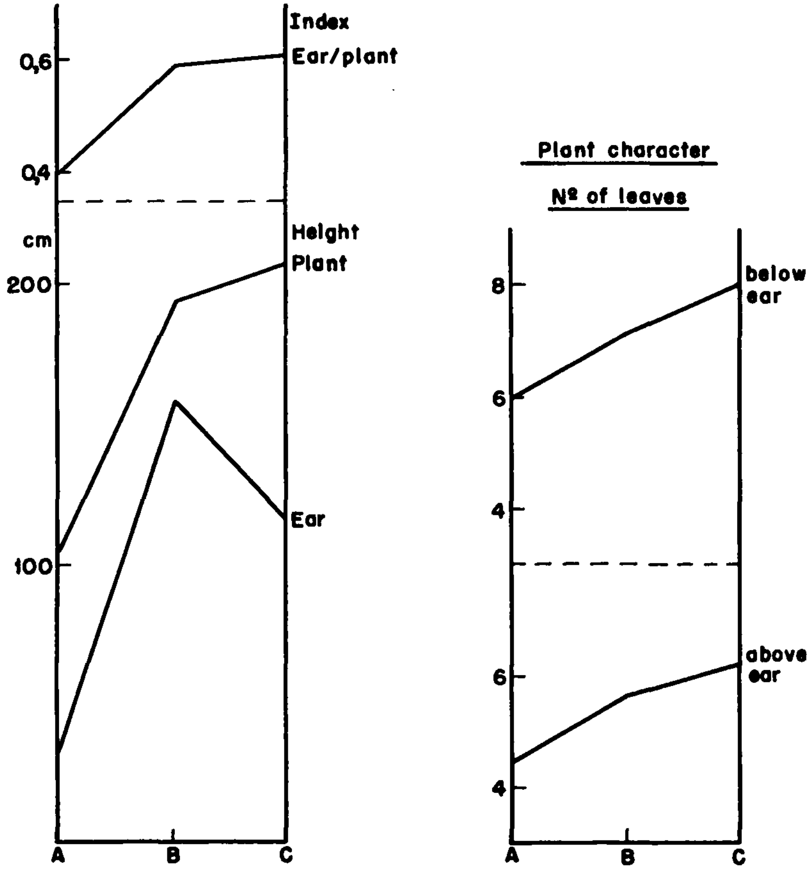

FIG. 13. Comparison between Ivaí Amarello (B) and its putative parents *Avatí Mitá* (A) and *Caingang White Dent* (C).

comment that will be given later. First we want to summarize these results:

Character Contrasts	*Interme-diate*	*Caingang Prevail-ing*	*Avati Prevail-ing*	*Exceeding Both Parents*	*Total*
in the ear	8	2	2	—	12
in the tassel	1	1	1	6	9
in the plant	2	2	—	1	5
Totals	11	5	3	7	26

The synthetic *Ivaí Amarello* is intermediate in eleven of a total of twenty-six character contrasts (42%) or in less than half of the cases, and it goes beyond the range of variation of either parent in seven characters (27%), both results being quite contrary to the hypothesis which we were trying to test. It is especially important that the geographically dominant race, which should contribute more genes (*Caingang*) than the other race (*Avatí*), contributes in fact about equally. Thus it is quite evident that synthetics need not be and in fact are not at all intermediate between the putative parents, and the selection of the latter based on the principle of such a required intermediate nature must be considered as quite incorrect.

Special attention should next be given to a few cases where index values were calculated and where there is evidently quite an interesting correlation. Since, in the tassel, the branched part increases considerably, it follows that the total length of the tassel increases also, and at the same time we get a higher value for the proportion of branched part to terminal spike. This still seems quite logical and we may assume that, to some extent, the length of the branched part and of the terminal spike may vary independently. The situation is quite different if we compare plant and ear height. The graph for plant height and for the index ear height/plant height are almost identical, and in both cases *Caingang* is prevalent. The variation of ear height is only a consequence of this. The relations between plant and ear height have been studied recently by Vencowski (1958).

The primary synthetic *Morocho* and the secondary synthetic *Bola Blanca* will be discussed next. *Morocho* is a white flint with near cylindrical ears, and it not only appears somewhat strange within the ordinary range of variation of races in the High Valley of Humahuaca, but it is limited to this area and does not penetrate into the Bolivian valleys. Since *Calchaqui White Flint* is geographically a neighbor, we may assume that it infiltrated into the High Valley, and we may furthermore assume that *Capia Blanco,* the main field corn in Humahuaca, may be the other parent. *Bola Blanca,* in turn, appears very much like an infiltration of *Morocho* into the Altiplano group of races. The ears are shown in Figure 14 and the data may be found in the corresponding tables of Humahuaca races. The graphical illustrations are given in Figures 15 to 17. We shall not go into any detail, since the reader can easily draw his own conclusions which, on the whole, are the same as before: the synthetics need not be at all intermediate between the parent races. In fact, there are hardly any ear or plant characters showing an intermediary nature, but there are some tassel characters.

Next we shall discuss the synthetic *Cristal Paraguay* and *Paulista,* interpreted, as stated above, to have resulted from crosses between *Guaraní Soft Corn* and *Calchaqui White Flint* (Figs. 18 and 19, Tables 2 to 4, diagrams in Figs. 20 to 23). In the same tables another synthetic is represented, *Cristal "Perola,"* probably resulting from the crossing of *Calchaqui Flint* and *Interlocked Soft Corn* (Figs. 24 to 26). The same rule as before holds true, though there is now perhaps a slightly higher frequency of intermediate characters. With regard to the *"Perola St. Cruz"* in Figure 20 (ear diagram), we must assume that some third race played some role, and this may have been the Guaraní corn, *Avatí Moroti Guapi,* given under the letter (5d). Another interesting feature is that different synthetics of the same type of origin behave differently. This is also not too surprising since it is not probable that only one character combination from such racial hybridization may become stabilized in every synthetic derived from the crosses between different members of each race.

In the region where some *Cristal Perola* synthetics occur, another new synthetic seems to originate, between the *Soft Corn* races and the deep orange *Cateto* (Fig. 27).

The fifth and last case refers to the intercrossing between the two races of the same area, *Capia Blanco* and *Amarillo de Ocho* of

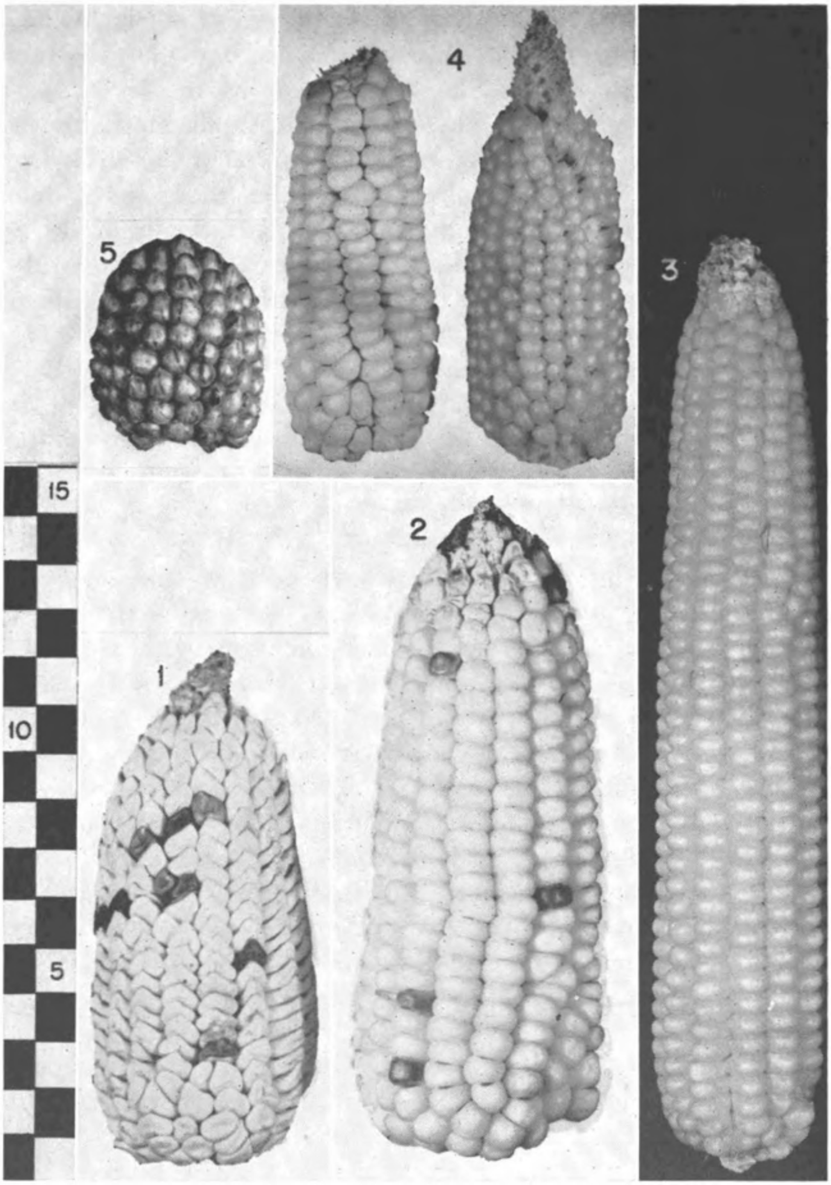

FIG. 14. *Morocho* (2) a white flint from the Andean High Valley around Humahuaca is considered as a synthetic between *Capia Blanco* (1) of the same region and *Calchaqui White Flint* (3) from lower altitudes further south. In its turn Bola Blanca (4) is assumed to be a secondary synthetic between *Morocho* and *Altiplano* (5).

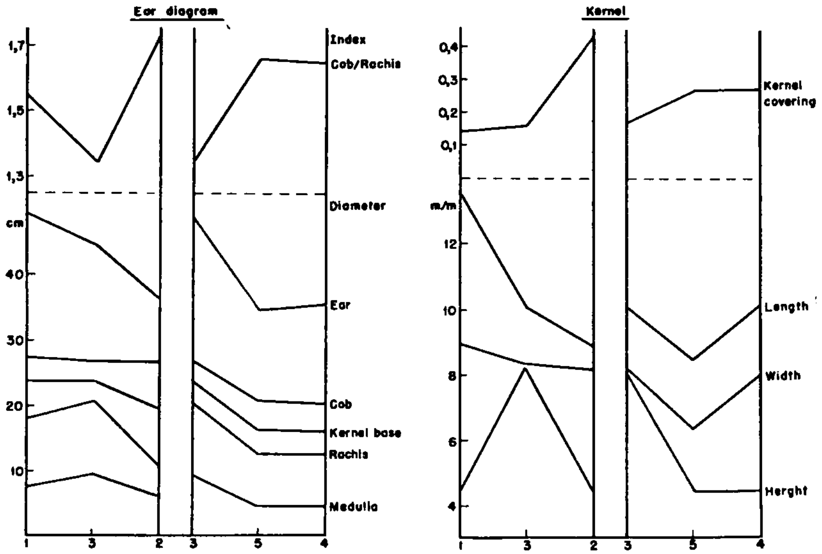

FIG. 15. Comparison between Morocho (3) and Bola Blanca (5) with their putative parents: Capia Blanco (1) and Calchaqui White Flint (2), resp. Morocho (3) and Altiplano (4).

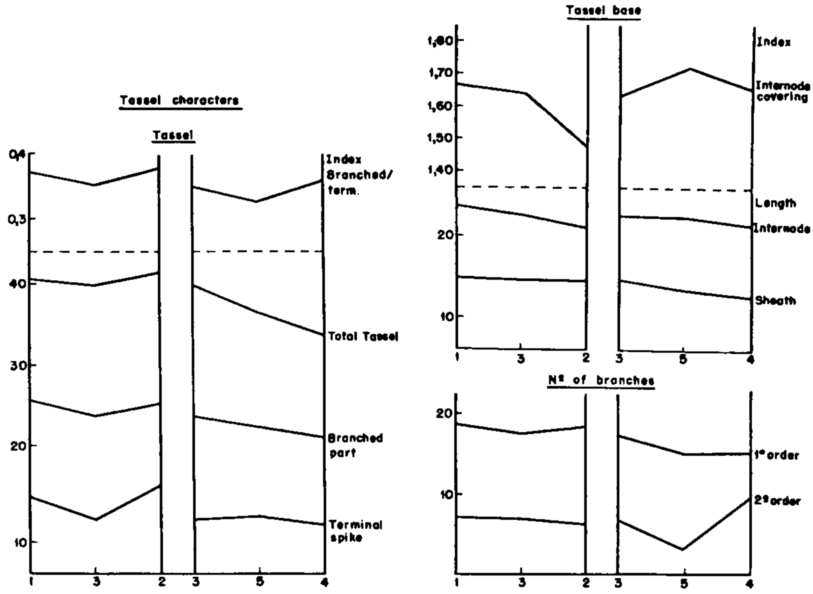

FIG. 16. Comparison between Morocho (3) and Bola Blanca (5) and their putative parents: Capia Blanco (1) and Calchaqui White Flint (2), resp. Morocho (3) and Altiplano (4).

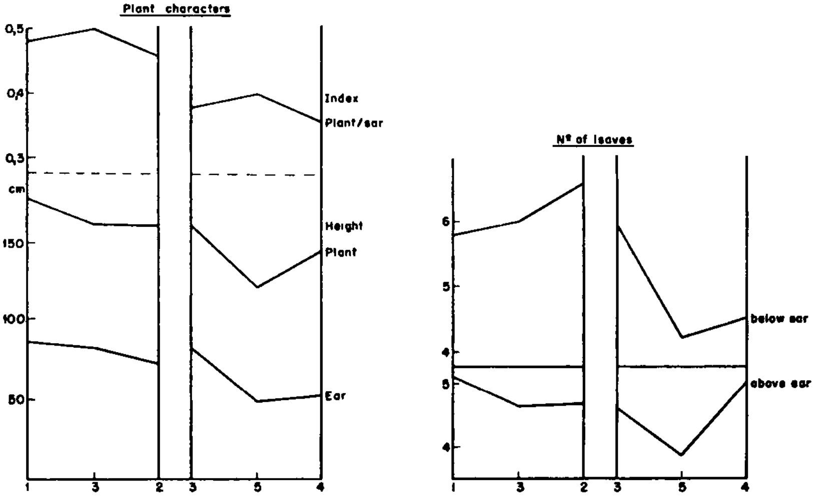

FIG. 17. Comparison between Morocho (3) and Bola Blanca (5) with their putative parents: Capia Blanco (1) and Calchaqui White Flint (2), resp. Morocho (3) and Altiplano (4).

FIG. 18. *Cristal Paraguay* (2) a very hard white flint, is considered as synthetic between *Avatí Morotí*, a Guaraní Soft Corn (1) race and *Calchaqui White Flint* (3).

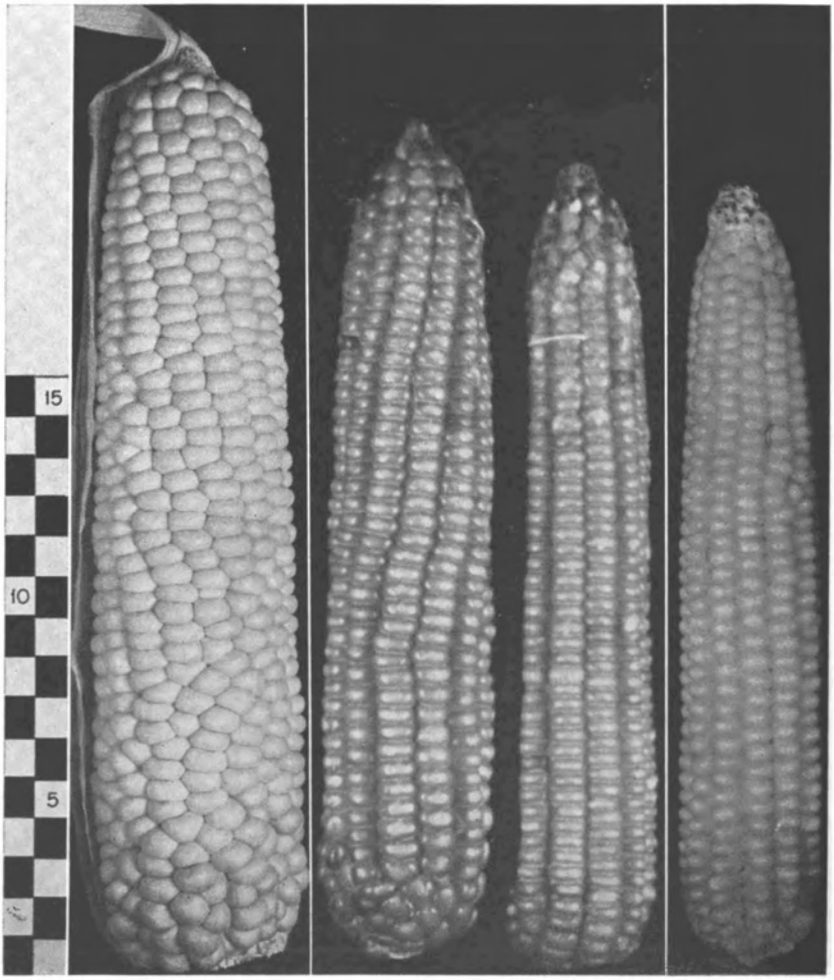

Fig. 19. *Cristal Paulista* is considered as a synthetic between *Avatí Morotí*, a Guaraní Soft Corn (1) race, and *Calchaqui White Flint* (3).

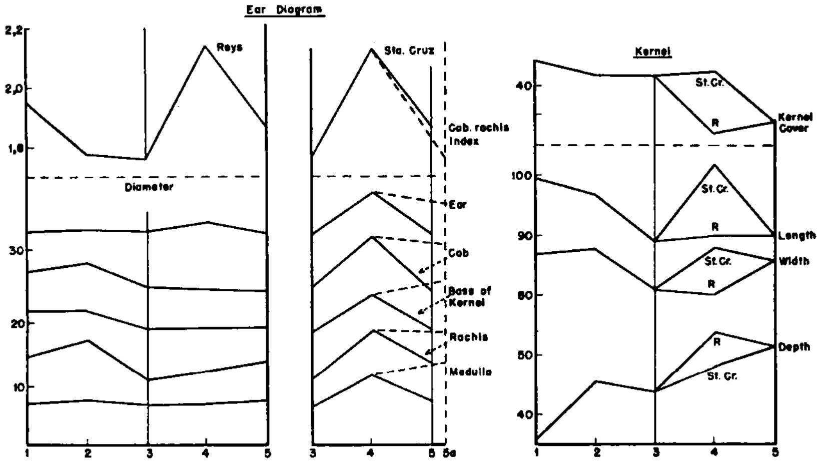

Fig. 20. Comparison between Cristal Paraguay—S. Paulo (2) and Cristal Entrelacado (4-R-Reyes-St. Cr: Santa Cruz) and their putative parents: *Avatí Morotí* (1) and *Calchaqui* (3), resp. Interlocked (5) and *Calchaqui* (3). *Avatí Morotí Guapí* (5a).

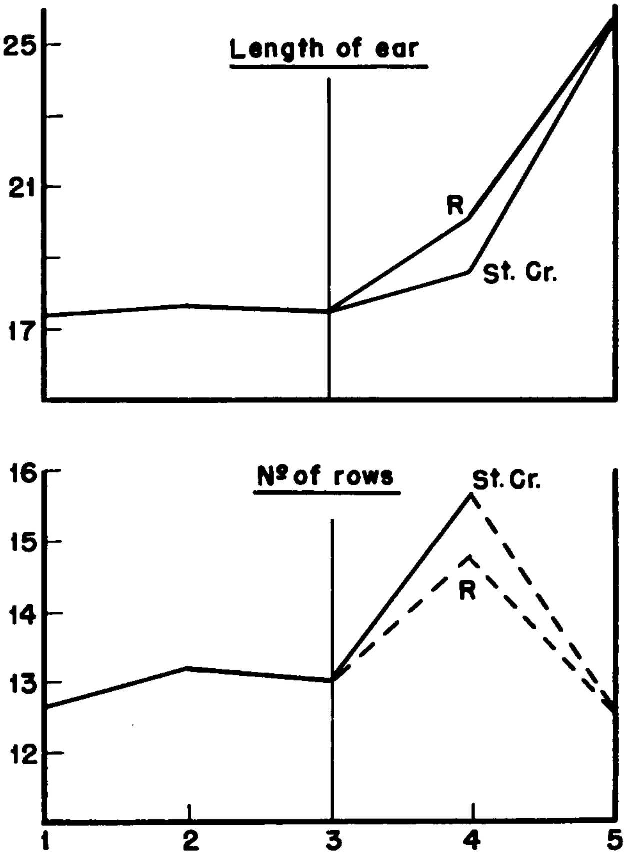

FIG. 21. Comparison between Cristal Paraguay S. Paulo (2) and Cristal Entrelacado (4-R: Reyes-St. Cr.: Santa Cruz) and their putative parents: Avatí Morotí (1) and Calchaqui (3), resp. Interlocked (5) and Calchaqui (3).

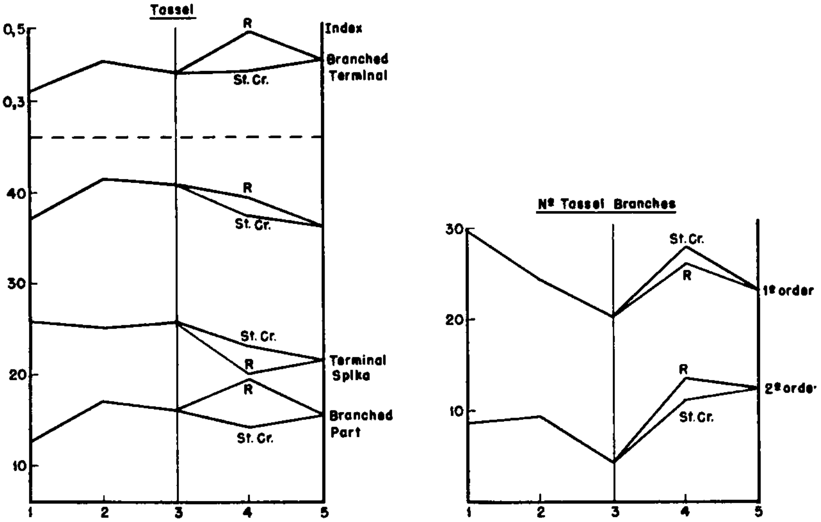

FIG. 22. Comparison between Cristal Paraguay—S. Paulo (2) and Cristal Entrelacado (4-R-Reyes-St. Cr.: Santa Cruz) and their putative parents: Avatí Morotí (1) and Calchaqui (3), resp. Interlocked (5) and Calchaqui (3)—Avatí Morotí Guapí (5a).

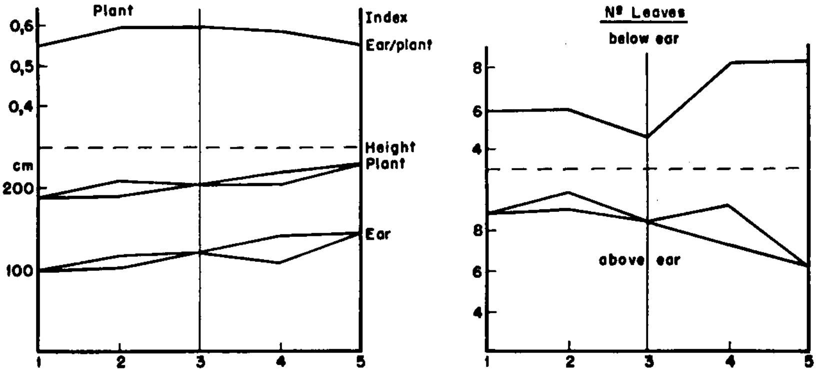

FIG. 23. Comparison between Cristal Paraguay—S. Paulo (2) and Cristal Entrelacado (4) and their putative parents: Avatí Morotí (1) and Calchaqui White Flint (3) resp. Interlocked Soft Corn (5).

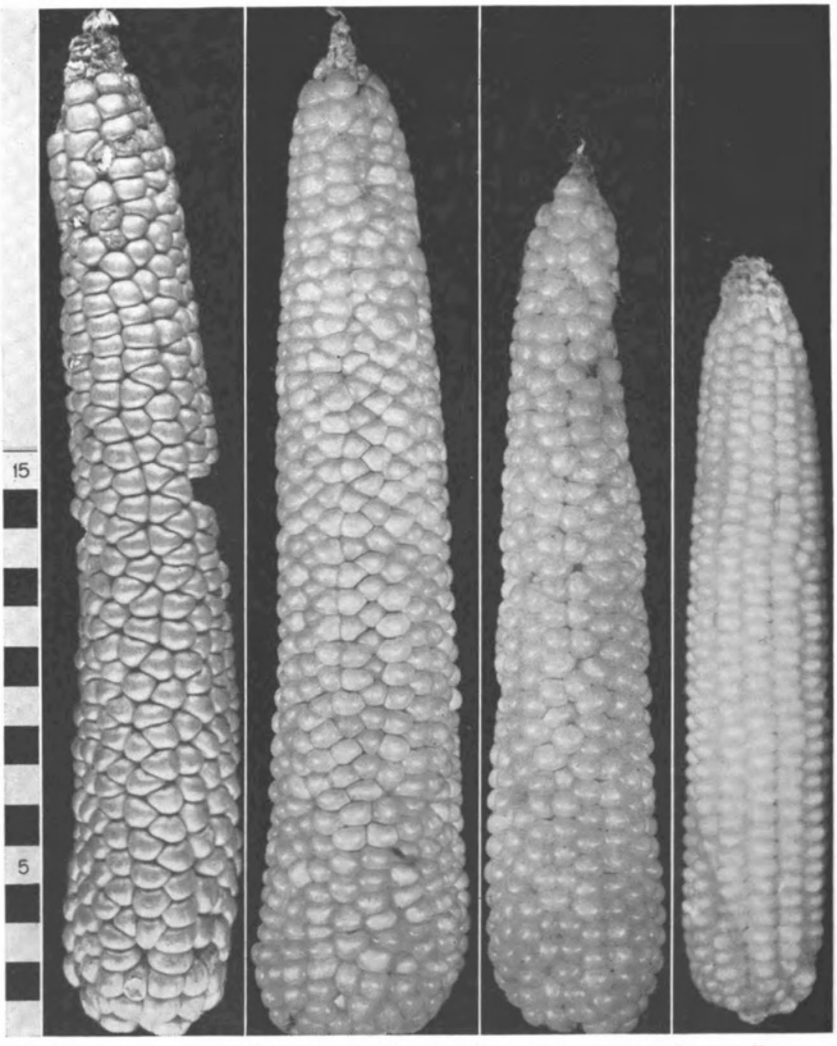

FIG. 24. Cristal Interlocked "Perola No. 1008" (2) is a recent and partially even incipient synthetic between the Interlocked Soft Corn of Reyes (1) (Bolivian eastern lowlands) and Calchaqui White Flint (3) from northeastern Argentina.

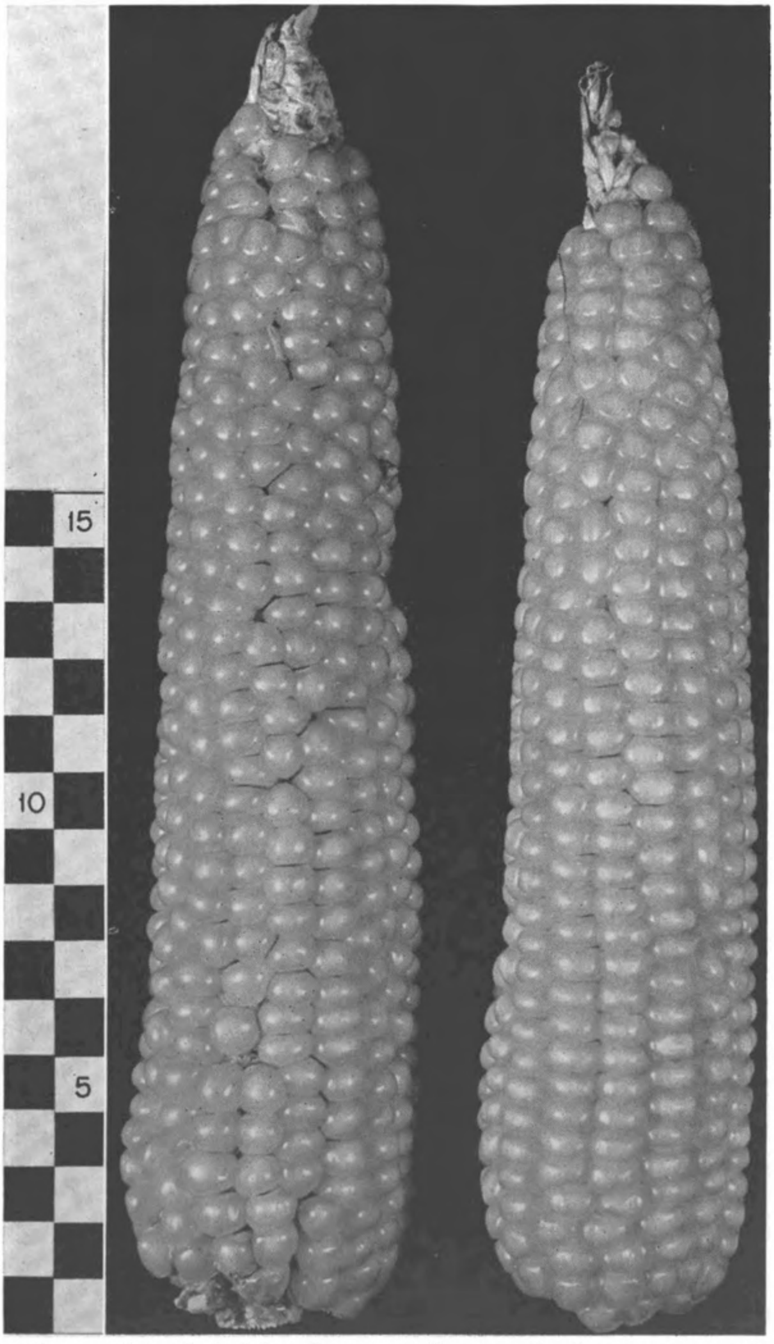

FIG. 25. Cristal-Interlocked "Perola No. 1013" is considered as a recent synthetic between Interlocked Soft Corn of the eastern Bolivian lowlands and the Argentinian Calchaqui White Flint.

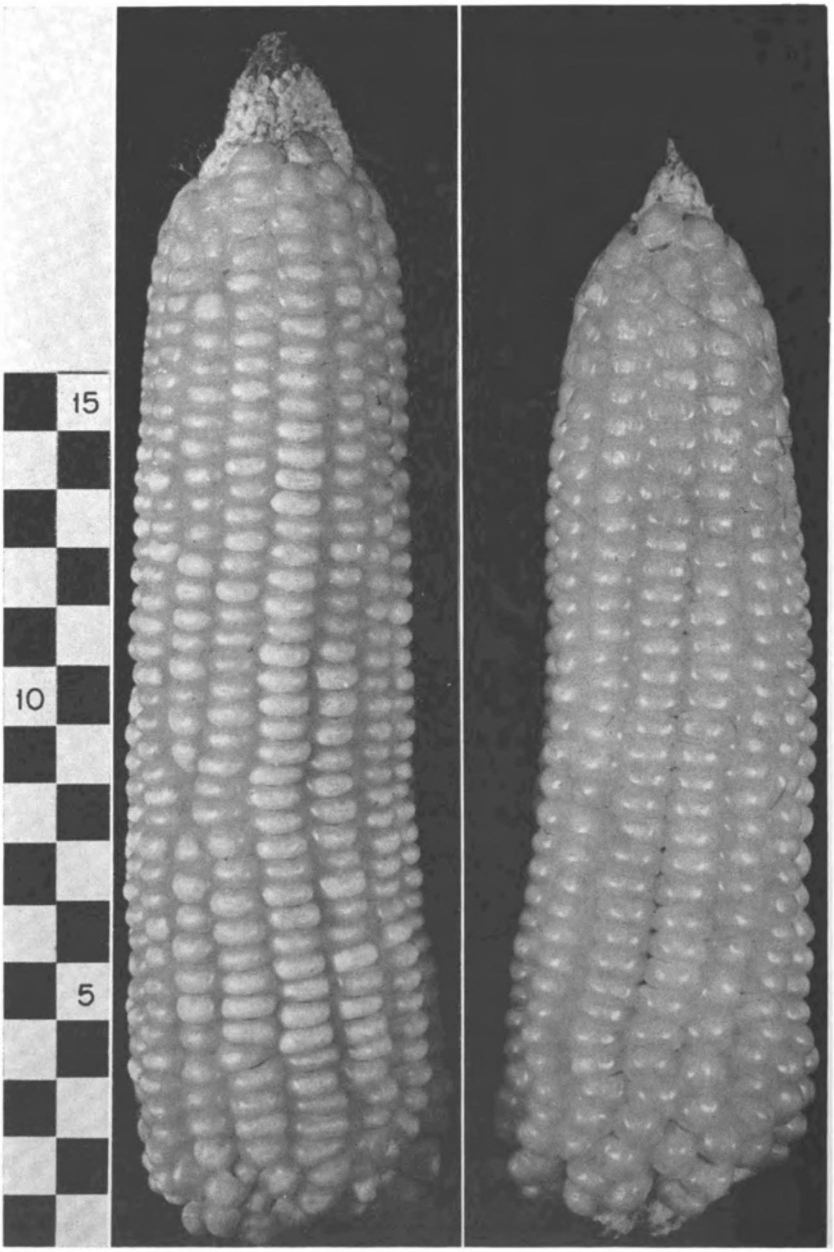

FIG. 26. Cristal-Interlocked "Perola Santa Cruz" is considered a recent synthetic between Interlocked Soft Corn from the eastern Bolivian lowlands and Calchaqui White Flint from northwestern Argentina. It must be assumed that perhaps one race of Guaraní Soft Corn participated also, which would explain the increase in the diameter of the ear.

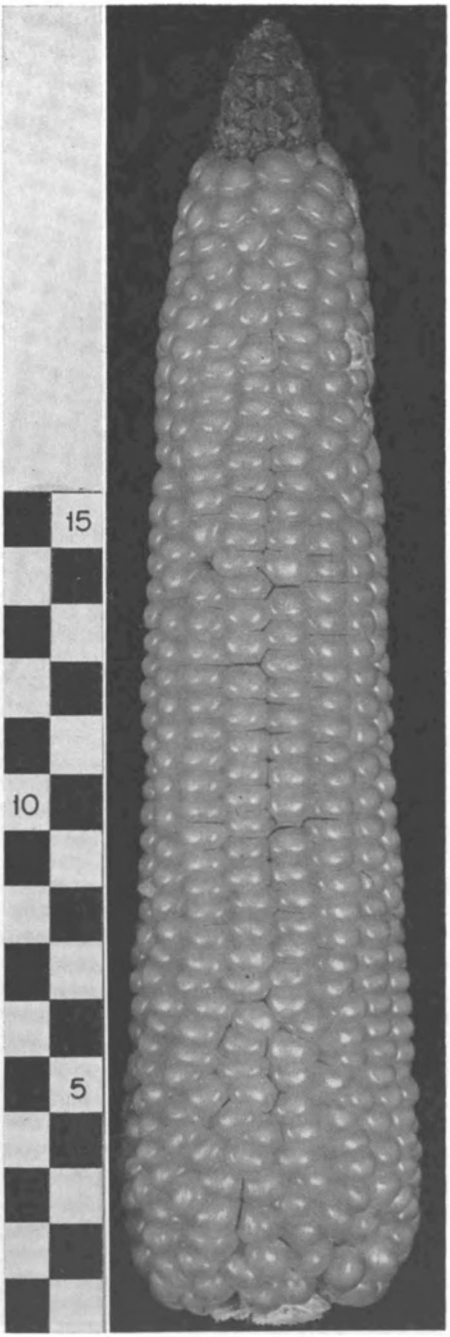

FIG. 27. Cateto-Interlocked is an incipient synthetic, owing to the recent introduction of a hard orange Brazilian flint Cateto into the area of the Interlocked Soft Corn.

the Humahuaca area. Ears are reproduced in Figure 28, diagram in Figures 29 to 31, and data in Tables 5 and 5a. Since the subrace *Capia Amarillo* shows quite clear indications from Amarillo de Ocho for example in the reduction of row number, in the more cylindrical and slightly more slender ears (*Capia Amarillo, Capia Variegata*), these are also included in the diagram. The diagrams show the usual role: there is no preference for intermediate behavior of characters, and even the sequence of the synthetic types is not always the same. *Capia Amarillo* (given under al in the diagram) sometimes stands near *Capia Blanco* (ear and tassel characters), but it is rather nearer *Amarillo de Ocho* in plant characters.

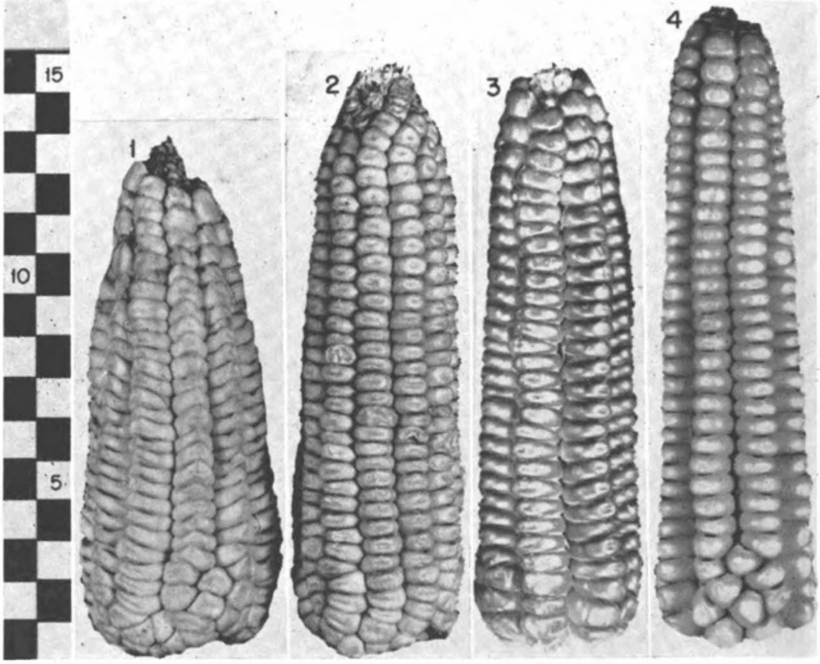

Fig. 28. In the High Valley of Humahuaca intercrossing is frequent between Capia Blanco (1) and Amarillo de Ocho (4). As a result the subrace Capia Amarillo (Fig. 29) arose, by the infiltration of genes from Amarillo de Ocho into Capia. There are several types of the other synthetics (2 and 3), approaching Amarillo de Ocho, which seems to be a disintegrating race.

These last synthetics show another very important point. There cannot be any doubt that *Capia Amarillo* is only a subrace of

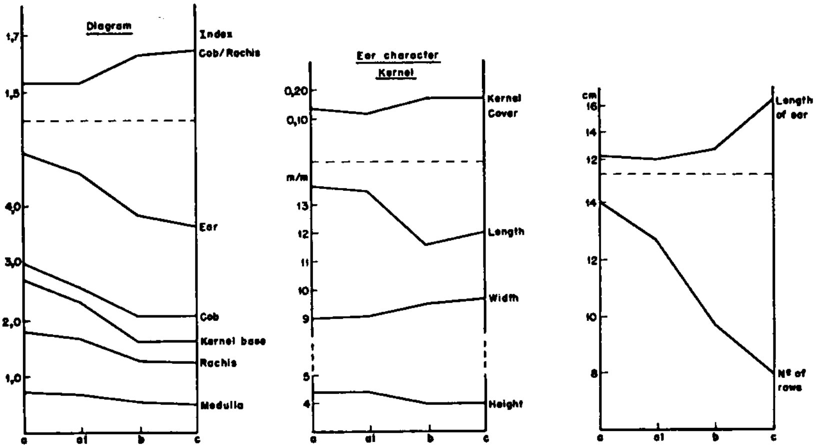

FIG. 29. Comparison between Capia Amarillo (a1) and different forms of Capia-Amarillo de Ocho (b, resp. b1., etc.) with the putative parents: Capia Blanco (a) and Amarillo de Ocho (c).

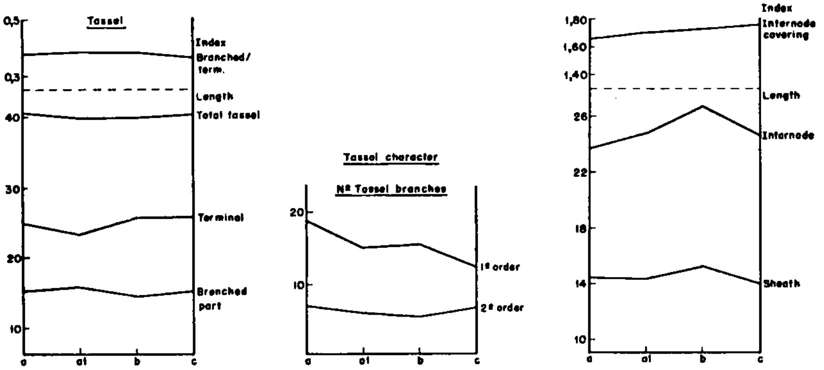

FIG. 30. Comparison between Capia Amarillo (a1) and different forms of Capia-Amarillo de Ocho (b) and their putative parents Capia Blanco (a) and Amarillo de Ocho (c).

Capia. Thus infiltration from another race has only produced a subrace but has not altered very profoundly the main racial characters, such as the form of the pointed and dented kernels with soft endosperm. On the other hand, the synthetics called here *Capia/Amarillo de Ocho* are quite near to Amarillo de Ocho, with eight, or more often a higher, row number, with nearly cylindrical ears, and with kernels very similar except for a definite tendency for denting and very rarely for the formation of a slightly curved and pointed tip of the kernel. When collecting this material around Humahuaca, we found difficulty in obtaining good samples of the pure race *Amarillo de Ocho.* It seems that infiltration from the more productive *Capia* endangers the preservation of the eight-rowed flint race. The two parent races thus react quite differently with regard to their intercrossing: *Capia* by producing a subrace and *Amarillo de Ocho* by the tendency to disappear.

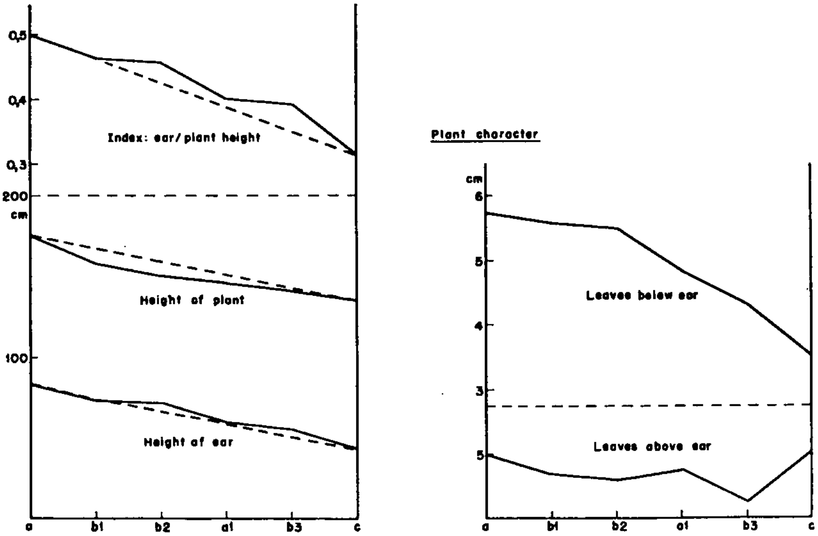

FIG. 31. Comparison between Capia Amarillo (a1) and different forms of Capia-Amarillo de Ocho (b, resp. b1., etc.) with the putative parents: Capia Blanco (a) and Amarillo de Ocho (c).

In concluding this section we may state: (a) It is quite evident that hybridization and the subsequent fixation of synthetics played an important role in race formation. (b) It is equally evident that the Indian breeder, when receiving interesting material from the outside, *i.e.*, from other tribes nearby, may have started a breeding program, trying quite successfully to maintain the kernel characters (texture, shape, and color) of the introduced race. As far as other characters are concerned, the synthetics may be intermediate, but they may also show either a predominance of one or the other parent or character combinations. (c) There is no objective justification for accepting the thesis that synthetics "must" be intermediate between their parent races, and that thus the latter may be identified by using the principle of intermediacy. (d) We have finally seen that a new race may develop from racial mixtures, as in the case of the different types of *Cristal,* which really are the start, not for one synthetic, but for an incipient racial group. It is also possible that only subraces may result, as in the case of *Capia Amarillo,* and finally one of the parent races may become extinct and be replaced by a new race, as in the case of *Amarillo de Ocho* and the types which we called *Capia-Amarillo de Ocho* but which we may equally well call with a new name, "*Indentado de Ocho,*" or simply eight-rowed dent.

SUMMARY

The results of our discussions and of the presentation of a few new facts may be condensed as follows:

1. *Time of origin.* Since maize did exist, nearly as it is today, some 5,000 years ago, nothing definite can be said about how old this crop plant really is, except that it must be much older still, if we want to consider the beginning of its domestication.

2. *Place of origin.* We may say something definite about the probable ecological habitat of hypothetical wild maize: It must have been a plant of tropical open grasslands, which are quite common in the Americas at intermediary altitudes of a few hundred meters. There are many places which have such a vegetation, and we do not even know how vegetation may have changed in the tropical area within the last 5,000 to 10,000 years. Thus nothing can be said as yet with certainty about the place of origin, except that it must have been in the Americas, and probably in South America, east of the Andes.

3. *Maize migration.* Migration, such as that of wild species, is subject to limitations of climatic-ecological zones, and it seems highly improbable that a race would have migrated much more than a distance of 10 degrees of latitude without infiltrating into a locally adapted race and thus becoming completely transformed. Furthermore, the ways and means of such migrations must have been changed profoundly after the establishment, in many regions, of white and mixed populations in place of the old Indian population.

4. *The mode of origin of maize.* Maize as a domesticated crop plant must have been derived from some still unknown wild grass. The hypothesis of the existence of two types, different in principle, namely of a "pure" maize and another type considered to be contaminated by either *Tripsacum* or *Euchlaena,* could not be maintained.

5. *The origins of the four basic types* (pop, flint, floury, dent) correspond possibly to four different levels in the course of domestication. Of the popcorn phase only relicts still remain. The flints now occupy marginal areas, while the floury or soft corn races represent the main bulk of indigenous races. Dent corn has arisen independently in several places, and it is eventually gaining predominance now under the white man's agriculture.

6. *Origin of races.* Races may have originated and may still originate by two processes: (a) slow selection of mutants and modifier complexes, or (b) rather rapid selection after intercrossing of races. Thus synthetic races are certainly of very great importance, but the principle should not be used in an exaggerated form. In the attempt to identify putative parent races of an assumed synthetic, one should not expect that the synthetic will be intermediate in all or even in most characters. Racial intercrossing and the formation of synthetics may have many results, such as the formation of completely new races or even of new racial groups, the formation of subraces only, or the extinction of an old parent race by a too frequent infiltration from another race.

These conclusions will be of importance in our discussion of the fifty races found in the area under study. At the end of the detailed description of these races we shall come back to some of these general questions in order to see whether new evidence may change the situation, though in anticipation new facts have already been used in the foregoing discussion.

MATERIAL AND METHODS

THE MATERIAL AND ITS STUDY

In the introduction to this paper, some explanations were given about the methods used in collecting the original samples of maize races, and thus there is no need to go into more detail. It should be emphasized that no measurements, and frequently not even observations, on plant or tassel characters could be made on the spot where the material was collected. Furthermore, it might have been considered desirable that the collector should make his own sampling in the field, but this again is difficult, mainly because it is practically impossible to time the collecting activities in such a way that one finds mature maize still in the field. It was even found impracticable to take measurements of ears during the collecting trips.

For these reasons, all measurements of ear characters were made either on the collected samples or on material harvested at Piracicaba. Tassel and plant characters had to be studied on material grown in our experimental plots at Piracicaba. This results in one advantage: all the material was grown under more or less identical, or at least comparable, conditions. But the possibility remains that under these conditions the plant and ear characters may be different from those which the same material would show when grown in its normal habitat. We know, for instance, that plant height is influenced by general climatic factors, and when grown in our plots at Piracicaba, at a latitude under the Capricorn, there is a very pronounced negative correlation between plant height and the latitude from which the material came originally. Thus plants from the fully tropical conditions of the Amazon Basin were the tallest and those from temperate latitudes of Argentina the smallest. But the same races, when grown in Argentina, were much taller.

There are indications that variations of tassel characters are much less pronounced than those of plant characters. Hardly any phenotypical effects were observed with reference to ear characters. Thus, except for the ears of the races from the Andean High Valley of Humahuaca, which generally do not mature at the low elevation of Piracicaba (about 600 meters), nearly all ear measurements were made on material harvested at Piracicaba.

In these plantings at Piracicaba we could again verify that maize is an exceptionally tolerant plant and can stand a very wide range of climatic variation. Only material from very high latitudes, such as races from Canada (Northeastern Flints and especially *Gaspé Flint*) did very poorly and remained very small, becoming at the same time extremely early (*Gaspé Flint* flowered in 30 days), while the material from the Pampas of Argentina or from northern Chile matured normally. Material from the full tropics of the Amazon Basin could generally not be grown to maturity. Growth until flowering time was normal, but then heavy rust attack set in and the ears either did not mature or set poorly. Furthermore, maize from altitudes above 2,000 meters from Bolivia, Peru, and Colombia, also showed very poor development and hardly produced ears except in some special years. For the latter races, it was necessary to plant the material very early, about two months before the beginning of the summer rains, and use artificial irrigation.

The material was grown in our field plots without any special experimental design. The main reason for this omission was the fact that we preferred to plant all the material in which we were interested, to subdivide the original material in subsamples whenever this seemed indicated, and to vary the number of plants in the different families when this seemed advisable. The use of any of the modern designs would have imposed restrictions and limitations which would have hampered the experimental work. Repeated plantings, however, either in the same year or in subsequent years, gave information about the range of phenotypical variation.

THE MAIN CHARACTERS USED

In the course of the last years, a certain kind of convention has been reached as to what are the most important characters to be used in the description of maize. It hardly seems necessary to cite the authors who first suggested one or the other character, or to enter here into a discussion of the merits of all these suggestions. We shall state simply which characters of ears, tassel, and plants have been used in the present paper. In each case, we shall give references both to qualitative and to quantitative characters.

EAR CHARACTERS

Ear shape. This may be cylindrical with or without a butt, conical, or spherical to egg-shaped. One may expect perhaps that measurements of the diameter at the base, in the middle, and near the tip of an ear might give data by which these different shapes may be described quantitatively. However, we found that this is not the case. A cylindrical ear, with a pronounced butt at the base, will yield measurements similar to those of a conical ear. The measurements "near the tip" depend on a subjective decision as to what we may call part of the fully grained ear and what the real tip, often containing only few or even no kernels. For this reason, only descriptive references will be given regarding ear shape.

Kernel shape. The kernels may be more or less flat. At the tip they may be pointed, round, flattened, or dented. These four differences do not represent alternatives, since there are races with kernels which are at the same time pointed and dented. Since these characters intergrade frequently, one might prefer the use of an artificial system of grading, for instance by giving deep denting the grade number 5 and no denting the number zero. However, such a system of grades is far from objective and there is the practical danger that for each race we may alter our scale somewhat, in accordance with what may be extremes present in each individual case. Though of importance for a statistical analysis of the data, it is always hard to decide whether the grades are in fact evenly distributed over the whole range of variation. For these reasons we decided in the present paper, and for all similar cases, not to introduce an artificial scale of grades, but to use only descriptive terms.

Kernel texture. Since it seemed to us, at least for a time, of considerable importance to distinguish flint and floury races, we tried to find some objective method for such a distinction, but without success. A kernel may appear rather hard when one tries to break it with the teeth, but when studying a cross-section one may find that there is only a hard outer shell of a few cell layers with horny starch, while the rest is rather soft and breaks easily. We tried also to determine hardness through classifying the kernels in accordance with the amount of light that may pass through them. However, when the intensity of the light used in such tests was changed, the classification changed so considerably as to make the tests useless. Furthermore, since translucency depends on kernel thickness, and thus changes with kernel shape, considerable differences may be found even between kernels of an ear from a pure line flint, when using the flattened kernels from the middle portion of the ear or the more or less round kernels from the tip of the same ear. There is also no clear genetic difference between flinty and floury maize, and some races may behave ambiguously in genetical tests. Thus *Negrito* from northern Colombia behaved as a "flint" in crosses with soft races such as *Cariaco* or *Guaraní Soft Corn,* but it behaved as floury when crossed with popcorn.

It should also be remembered that the kernels of dent corn may have an outer layer of very hard horny starch near their base or they may be rather soft throughout.

Kernel color. Whenever possible, the colors of the three main parts of a kernel were given: pericarp, aleurone, and endosperm, and only rarely did difficulties of classification arise. It is, for instance, not always possible to be sure that the pericarp may not be of light orange color when at the same time either aleurone or endosperm is colored. Small isolated pieces of the pericarp may not show its color when the latter is only weak. Red or black color of the aleurone layer is rather rare, and there are very few races with such colors, one being *Negrito* from Colombia. The black *Culli,* from the Andes, owes its color to the pericarp. However, brown aleurone color is very frequent in South American lowland material, and the coloration may vary from a rather light lemon-yellow to deep orange or almost red or to a strong brown, though the last is rather rare. It is in fact rather unfortunate that the name "brown aleurone" has been given to the main responsible gene. Endosperm color is always easily seen in flint races, but, if the endosperm is very soft, even the presence of the genes for full yellow color can give only a pale creamy coloration.

It should be mentioned that generally we shall indicate coloration of the kernels only when it is present, and thus the absence of such a reference signifies that no color was present.

Glume and cob color. Purple cob color is generally correlated with plant color, and a brownish coloration is caused by the alleles of the P-series for pericarp color. In South American material, deep purple coloration of the husks is not too rare and seems to be due to the action of some alleles of the B-series, and deep husk color is generally correlated with deep cob color. The coloration of the rachis surface and rachis flaps is genetically independent from that of the glumes (cob color), but it is very hard to study except in two-ranked ears.

Quantitative data. Measurements taken were: total ear length (in cm.), number of rows, and the following diameters, necessary for drawing the ear diagrams: medulla; rachis, at the base of the kernels—half the difference between the latter two giving an approximate measurement of the rachilla length; cob (to the tip of the glumes); and the whole ear. Half the difference between cob diameter and a point halfway between the diameters of the rachis and at kernel base gives a fair estimate of glume length. Following Mangelsdorf's suggestion, the cob/rachis index was always calculated. Length, width, and thickness of the kernels were determined by putting five kernels in a row and then making the measurements. Recently much importance has been given to the possible effects of alleles of the Tu-series, and for this reason the relative coverage of the kernels was determined by the following procedure: half the difference between the diameter of the ear and of the cob gives a good estimate of the size of the part of kernel not covered by the glumes, and by subtracting this value from the total kernel length, it is easy to determine how much of the kernel remained really covered by glumes. The same value should be obtained by taking half the difference between the diameter "at kernel base" and that of the cob. The length of the covered part of the kernel divided by the total kernel length gives a fair estimate of the relative amount of glume coverage, and may be multiplied by 100 to give the "glume cover percentage."

TASSEL CHARACTERS

The color of the tassel is generally that of dilute purple or sun-red plants, and green tassels were rare owing to the presence of the r^{gg}/allele. (They appeared, for example, in *Cuarenton* of the *Cateto* group). The tassels may be erect and stiff or pendant. The form of the tassel is always more or less pyramidal.

Quantitative data were taken for the following characters: Length of the sheath of the last leaf just below the tassel and of the last internode, between this last leaf node and the first tassel branch. Internode length divided by sheath length gives a good measure of the amount of coverage of the internode and of the lower part of the tassel. If this index is greater than one, there is no tassel coverage at all, and if it is less than one, part of the tassel and all the internode is covered by the leaf sheath. It was found that the mean values per family for this index did not give very clear results, at least not at first sight. Since the coefficient of variation (= sampling error divided by the mean and multiplied by 100) is about 20 per cent for this index and since we may assume that, with a normal chance distribution, variants may occur which differ from the mean by a deviate twice (5 per cent limit) or two and a half times (1 per cent limit) the size of the sampling error, this means that we may expect deviates among the individual measurements of up to 40 per cent or 50 per cent of the mean. Thus, with a mean for the tassel coverage index of around 1.1, half the individual variates should be between 0.6 or 0.7 and 1.1. This means that, though the mean does not indicate the presence of a partial coverage of the tassel base by the last leaf sheath, such a coverage exists in nearly one half of the plants, and in some of them not only the last stem internode, but a good part of the tassel branches will still be enclosed within the sheath (individual index values below 1.0). On the other hand, if the coverage index reaches a value of around or above 1.5 hardly any plant can have a tassel coverage.

The next two measurements refer to the length of the branched and of the non-branched part of the central spike. The former divided by the total length of the central spike gives an index which we may call the "branching index." Multiplying by 100, we may translate this to a percentage value. Finally, the number of primary and of secondary tassel branches was counted.

PLANT CHARACTERS

The coloration of nearly all races is either dilute purple or sun-red, though very light coloration is not uncommon. The distinction between these two possibilities is not always easy, since special genes exist for coloration of the culm and of the husks, and since there are many modifier factors, especially of the B-type. Deep purple plants, and very rarely also brown plants, were only observed in the Andean race *Culli.*

Quantitative data. First the total height of the plant (from its base to the first tassel) and of the ear (from the base of the plant to the base of the uppermost ear) were taken, and by dividing the second by the first an "ear height index" was obtained. There seems to be an interesting relation between plant and ear height. Vencowski (1958) has shown that no correlation exists between means of different races, *i.e.*, in these cases the relative position of the ear on the plant is determined by special genetic factors. But within races, and especially within families, this correlation is rather high, *i.e.*, phenotypic variation is correlated and the ear is generally higher on tall plants and lower on small plants.

The number of leaves (nodes) above and below the ear node was determined, but the latter was not always accurate, since a number of leaves at the base always get lost, and the counting of nodes is not too easy in this part of the plant, near the soil or even below its surface.

The length of each internode was determined for a number of plants, though these values were not reported individually in the tables. These measurements were used for constructing the diagrams, known as "internode pattern." As did Paterniani (1955) and Alleoni (1957), we found it advisable to give two such diagrams for each case: one starting as a fixed point from the node which carried the ear and including to the right and left all internodes measured, and the other starting as a fixed point from the node which carried the first tassel branches and recording only one or two additional internodes. Thus the corresponding ordinates of these fixed center points are those of the last internode of the stem, just below the tassel, and of the first internode below the ear. The diagrams of internode pattern register for each print the mean length of each internode of ten plants.

In a number of races the length and width of the leaf bearing the ear was determined and the number of main veins counted. Dividing the last value (number of veins) by the second one (leaf width) gives the "venation index," which represents the average distance between veins, assuming that they are more or less equidistant in the leaf.

The tables contain the means for the above-mentioned quantitative characters, with results referring to their statistical analysis.

METHODS OF STATISTICAL ANALYSIS

In most recent publications on races of maize, data similar to that in the present one are presented, but in general no statistical analysis has been made. Following a suggestion made by Brieger (1952b), Paterniani (1955) and Alleoni (1957) made a special analysis of their data. A certain amount of analytical work has also been given by Suto and Yoshida (1952–3) in their studies of Asiatic races of maize.

E. Anderson and his school have substituted graphic illustrations for the statistical analysis, using "scatter diagrams." Applying arbitrary scales in a system of rectangular coordinates, they use one main character as abscissa, and one or more other characters as ordinates. Such scatter diagrams may be excellent illustrations when the correlation of characters is under consideration, but it must be emphasized that the use of graphic illustrations represents a highly subjective procedure. If there is some correlation, we may exaggerate visually its effects by choosing the relative scale of ordinates and abscissae accordingly, or we may also minimize the effects of correlation. The only correct procedure is not the graphical but the analytical one, which has been used extensively by Suto and Yoshida (1952–3), *i.e.*, the ordinary technique of correlation analysis.

The first step in preparing for a statistical analysis consisted in determination of means and sampling errors. Of course comparable material of the same race or subrace, etc., was then pooled and their common sampling error (residual errors in the terminology of the analysis of variance) calculated.

These general estimates of error were divided by the correspondent general mean and multiplied by 100 to obtain the coefficients of variation. These can serve as a good measure of the reliability of a character for classification. It is a known empirical fact that in chemical or physical experiments it is generally possible to maintain the general conditions of an experiment quite constant, and thus the coefficient of variation should be only of the order of 3 per cent. In agricultural experimentation, or in general in experiments with biological material, the control of conditions is much more difficult and thus much more incomplete, resulting in higher values for the coefficient of variation, which however should not go beyond 20 per cent. In samples with a normal chance variation, as stated above, allowing for deviates up to twice (about 5 per cent limit of chance probability) or two and a half times the sampling error (1 per cent limit of chance variation), we may expect in our samples variates which differ from the mean by up to 40 or 50 per cent, while about half the variates should be within a range of about 30 to 35 per cent above or below the mean. This is quite a considerable range of variability, and characters which show a higher degree of variation can hardly be considered as useful for the purposes of description.

We may also calculate the least significant differences between means. Assuming that most samples will consist of from 10 to 20 variates, or on the average of 16 variates, we may calculate the sampling error of means and the corresponding coefficient of variation by dividing the residual error of the samples by the square root of the number of members in each sample, or in our case by about 4 (square root of 16 members per sample). To obtain the error of a difference, we must still multiply by about 1.4 (square root of 2) and by the value of the corresponding limit of significance (about 2 or 2.5 as mentioned above). Thus the least significant difference between means, admissible by chance and with a coefficient of variation of 20 per cent, will be of the order of 14 to 17.5 per cent, or roughly 15 per cent of the means under comparison. Characters with a higher coefficient of variation, where not even differences of the order of 15 per cent of the mean values will be significant, can hardly serve in the distribution of races.

In order to evaluate the actual data under these viewpoints, the weighted means of all the coefficients of variation given in the tables were calculated and their range of variation indicated, limiting in the latter case the citations to coefficients from at least 20 degrees of freedom. We come thus to the following summary:

COEFFICIENT OF VARIATION

Character	*Mean*	*Range*
Ear:		
Length	12.9	8.5-16.8
Number of rows	17.1	6.0-(55.0)
Diameter of Medulla	25.7	17.4-32.6
Rachis	17.0	11.0-27.3
Base of kernel	15.2	7.4-16.9
Cob	12.2	7.1-13.2
Ear	9.2	5.1-12.0
Cob/rachis index	13.2	9.2-26.1
Kernel		
Length	9.3	5.1-12.4
Width	9.4	6.6-12.3
Thickness	12.4	7.0-20.4
Glume covering	25.1	20.0-28.6
Tassel:		
Sheath length	12.4	10.5-16.4
Internode length	17.6	10.6-21.8
Internode covering	19.4	15.1-36.7
Length of branched part	18.8	15.7-30.1
Length of terminal spike	14.9	13.2-23.2
Proportion of branched part	19.1	8.2-31.1
No. branches 1′	22.7	19.4-45.0
No. branches 2′	47.4	39.1-56.9
Plant:		
Plant height	10.9	7.2-17.0
Ear height	18.0	10.5-34.3
Ear/plant height	12.9	10.5-39.1
No. leaves above ear	13.1	11.2-24.2
No. leaves below ear	17.0	7.5-25.2
Leaf length	8.4	8.0-10.9
Leaf width	12.5	10.4-16.4
No. of veins	11.5	9.5-15.9
Venation index	15.8	10.0-27.8

The weighted means of the coefficients of variations are below 20 per cent for all characters except the following four:

Diameter of medulla of the ear, 25.7 per cent. The determination of this value is in fact highly inaccurate, since in assuming that there is a "diameter," we implicitly admit that the cross-section through the medulla should be a circle, but its outlines are rather irregular and the determination of its diameter represents more a subjective estimate than really a precise measurement.

Index of kernel covering, 25.1 per cent. Measurements were taken in millimeters, but the variation of kernel length is of the order of fractions of millimeters, and thus slight inaccuracies are unavoidable even when measuring five kernels simultaneously. The determination of the cob diameter, likewise, is not too exact, and these slight inaccuracies have a strong effect and may become exaggerated when we divide the values obtained.

The coefficient of variation for the number of tassel branches of 1° order is only slightly above 20 per cent (actually 22.7 per cent), while that of the *number of secondary tassel branches* is 47.4 per cent. It must be remembered, however, that the mean number of secondary tassel branches is on the whole rather low and varies around 5 to 7, with the extremes being on the one hand practically zero and on the other 12.8 (*Interlocked Soft Corn*). Thus we can hardly expect a normal variation, but should rather expect that of a *Poisson* series. Thus the calculation of the coefficient of variation loses much of its importance.

We have seen that only four values among a total of twenty-nine characters studied show a higher variability than the one we admitted previously as satisfactory. Four other characters have coefficients below 10 per cent. The remaining twenty-one values are between 10 and 20 per cent.

It should be mentioned that it is desirable, if not in fact necessary, before studying the coefficients of variation and even before calculating the residual errors of groups of races or at least of samples, to carry out a heterogeneity test for the individual sampling errors, in order to determine whether their pooling (confounding in statistical terminology) is justified. Paterniani (1955) and Alleoni (1957) have carried out such tests in detail and found a certain amount of heterogeneity. Similar tests were carried out with the remainder of the material discussed in this publication. But we came to the conclusion that the degree of heterogeneity was not sufficient to preclude the use of pooled estimates of residual errors.

The next step in the analysis of the data consisted in the use of the methods of the analysis of variance, which allows the breakdown of variation in accordance with recognizable sources of variability. When R. A. Fisher first introduced this method of analysis, he suggested carrying out all tests of significance using the natural logarithm of the ratio between two error components. The use of these logarithms is of advantage for the interpolation of values not contained in tables, but otherwise it obscures the basic reasons for the procedure. This value "z" of Fisher was then substituted by the variance ratio F of Snedecor (1937) or the error ratio "theta" of Brieger (1946), and for both the latter values complete tables now exist (tables of Fisher and Yates for F and of Brieger (1946) for theta). We prefer in this publication to give the error ratio and then indicate its probability, since they show immediately to what amount the variability has been increased. The variance ratio F of Snedecor has no practical direct significance. One may also have some doubts as to which level of significance should be used (5 per cent or 1 per cent). In a simultaneous comparison of a large number of samples the 5 per cent limit may be considered as quite insufficient, and even the 1 per cent limit may not be admissible. Thus frequently only the 1 per cent limit remains as the decisive limit.

One of the purposes of this analysis is to distinguish between minor genotypical or phenotypical variation on the one hand and the major genotypical differences which should exist between races. Phenotypical variation can be measured by comparing data obtained from repeated plantings of the same material (Paterniani 1955, Alleoni 1957). Minor genetic differences within races may be found when comparing independently collected samples of the same race. Thus, for instance, in Table 8 we see that the error ratio between two types of *Capia-Humahuaca,* one with white and the other with yellow endosperm, increases the residual variability by about 4 to 9 times (minimum error ratio 3.73 and maximum ratio 8.57), while the effect of phenotypical variability (between successive plantings in more than one year) gave only an increase of up to 4 times, and in many cases even an insignificant reduction of variability (values below *one* for the error ratio). The same Table 8 shows that the two groups behave more or less in the same way in different years of planting, since the component "interaction" is on the whole insignificant and gives an increase of variability of the same order as the factors for phenotypic variability (between years). There is a significant variation in only two characters, but the increase of variability, to about twice (1.82 and 2.11) that of residual variability, is of the order of phenotypic variability (between years) and not of the order of the variability between the two years or subraces. Thus we may conclude from this analysis that the two types of *Capia* differ in fact significantly, and this is in accord with another conclusion, namely that the yellow endosperm type has suffered some infiltration from another race, in this case probably *Amarillo de Ocho* from Humahuaca.

In order to explain one more example, we may refer to Table 27, which gives the results of the analysis of plant characters of representatives of the *Guaraní Yellow Soft Corn.* The analysis shows that there are two levels of a significant increase in variability. One race, the early *Avatí Mitá, differs* from the other four races, and this difference corresponds to an increase of the basic or residual variability by 20 times on the average. The differences between the means of the four remaining races corresponded to an increase of variability, on the average, of only about 6 times. An increase of 6 times in the variability was also found when comparing samples of the same race, collected in different regions (combined component "between other 4 races and origins"), the combination of these two components having been made only after previous determination that they cause an identical amount of variation. Finally the different families, obtained from the several ears collected for each race and locality, give an increase of residual variability of only 2 to 3 times the residual error. Owing to the high degree of freedom, combined in calculating the estimates of the residual error, all these increases of variability are statistically significant. Only an evaluation of the amount of increase for each component, by a study of the error ratios, shows that the significant increases for each probable source of variation are really of different order for the different error components.

When comparing the tassel characters of the same material, quite different results were obtained, as shown in Table 26. Here it was advisable to distinguish one more component, *i.e.*, to separate the effects "between four races" and "between origins of the samples of these races" (second and third component in Table 26 as against combined second component in Table 27). The increase of variability within the origins (families derived from different ears collected in each case for the same race at the same locality) amounted to only about one and a half times the residual variability, though even this rather slight increase was statistically significant at the 1 per cent limit of probability. As indicated by arrows for two characters (sheath length and internode length) all other sources of variability showed an identical rate of increase in variability, *i.e.*, added nothing to the variability. In two cases (length at last internode), the remaining sources of variability gave an increase of the order of about 3 times (2.82) the residual variability. For only four characters did *Avatí Mitá* differ considerably from the other four races by an increase in variability from 6 to more than 20 times. Thus we may conclude that, as far as tassel characters are concerned, four of the races may be considered as practically identical, their differences being of the same order as the slight genetic differences between samples ("within origins") and only the race *Avatí Mitá differed* considerably from the rest in the shortness of the branched portion of the tassel and the low number of primary and secondary tassel branches. The length of the unbranched terminal spike and that of the last leaf sheath and last stem internode were essentially the same for all races. These characters are thus typical for the racial group called *"Guaraní Soft Corn"* as a whole.

Table 25 shows that the races in question behave again quite differently from the results which we obtained before when comparing ear characters. It seemed indicated here only to maintain the distinction of two components in addition to the residual error: "between three groups of races" and "within the one group" still containing three races. The differences between the latter amount to an increase of variability of about one and a half times on the average, while the difference between the three groups of races corresponds to an increase of residual variability of from 4 to 7 times, with the exception of kernel width and kernel height, which were identical in all races.

In combining the results of such an analysis, we see that *Avatí*

Mitá differs quite considerably from the rest in almost all characters. The others form two groups regarding ear characters, with *Avatí Moroti Guapi* having shorter and thicker ears and the remaining three races being distinguished mainly by qualitative characters or even not being very different. It is also important to note that ear characters show most distinctive differences, while plant and tassel characters tend to be rather uniform within this racial group.

Similar conclusions can be drawn from the other tables and will be mentioned in the descriptive discussion of the races whenever necessary.

In conclusion, we wish to say that we feel justified in giving the results of the statistical analysis in this condensed form, since we believe more details may interest only specialists in statistical methods and would considerably increase the number of tables to be presented. On the other hand, a really complete and objective presentation of the methods of analysis used would require the publication of all the individual data, or at least of all the partial sums of squares and their degrees of freedom, but this would, we believe, result in an increase of publication costs which would hardly be justified.

DESCRIPTION OF THE RACES

The races which will be described in this paper will be subdivided into four main groups, which correspond to the four main climatic regions under discussion and to which some references have already been made.

The first region belongs today politically to Argentina, but it did belong before the conquest to the large region which was under the influence of the Inca government, and it represented the southern border of this Empire. It is formed by the High Valley or, as it is called, the Quebrada de Humahuaca, and the surrounding High Plateau or Altiplano, and thus belongs geographically to the Bolivian Andean region.

A small strip which corresponds to the eastern Andean slopes represents the second region, lying between the two lowland regions on the one side, the tropical one in the North and the subtropical one in the South, and the Andean Highland on the other.

The third region extends from the Pacific to the Atlantic, through northern Chile, northern and central Argentina, all of Paraguay, the southern part of the Bolivian Lowlands and southern Brazil. Its climate is subtropical on the whole, and we may call it the "region under the Capricorn."

To the north of this zone, between the Andes and the Atlantic, lies the fourth region, the Amazon Basin and its southern margin.

THE ANDEAN HIGH VALLEY OF HUMAHUACA IN NORTHWESTERN ARGENTINA

The following description is based on the more detailed paper by Alleoni (1957) which also gives full literature references. We shall first give a very brief description of the region and its geographic relationship to the neighboring countries. In the map (Fig. 32) the principal agricultural zones of the High Valleys are indicated under "5" (vertical striping). There are four main regions of this nature: The Valley of Quebrada of Humahuaca in the south, the High Valleys or "Yungas" of La Paz and of Cochabamba, and the High Plateau or Altiplano around the Lake Titacaca. The three High Valleys are separated by Altiplano areas, and there are only a few additional smaller agricultural regions in Bolivia, around small towns like Potosí and Sucre. The three High Valleys begin at rather low altitude, the Yungas of La Paz and Cochabamba in the region of the tropical rain forest, while in the lower part of the Humahuaca Valley, around JuJuy, no forests exist today, though the tropical rain forest extends on the eastern slopes of the Andes to the latitude of Tucuman. Between this forest on the slopes and the High Valley there is a narrow belt of shrubs of *Alnus* and other non-tropical species.

As far as maize is concerned—and the same seems to be true for other typically Andean crops—cultivation begins around an altitude of 1,700 to 2,000 meters and continues to about 3,500 meters. Beyond this last limit, and only in favorable places where agriculture is still possible, the Altiplano races of maize and other crops (potato, etc.) appear. The High Valleys are situated beyond the main cloud zone, and they receive on the one hand very little rain and on the other a very high amount of insulation. Under such conditions, cultivation is only possible in irrigated plots, and the cultivated area is thus terraced to a very pronounced degree and with great efficiency. Further detail on the special conditions of the Valley of Humahuaca can be found in the paper of Alleoni (1957), who also cites the older literature of Parodi (1935, 1948), Martins, and others.

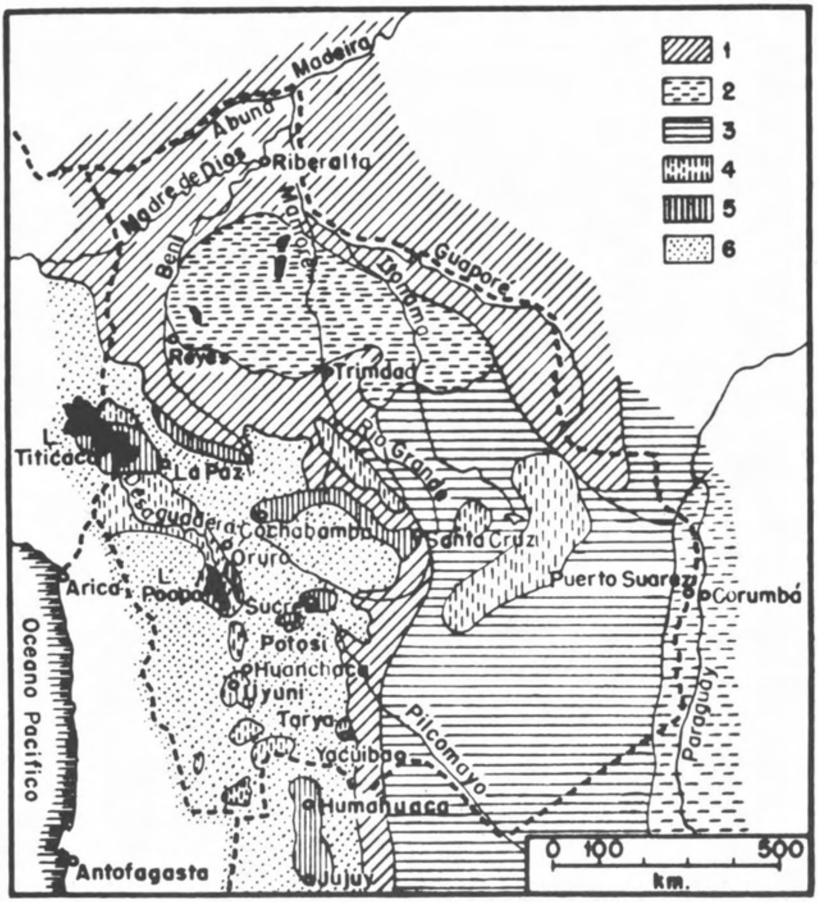

FIG. 32. Bolívia—1) Tropical Rain Forest; 2) Swamps; 3) Dry Forest and Savanna; 4) Pastures; 5) Agricultural areas; 6) Andean High Plateau.

In the Humahuaca region, we collected representatives of at least 10 races or groups of races which are clearly distinct. Of these, two seem to predominate as main field crops: *Capia* and *Amarillo de Ocho,* though the latter is restricted in its area of cultivation. There are seven more special races, and finally we come to the *Altiplano* group of races. The latter can always easily be distinguished by studying the ears, which are small and spherical to egg shaped. A more detailed study has shown that there must have existed and still exists today a good deal of gene interchange between Valley and Altiplano types.

Considering that the total area of the Humahuaca Valley is of the order of 70 by 30 kilometers, it may seem astonishing that so many distinct types occur. This phenomenon, however, is not limited to maize but is typical for crops under cultivation in high altitudes. It is not easy to find an explanation for this pronounced diversification. Such an increase of diversification is sometimes explained as a result of increased geographic subdivision and isolation, but in the region in question there is no indication of a geographic isolation in separate smaller valleys. The main Valley of Humahuaca and its side valleys are all in rather close communication, and furthermore a farmer may cultivate in his small lots, side by side, five or six different races of maize to be used for different purposes. It seems too early to try to find an explanation.

1. THE GROUP OF THE POINTED DENT CORN CAPIA

The main characteristics of this group are the shape and texture of the kernels, which belong to a soft dent type with clearly pointed kernels. The group can be divided into two main races: those with white endosperm and those with yellow endosperm. The white endosperm type represents the typical *Capia,* while that with yellow endosperm is forming another race, in consequence of the infiltration from *Amarillo de Ocho,* as mentioned above. The *white Capia* has, in general, conical ears, which are very large at the base, while the yellow form or *Capia Amarillo* has less conical or even almost cylindrical ears. The *white Capia* can be subdivided into a number of subraces based on the color of aleurone or pericarp, and we found also two subraces of *yellow Capia,* one with and the other without pericarp color.

White Endosperm Capia

Ear photographs, Figures 33 to 35
Ear diagrams, Figure 45.2
Internode pattern, Figure 46.1
Tables 6 to 8

Ear: Always conical in shape, with the somewhat rounded tip completely covered by kernels; ear length 12.3 cm. The rows are quite regular, with a mean number of 14.1 (range from 10 to 18). Ear diagram: diameter of medulla 0.8 cm.; of rachis 1.8; at kernel base 2.3; of cob 2.7; of the whole ear 4.9 cm.; rachilla about 2 mm. length; cob/rachis index 1.53. The cob is colorless except in the subraces with colored pericarp, where the cob is also colored.

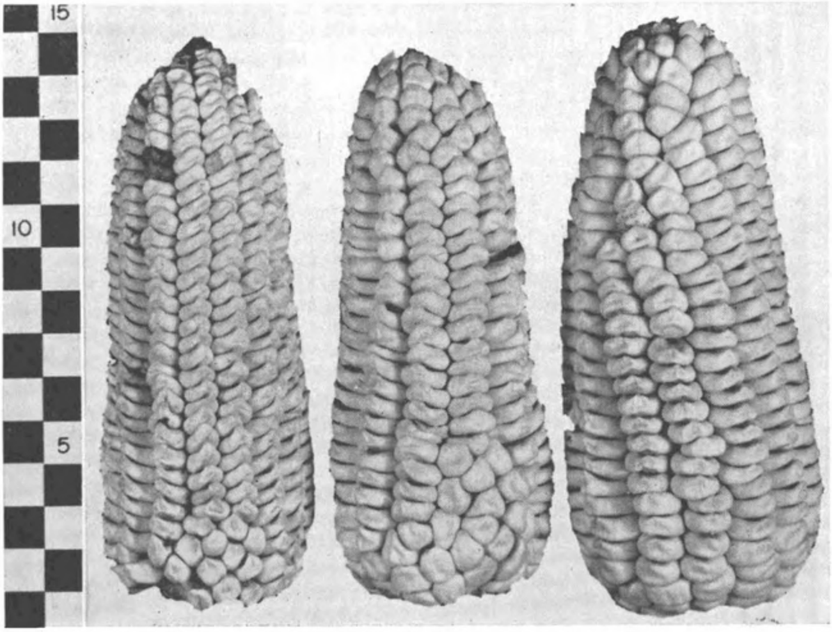

FIG. 33. Races from the High Valley in the Andes of northern Argentina, the "Quebrada de Humahuaca": Capia Blanco, a white soft dent with pointed kernels, the most important field corn of this region.

Kernel: Rather long, more or less deeply indented at the tip and always with a very pronounced and upcurved tip above the end. The kernels generally form an acute angle with the cob surface and thus cover each other more or less like shingles on a roof.

Endosperm texture is soft or floury. Length 1.4 cm., width 0.9 cm., height 0.4 cm. The glumes are rather short in proportion and cover only 14 per cent of the kernels. The kernel color varies in the subraces: *Capia Blanco* with colorless pericarp and aleurone, *Capia Carapato* with colorless pericarp and mottled aleurone, and *Capia rosado* with rose-colored pericarp (probably r/cherry) and colorless aleurone.

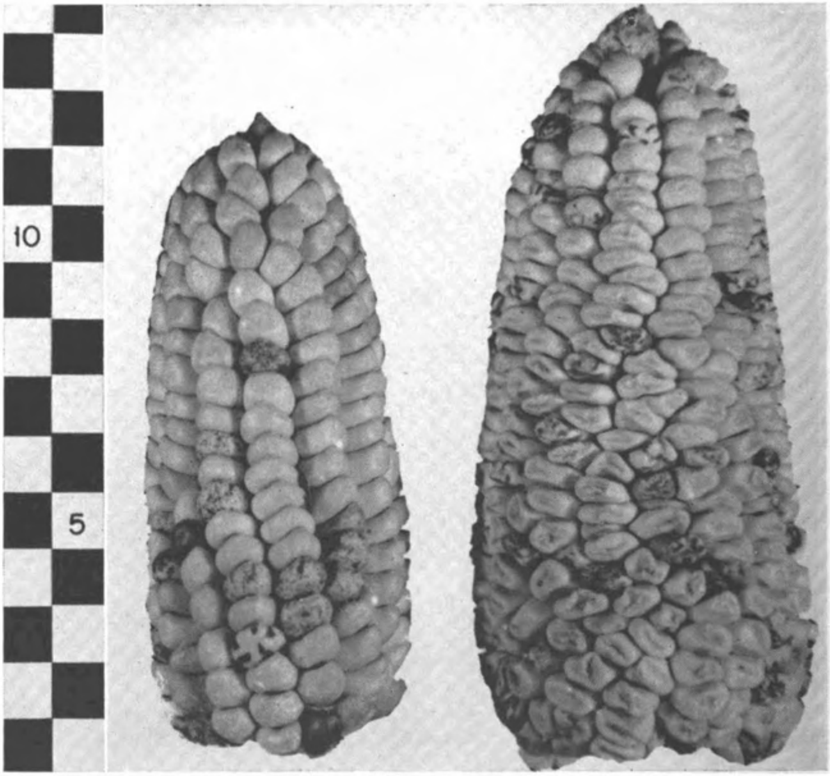

Fig. 34. Races from the High Valley in the Andes of northern Argentina, the "Quebrada de Humahuaca": Capia Carrapata, a subrace with mottled aleurone over white endosperm.

Tassel: Rather stiff. Length of the last leaf sheath 14.5 cm. and of the last stem internode 23.8 cm. Internode covering 1.66, *i.e.*, only about 60 per cent of the internode remains covered by the sheath, and the tassel itself is completely free and exposed. The branched part of the tassel is relatively short (15 cm.) when compared with the terminal spike (25.4 cm.), and forms only 37 per cent of the total tassel length. There are on the average nineteen primary, and seven secondary, and practically no tertiary branches.

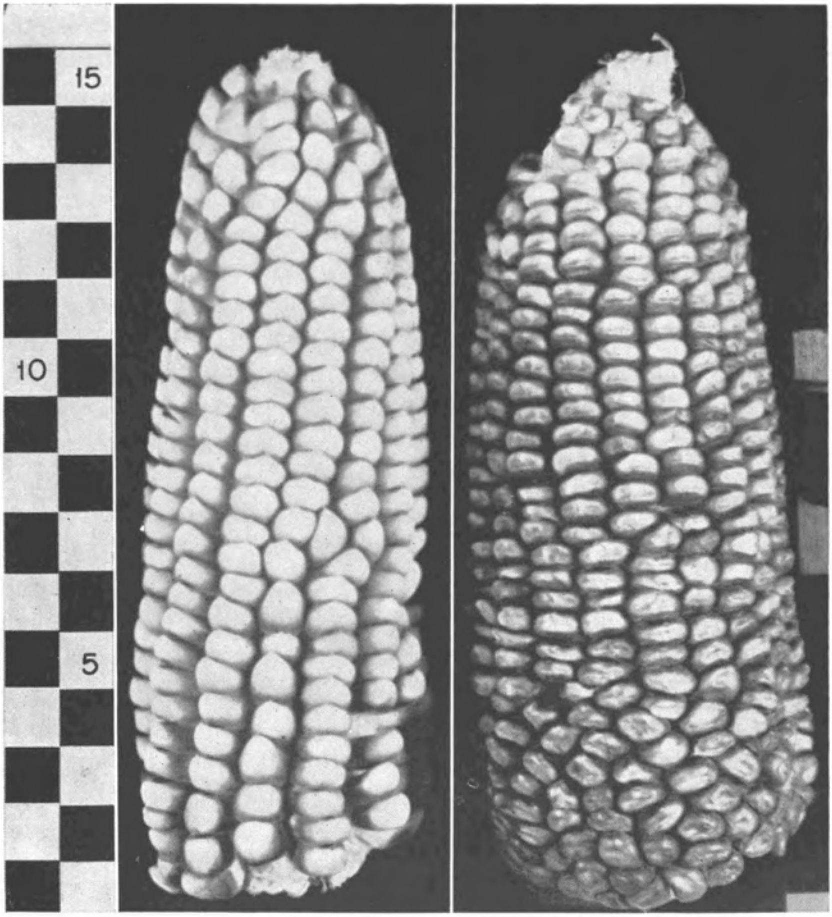

FIG. 35. Races from the High Valley in the Andes of northern Argentina, the "Quebrada de Humahuaca": Capia Rosado, a subrace with rose colored pericarp and white tips, over white endosperm.

Plant: Of normal height (175 cm.) even when grown at Piracicaba, with the ear about in the middle of the plant. There are about 6 leaves below and 5 leaves above the ear. The ears are relatively long (84 cm.) and wide (10 cm.). There are an average of 22 veins, and the venation index is 2.25.

Origin and relationships: Capia Blanco and its subraces are not limited to Humahuaca, but also represent the main field corn further north, around Sucre, Potosí and in the Yungas of La Paz. There it is known by the name of *Chechys* (see also Cutler 1946). As shown in Figure 46.2 *Chechys* and *Capia* are identical in all ear characters. Nothing is yet known about plant and tassel characters. From an inspection of Dr. Grobman's collection it was evident that the same race extends into the Peruvian Valleys, though north of the Lake Titicaca it seems less known and is probably of minor importance. It should be mentioned, however, that even in the region south of Lake Titicaca, *Capia* or *Chechys* is not always the main field corn. In the Yungas of Cochabamba it occurs but, according to information given by Cardenas, the main field corn there is *Huilcapara* (Fig. 54.1), a dark-colored type, with conical ears which are on the average longer than those of *Capia,* with kernels that are rather round, not so dented or only slightly and without pointed tip, and always of a brownish-black color. *Huilcapara* may be a rather recent synthetic race, into which *Capia* entered together with some other, unknown race. A counterpart of *Capia* in the North, in the High Valleys around Cuzco (Urubamba and Uyucalli), is the famous *Large Grained Cuzco Maize,* which is also a soft dent corn but otherwise differs completely from *Capia* or *Chechys.* It may sometimes have a small beak at the tip, but the ears are cylindrical and have few rows (mean slightly above 8 rows). (Figs. 54.3 and 54.4.)

Nothing can be said with certainty about the origin of *Capia.* Of course, one could try to explain it as some form of synthetic, for example between the conical pointed popcorn *Pisincho,* of the same region, and some other race from elsewhere which may tend to increase kernel size, soften the endosperm, and introduce denting. However, this would be complete speculation, without any real foundation. It must also be remembered that more or less soft and pointed dent corn races exist also in other regions, as mentioned above, and that today the distribution of this peculiar type is so scattered that one may rather consider it as an old and almost extinct type. As mentioned above, pointed dents were found in the Sierra of St. Martha, in northern Colombia, and possibly with the Karajá Indians in the eastern part of the Amazon Basin. But if we compare the photographs of *Capia* in Figure 33 with those of the other two races in Figures 2 and 8, it becomes evident that, except for the presence of indented and at the same time pointed kernels, no other characters are in common.

Capia or *Chechys* plays a role south of Lake Titicaca similar to that of Cuzco Large Grain in the region of Cuzco. Even at present, both still represent a well adapted and fairly productive type of field corn under the special conditions of their region, and it would certainly not be too difficult to improve them further. Thus those races should be fully taken into consideration in any modern breeding program for the Andean High Valleys, instead of attempting to introduce from the outside, especially from the lowlands, races, commercial varieties or even hybrids which are not adapted and would have to undergo an extensive adaptation process requiring outcrosses to the old local types. It seems to us doubtful that new synthetics which might thus be obtained would eventually become superior to selections and improvements made out of *Capia* or *Chechys,* without any outcrossing.

Yellow Endosperm Capia

Photographs of ears, Figures 36 and 37
Internode pattern, Figure 46.2
Tables 6 to 8

Subrace Capia Amarillo, with colorless pericarp and aleurone over deep yellow endosperm.

Subrace Capia Variegata, with variegated pericarp and cob.

Ear: Frequently not so conical as in *Capia Blanco;* less thick and with fewer rows, a fact which we attributed above to an infiltration of genes from the 8-rowed flint *Amarillo de Ocho.* Ear diameter 11.9 cm.; mean row number 12.7 (from 10 to 16). Ear diagram: diameter of medulla 0.8; of rachis 1.7, at kernel base 2.2; of cob 2.5; of whole ear 4.6; cob/rachis index 1.53.

As shown by the statistical analysis in Table 6, the component "between subraces" is highly significant for row number, which is mainly caused by the fact that *Capia Variegata* has the same high row number as all the subraces of *Capia Blanco,* while the mean for the subrace *Capia Amarillo* is much lower—10.5. It seems that *Capia Variegata* has undergone less infiltration from

Amarillo de Ocho. Next there is quite a pronounced difference of the diameter "at kernel base," which means that *Capia Amarillo* has a considerably shorter rachilla. Finally, and in consequence of the shortness of the rachilla, the glumes cover the kernels slightly more than in the other subraces.

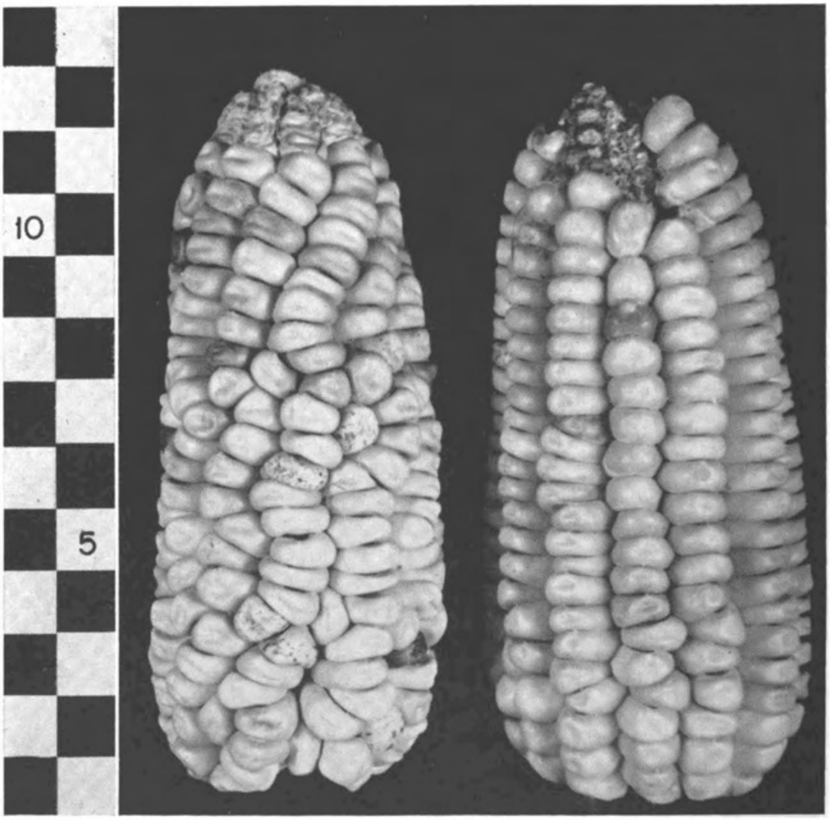

FIG. 36. Races from the High Valley in the Andes of northern Argentina, the "Quebrada de Humahuaca": Capia Amarillo, a subrace with yellow endosperm, and generally with strong infiltration from the race Amarillo de Ocho, which is clearly visible in the ear on the right with rounder kernels, salient rows, and a nearly cylindrical ear.

Kernel: There is very little difference between the yellow and the white endosperm races of *Capia* regarding kernel size, as shown by the fact that all error ratios can be expected by chance, with frequencies of more than 5 per cent probability. The only exception, which we mentioned earlier, is kernel covering, which amounts to 22 per cent for *Capia Amarillo,* against 13 per cent in all other subraces.

Tassel: Except for a slight difference in the number of tassel branches, which is lower for *Capia Amarillo,* there is no statistical difference between the white and the yellow endosperm *Capia.* Within the subraces there are some irregularities owing to phenotypic factors ("between plantings") and also to unimportant genetic factors (within subraces).

Fig. 37. Races from the High Valley in the Andes of northern Argentina, the "Quebrada de Humahuaca": Capia Variegata, a subrace with variegated pericarp over yellow endosperm. The infiltration from Amarillo de Ocho is less pronounced.

Plant: The yellow endosperm Capia plant differs quite considerably from the white endosperm type, being smaller, with fewer and smaller leaves. Plant height 176 cm.; ear height 60 cm.; relative position of the ear 0.40; number of leaves below the ear and above the ear, about 5. Length of leaf 76 cm.; width 8.3 cm.; number of veins 19; venation index 2.21.

Origin and relationships: As pointed out earlier, we have no doubt that the subraces of *Capia* with yellow endosperm are the result of an infiltration of genes, including those for the color in the endosperm, from *Amarillo de Ocho.* We may, however, doubt if this infiltration has already reached a stage resulting in a really new synthetic race, or if it ever will reach such a stage. Under present breeding tendencies by the local farmer, the yellow *Capias* will remain within the group of *Capia* subraces, while it is very likely that the *Amarillo de Ocho* may be replaced by a new synthetic race.

2. ACHILLI

Ear photograph, Figure 38
Internode pattern, Figure 47.3
Tables 12 to 14

This race still belongs to the group of pointed dent corn, though the point is much less pronounced than in *Capia,* and may even be completely absent.

Ear: Rather long and slender; may be almost cylindrical or at the most only slightly conical. Ear length 15.5 cm.; number of rows on the average 10 (range from 8 to 14). Ear diagram: medulla 0.7; rachis 1.6; at kernel base 2.0; of cob 2.4; whole ear 4.5 cm.; cob/rachis index 1.50.

Kernel: The largest among the races of Humahuaca: length 1.4 cm.; width 1.0 and height 0.4 cm. Glume cover is very much reduced, only 13 per cent of the kernel covered. The kernels are generally colored, either by the presence of black pigment in the aleurone or red pigment in the pericarp, and the latter may also be variegated.

Tassel: As shown in Table 13, the tassel agrees completely with that of *Capia Blanco,* and no data need be given here.

Plant: Here again, no significant differences exist between *Achilli* and *Capia Blanco* (Table 14).

Internode pattern: Figure 47.3 shows the typical pattern of Capia, with two maxima, one immediately below the ear and the other immediately below the tassel.

Origin and relationships: Achilli has a rather restricted distribution. It seems not to be known outside the Valley of Humahuaca, and even there it is not widespread. As we have seen, it agrees almost completely in tassel and plant characters with *Capia Blanco,* and differs only in some ear and kernel characters. There is little doubt that we are dealing with a rather recent development, and probably with a new synthetic of *Capia* with some other race. There is possibly evident a certain amount of gene infiltration from *Amarillo de Ocho,* as shown for example in the reduction of row number and the fact that rows may be quite salient, as in the eight-rowed ear of *Achilli* (the second ear from the right in Fig. 38). There must have been in addition some other gene infiltration which would explain the increase in the size of the ear.

3. CHULPI FROM HUMAHUACA (SWEET CORN)

Ear photograph, Figure 39
Internode pattern, Figure 46.3
Tables 12 to 14

Ear: Slightly conical, broad at the base and rather short, with a mean length of 10 cm. Row number tends to be relatively high, with a mean of nearly 16 and a range from 12 to 18. Ear diagram: 11 measurements are slightly smaller than in *Capia,* though this reduction is approximately the same for all measurements and thus does not alter the shape of the ear; diameter of medulla 0.7 cm.; of rachis 1.6 cm.; at kernel base 2.2 cm.; of cob 2.7 cm.; of whole ear 4.5 cm.; cob/rachis index 1.65; rachilla length about 3 mm.

Kernel: Slightly smaller than those of *Capia Blanco:* mean length 1.24 cm.; width 0.74 cm.; and thickness 0.39 cm. Kernel coverage quite low: 16 per cent. As can be seen in Figure 39, the form of the kernels, in the absence of the sugary gene, is that of *Capia, i.e.,* of a pointed dent corn.

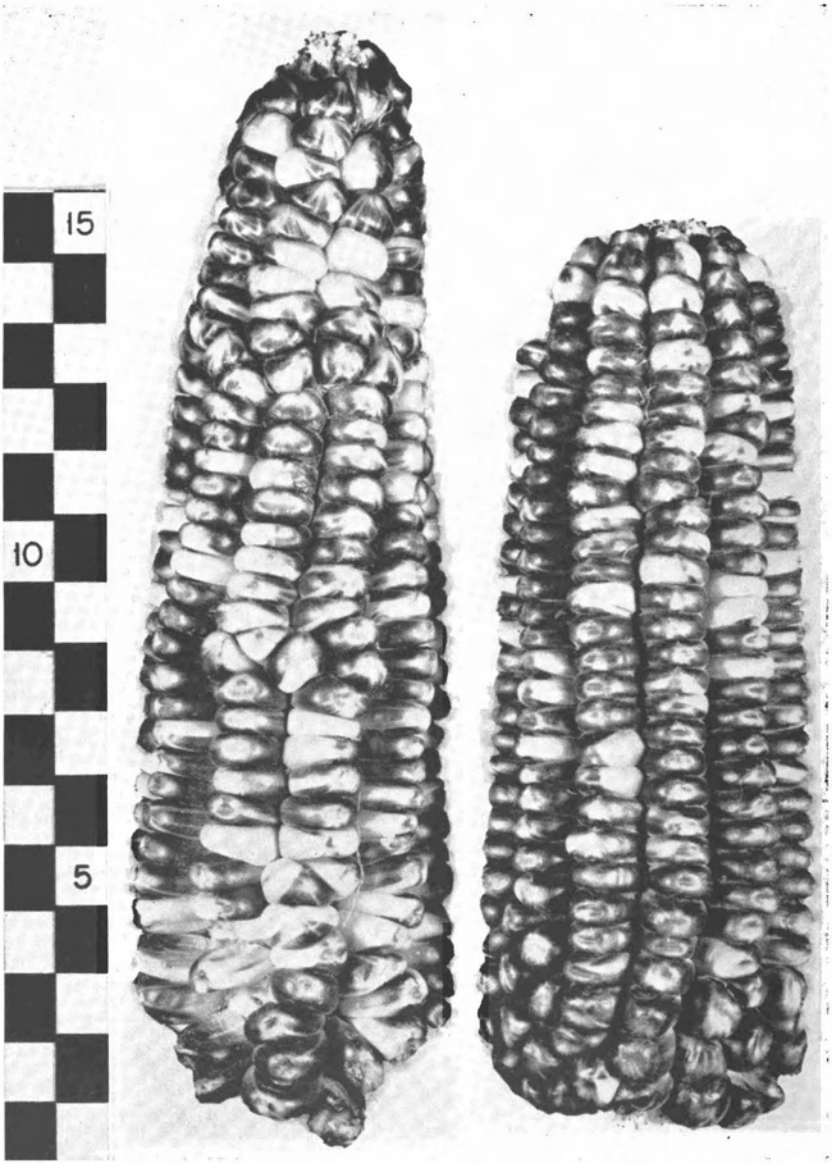

FIG. 38. Races from the High Valley in the Andes of northern Argentina, the "Quebrada de Humahuaca": Achilli, a rather large race, found near Tilcara in the same Valley, possibly a derivative from Capia.

Tassel: As the data in the first and second line of Table 13 show, there is no difference in any tassel character between *Chulpi* and *Capia.*

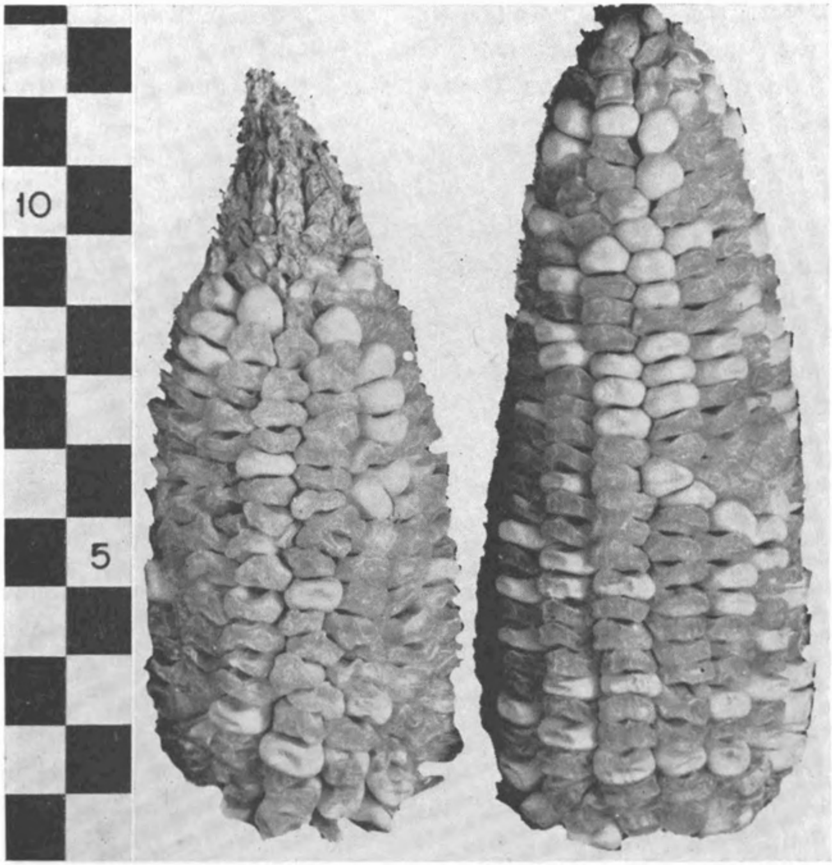

FIG. 39. Races from the High Valley in the Andes of northern Argentina, the "Quebrada de Humahuaca": Chulpi, the Andean sweet corn. In this area it represents a case of introduction of the recessive sugary factor of the 4th chromosome into Capia Blanco.

Plant: Plant height and ear height, and also the position of the ear in the middle of the plant, do not distinguish *Capia* and *Chulpi.* The latter tends to have slightly fewer leaves below the ear, the leaves are shorter (81 cm.) and narrower (8 cm.) and the veins fewer (19) than in Capia.

The most important character of this race, however, is the texture of the seeds. As in all Andean sweet corn, the expression of the *su* factor is in general not so strong as in modern sweet corn, and pseudo-starchy kernels are frequent. We did not test Humahuaca sweet corn genetically, but in crosses between Bolivian sweet corn and ordinary sweet corn, we found:

(a) that both contain the same allele of the *su* locus in the fourth chromosome,

(b) that the Bolivian sweet corn contains a large number of modifiers which change the endosperm from "sweet" to "pseudo-starchy" or opaque or even to a stage where the kernels are no different from ordinary "starchy."

In the F_2 of such a cross, families appeared with all kernels typically "sweet" corn but, except for these rather few cases, the majority of the F_2 families gave varying percentages of "sweet," "pseudo-starchy" or "starchy" kernels, up to families which gave almost exclusively starchy kernels. Evidently the different use made by the Andean Indians, who use ripe kernels toasted over the fire and not ears still in the milky stage, caused a different trend in selection—not directed against the modifier factors responsible for the "pseudo-starchy" effect. It is highly probable that special tests would show that the same is true for Humahuaca sweet corn.

Origin and relationships: There is little doubt that Bolivian Sweet Corn, known under the names of *Chulpi* or *Chuspillo,* forms a typical race as shown by the fairly large cylindrical ears in Figure 40. The kernels of *Bolivian Chulpi* are sometimes very long and almost like a nail, with sugary endosperm only near the tip, while all the rest of the kernel contains opaque or starchy endosperm. The *Humahuaca Sweet Corn* differs in all these respects from the Bolivian types, and in ear shape and most other characters studied it is identical with *Capia Blanco.* Thus we suppose that Chulpi from Humahuaca should be considered as a form of *Capia,* into which the *su* allele has been introduced. Though apparently no other characters are changed by infiltration of more genes, the constant kernel differences justify considering it as a race.

4. AMARILLO DE OCHO

Ear photograph, Figure 41
Ear diagram, Figure 45.3
Internode pattern, Figure 49.2
Tables 15 and 17

Ear: The general aspect of the ear is characteristic, with its 8 rows, salient in pairs and giving in cross section the figure of a cross. The ears are not very short, with a mean length of 14 cm. There are always 8 regular rows. The mean diameters of the ear diagram are given in Table 15: diameter of medulla 0.5 cm.; of rachis 1.3 cm.; at kernel base 1.6 cm.; of cob 2.0 cm.; of whole ear 3.6 cm.; cob/rachis index 1.64.

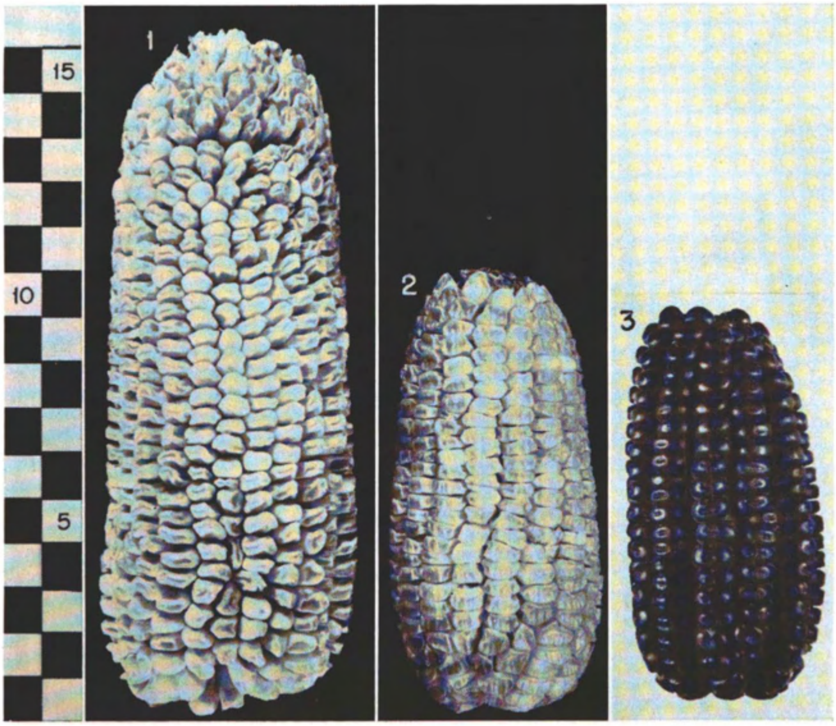

FIG. 40. The Bolivian forms of the sweet corn Chulpi (1 and 2) and of the black Culli (3).

Kernel: Fairly large, flinty, and containing yellow endosperm. Many ears contain slightly dented kernels, a sign of an infiltration

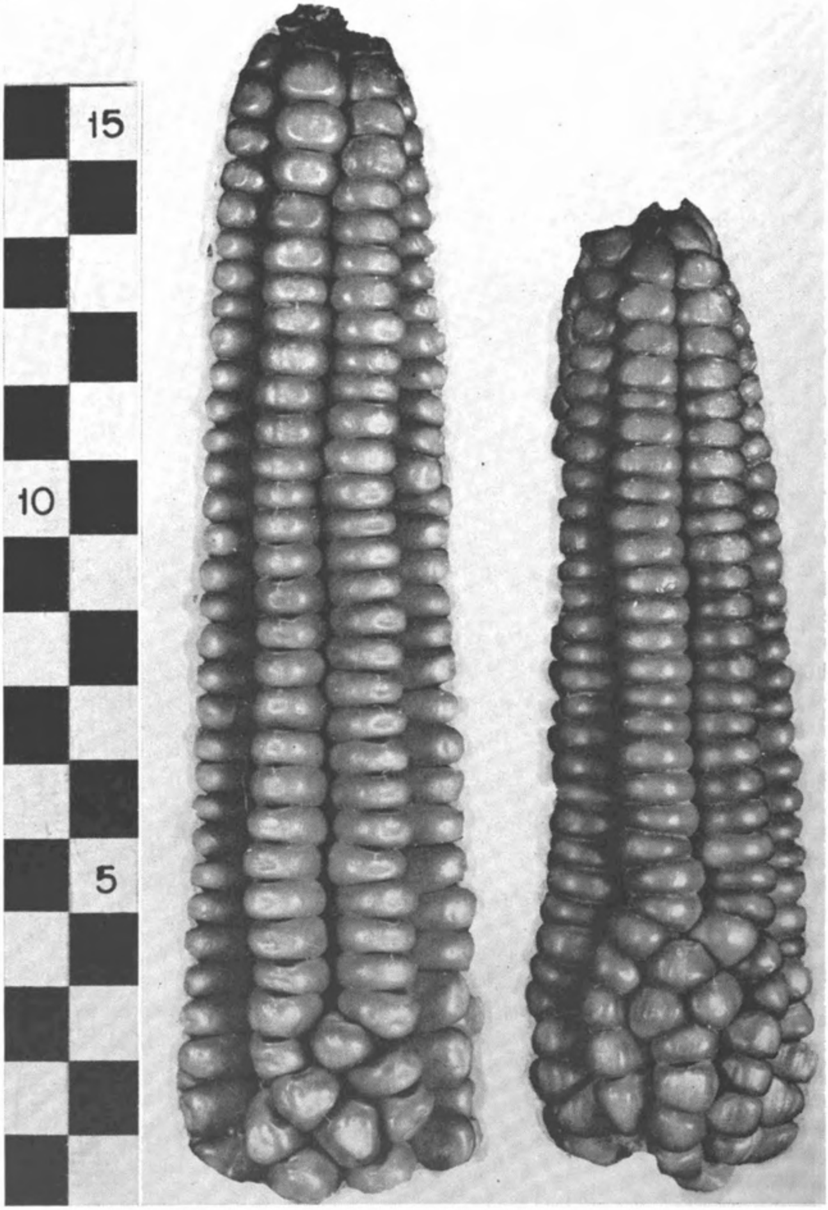

FIG. 41. Races from the High Valley in the Andes of northern Argentina, the "Quebrada de Humahuaca": Amarillo de Ocho, an 8-rowed yellow flint with straight salient rows, the second important field corn of the region, very often infiltrated by Capia. The ears shown are typical for the race, without any infiltration.

from *Capia* as a result of natural crossing to which reference has been made repeatedly. Kernel length 1.2 cm.; width 1.0 cm. and thickness 0.4 cm.; kernel covering only 17 per cent. Thus we have a very different diagram from that of *Capia,* as can be easily seen by comparing Figures 45.2 and 45.3.

Tassel: As shown in Table 13, there is hardly any difference in tassel characters between *Capia* and *Amarillo de Ocho.* The length of the sheath and the last internode and thus the internode covering are about the same: sheath 14 cm.; internode 23 cm.; internode covering 1.64. There are no statistically significant differences in the length of the branched part of the tassel with 15 cm., and the terminal spike, with 28 cm., the former being somewhat shorter than in *Capia.* There are significantly fewer primary tassel branches (mean 12.4).

Plant: The *Amarillo de Ocho* plant differs again profoundly from the *Capia,* being considerably smaller: mean plant height 132 cm., ear height 52 cm., relative position of the ear at 0.4 of the whole plant. The number of leaves above and below the ear is about the same, *i.e.,* in both cases slightly more than four.

Internode pattern: As shown in Figure 49.2, the pattern does not follow exactly the norm found so far for *Capia* and its derivatives. There is an increase in internode length from the base of the plant to the last internode below the ear, where internode length remains approximately constant except for the last internode below the tassel, which is about twice as long as the preceding internodes.

Origin and relationships: We have mentioned above that *Amarillo de Ocho* gives the impression of being a disappearing race of Andean field corn. It seems hardly to occur to any extent in Bolivia, where its place as a flint corn has been taken over by two other races: the yellow 8-rowed flint *Aizuma* (Fig. 55.1) and the white 10-rowed flint *Uchuquilla* (Fig. 55.2). Both these Bolivian races have smaller kernels than does *Amarillo* and the rows are not salient, a fact which greatly alters the appearance of an ear, but there is no doubt that *Aizuma* is closely related to *Amarillo de Ocho,* and that *Uchuquilla* is probably also derived from it, after an outcrossing to some white flint or popcorn.

We have not seen any good representatives of *Amarillo de Ocho* in the collections of Peruvian maize of Dr. Grobman, though some of the popcorn types, which now go under the Spanish name of "Confite," seem indistinguishable from poorly developed ears of *Amarillo de Ocho,* with the kernel size reduced to that of a popcorn. Furthermore, there can be little doubt about relationships between those of *Cuzco Large Grain,* which is a predominantly 8-rowed race also, and *Amarillo de Ocho.* If indications could be found in Peru of a large distribution, in the past, of *Amarillo de Ocho,* one might feel justified in supposing that it was one of the parents of the relatively new, though of course still pre-Columbian, *Cuzco Large Grain* or, as it is sometimes called, *Palta Hualtaca* (Fig. 54.3 and 54.4). However, the most important point about the race under discussion is that we feel convinced that it is quite old and belongs to the first level of cultivation of flint corn, which was introduced and became adapted in the extreme environment of the Andean High Valleys.

We shall discuss later the relationship between *Amarillo de Ocho* and other 8-rowed races of maize, especially of the lowland areas to the east.

5. CULLI FROM HUMAHUACA

Photograph of ear, Figure 42
Internode pattern, Figure 48.1
Tables 13, 15, and 17

Ear: Differs only slightly from *Amarillo de Ocho,* mainly in three measuremnts: length of ear (12 cm.) which is less than in *Amarillo de Ocho,* row number (10.5) which is higher, and whole ear diameter, which is thicker. The photographs in Figure 42 show two very different ears of *Culli,* one with 8 rows which closely resembles *Amarillo de Ocho,* and a larger ear with 12 rows.

Kernel: Dimensions about the same as those of *Amarillo de Ocho,* with the differences not statistically significant (length 1.2 cm., width 1.0 cm., thickness 0.4 cm.). Kernel covering is only 12 per cent. However, the kernels have quite a different structure, being indented and having generally a small beak. Endosperm is relatively hard. *Culli* has no aleurone or endosperm color, but the kernels have a deeply black stained pericarp.

Tassel: As shown in Table 13, the tassel characters are prac-

FIG. 42. Races from the High Valley in the Andes of northern Argentina, the "Quebrada de Humahuaca": Culli, a rather variable race, used exclusively for making a highly valued alcoholic drink, red Chicha. Contains always a black pericarp over white endosperm on purple plants with the constitution A B Pl.

tically identical in the present race and in *Amarillo de Ocho* or *Capia,* except for the number of primary branches, which are somewhat intermediary in *Culli* (14.9 as against 12.4 or 18.9 in the other two races).

Plant: As shown by the data in Table 17, the *Culli* plant does not differ statistically from that of *Amarillo de Ocho.* However, *Culli* has deep purple plants, while *Amarillo de Ocho* is dilute purple, like most other races from Humahuaca.

Internode pattern: Almost normal, with the longest internodes just below the ear and again below the tassel. The decrease in length of the internodes above the ear is not so strong as in *Capia* (Fig. 46.1) nor so slight as in *Amarillo de Ocho* (Figs. 49, 49.2).

Origin and relationships: Like the sweet corn *Chulpi, Culli* must be considered as a special-purpose type, where a special genetic constitution is all that is required. In the case of *Chulpi* this constitution requires the presence of the *su* factor. *Culli* must have the caseocyanin factors ABPI P r^{ch}, which guarantee deep plant color and also deep black pericarp color. *Culli* is the race from which a red alcoholic drink, red "chicha," is made, and a higher value is attributed to this red beverage than to ordinary white "chicha." Thus one cannot be surprised that the name *Culli* is used for somewhat different types of maize, as long as they have the deep red soluble pigments. *Culli* from Humahuaca is somewhat more variable than other races from this region, and we have some doubt as to the extent to which it may differ from what is grown under the same name in Bolivia. The ear shown in Figure 40.3 would still fall within the range of variation of the *Culli* from Humahuaca, though the ears are smaller, but kernel form and size, and of course its color, are the same.

6. MARRON FROM HUMAHUACA

Ear photograph, Figure 43
Internode pattern, Figure 49.1
Tables 12, 13 and 17

Marron is a rather peculiar form with brown kernel color (pericarp) which is only sporadically found in Humahuaca and equally rarely in Bolivia. It somewhat resembles *Culli* in kernel size and structure and may be related to it. In its ear characters it is clearly

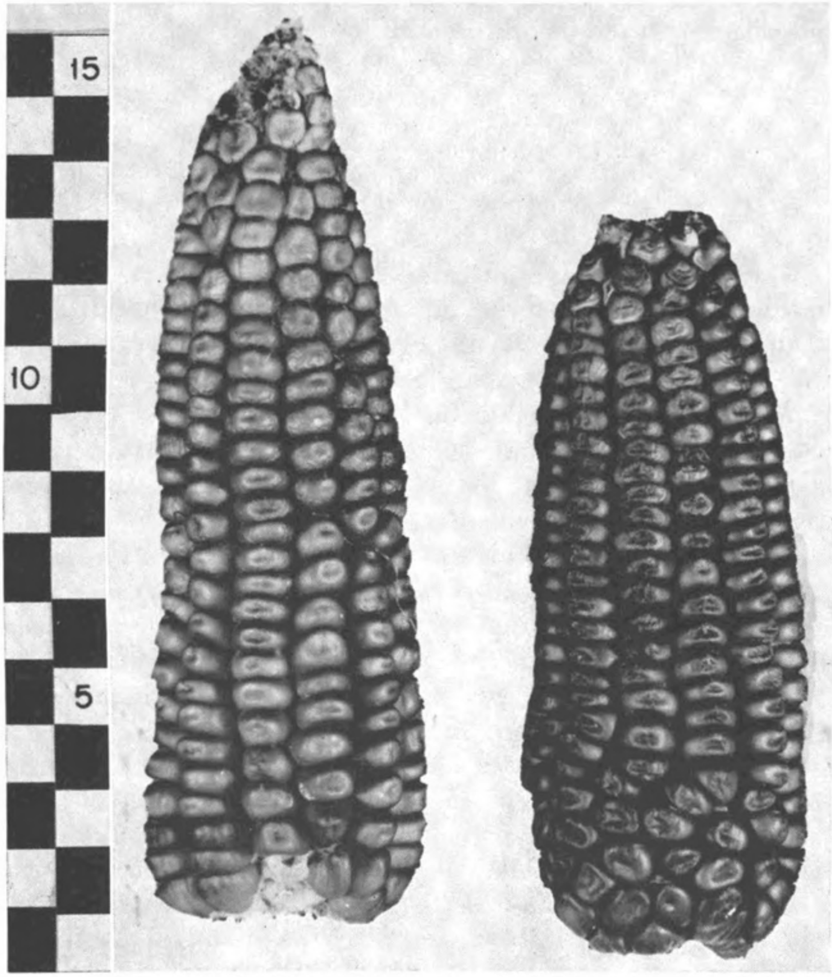

FIG. 43. Races from the High Valley in the Andes of northern Argentina, the "Quebrada de Humahuaca": Marron, a not very frequent race with brown pericarp.

very near to *Capia Blanco,* while in plant characters it resembles more *Amarillo de Ocho.* In tassel characters it is not distinguishable from either one, since they are similar.

Since *Marron* seems to be a race of very little importance, nothing more need be said about it.

7. MOROCHO

Ear photograph, Figure 50
Ear diagram, Figure 45.1
Internode pattern, Figure 47.1
Tables 12 to 14

Ear: Cylindrical or sometimes slightly conical; length 13.4 cm.; mean row number 14.5, with a range from 10 to 18. Ear diagram: diameter of medulla 0.9 cm.; of rachis 2.0; at kernel base 2.4; of cob 2.7; of whole ear 4.4 cm.; cob/rachis index rather low, 1.34.

Kernel: Nearly rounded tip like most flint types; very hard endosperm. Bluish white color, with no pigment in pericarp, aleurone, or endosperm. Kernel length 1 cm., width 0.8 cm., and thickness 0.4 cm. Kernel coverage 16 per cent.

Tassel: As shown in Table 13, the tassel of Morocho agrees very largely with that of *Capia Blanco.*

Plant: There are hardly any statistically significant differences between plant characters of *Morocho* and those of *Capia.*

Origin and relationships: As mentioned in the discussion of the formation of synthetic races, there can be little doubt that Morocho is a synthetic race which originated most probably after introduction of the *Calchaqui Flint* from farther south and from lower altitudes. This hypothetical origin is illustrated in the ear photographs of Figure 14, where the two putative parents, *Calchaqui White Flint* and *Capia Blanco,* are also shown. The time of this origin may be rather recent, since the Indians in the Andean regions evidently did not favor too much the hard flint types. We may suppose that the introduction of the Calchaqui race occurred after the Conquest. We have mentioned that Calchaqui infiltration was also observed in the lowland areas, both into the *Guaraní Soft Yellow Corn* and the *Interlocked Soft Yellow Corn,* resulting in the synthetic races now known in the respective areas as *Cristal* or as *Pérola.* It should be remembered that there has been a general attempt to convert and colonize the Indians in the lowland areas of Paraguay and neighboring regions, *i.e.*, in an area which still shows this today in use of the name "Misiones" for large regions. It thus seems probable that the Jesuit Missionaries may have been responsible for the formation of these different synthetics, not by directly and conscientiously producing them, but only by giving a rather high value to *Calchaqui White Flint* and by stimulating its expansion and cultivation. The rest can easily have been brought about by artificial selection, after natural hybridization between the old established field races and the newly introduced race.

Since the value of the hard flint types is today rather reduced and the tendency is mostly in favor of semi-hard or even soft dent types, it seems doubtful whether *Morocho* has any value for modern breeding programs, where certainly *Capia* would have preference.

8. ALTIPLANO TYPE FROM HUMAHUACA

Ear photographs, Figure 44
Ear diagram, Figure 45.5
Internode pattern, Figure 48.2
Tables 15 to 17

Ear: Always very short, and spherical or slightly egg-shaped, with a mean length of only 6 cm. On the average, the ears are about twice as long as they are thick (6.1 cm. by 3.6 cm.), but nearly isodiametric ears are not too rare. Row number generally rather low, with a mean of 12 and a range from 8 to 16. These rows may be quite regular, as shown in the first two ears on the left in the upper row of Figure 44. But it is more common for the row arrangement to become irregular following the discontinuation of several rows both towards the tip and towards the base of the ear. This has been shown in detail in the growing point in Figure 8, which we discussed earlier. In the ear on the upper right corner of Figure 44 we can count 7 to 8 rows in the middle, corresponding to a total of 14 rows, half of which are on the other side of the ear. Near the tip we can count only 4 kernels or rows, of a total of 8 rows from the whole ear. Thus from the middle to the tip, over a distance formed by only 5 alveoli, we have a dropping out of some 6 rows (3 ranks) of a total of 14 rows or 7 ranks. Toward the base of the ear also, some rows fall out, but we may still count 12 rows. The same situation can be seen in the two ears on the left in the lower row of the same Figure 44. As explained above, the same two phenomena which one finds frequently near the butt of an ear, *i.e.*, splitting of ranks and twisting of rows, or near the tip of an ear, *i.e.*, dropping out of ranks, can be observed on these very short ears almost simultaneously and without the possibility of a middle portion of the ear, between butt and tip, showing a more regular situation where row formation may remain stabilized.

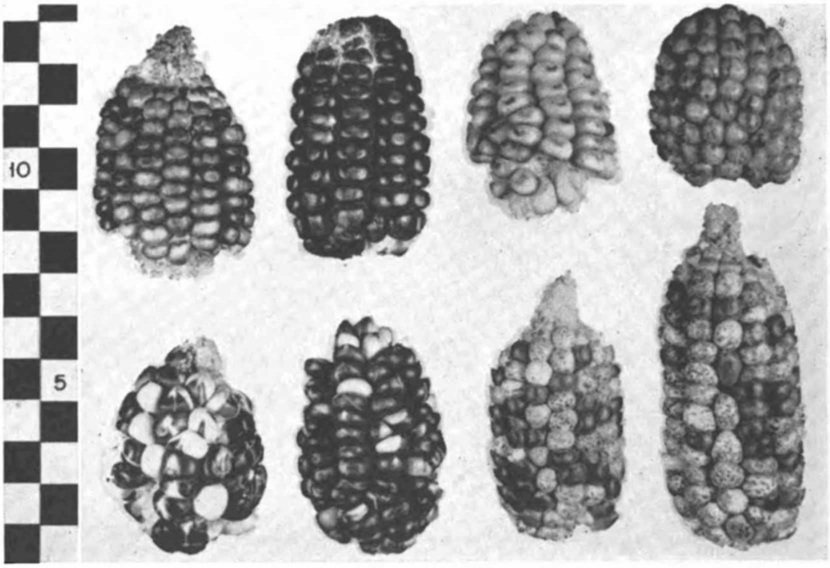

FIG. 44. Races from the High Plateau beyond 3,500 meters on the Cordilleras on both sides of the "Quebrada de Humahuáca": Altiplano represents really a mixture of many races, which have more or less the same type of plant and tassel and adaptation to the high altitude of around 3,500 meters. The ears are always small and often egg-shaped with irregular rows as shown in the lower left corner. The kernels repeat in color and shape nearly all races from the High Valley.

It might not be too far fetched to say that these small ears correspond to "cylindrical" but stunted ears, when row arrangement remains regular, or to "conical" but stunted ears, when the rows show the irregularities just mentioned.

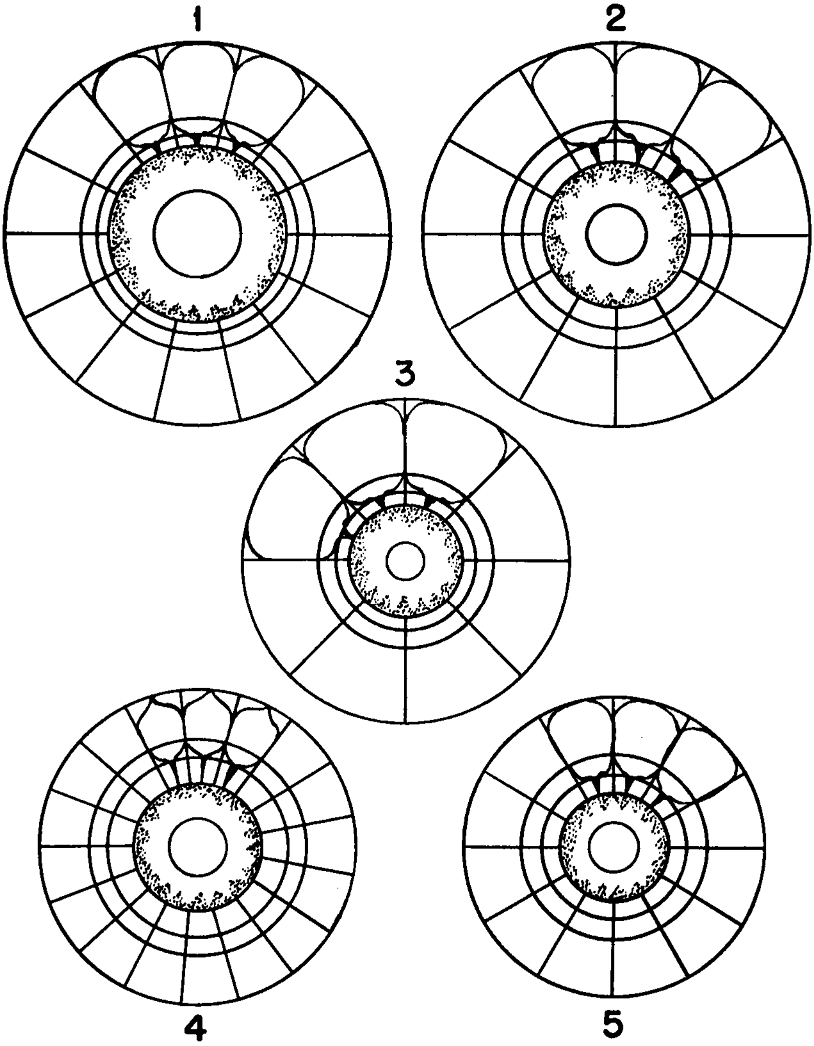

Fig. 45. Ear cross-section diagram of: 1) Morocho; 2) Capia; 3) Amarillo de Ocho; 4) Pisincho; 5) Altiplano.

Ear diagram: diameter of medulla 0.5 cm.; of cob 1.3 cm.; at kernel base 1.6 cm.; of cob 2.0 cm.; of whole ear 3.6 cm. (first row of Table 15); cob/rachis index 1.65. Thus, even with regard to the ear diameters, *Altiplano* maize is rather reduced in size.

Kernel: Normal, not reduced, size. Means: length 1 cm., width 0.8 cm., and thickness 0.5 cm. Glume coverage amounts to about 27 per cent, *i.e.*, slightly more than one quarter of the kernel is covered by the glumes. Kernel color and texture are extremely variable and as already pointed out, in this respect *Altiplano* maize can hardly be considered as *one* race. It seems rather that nearly all the races from the Valleys reappear in the Altiplano, but only as regards kernel structure, shape, and color.

Tassel: Differs little from that of *Capia, Amarillo de Ocho,* and several other races, which we may call the "Valley-type." The last leaf sheath is 13 cm. long and the internode 21 cm., and thus the internode covering amounts to 1.61. Using the reciprocal of this value, we may say that about two-thirds of the internode remain within the leaf sheath and that the tassel itself is completely free from the sheath. The branched part, with a length of 12 cm., represents 35 per cent of the total tassel length, and the terminal spike of 21 cm. corresponds to two-thirds. There are, on the average, about 15 primary and 9 secondary branches on the tassel.

Plant: Rather small, with a height of 141 cm. and an ear height of 55 cm. The ear stands about at the end of the first third of the plant. There are about 4 leaves below and 5 above the ear.

Internode pattern: There are two maxima, as in most races from Humahuaca, one immediately below the ear and the other below the tassel. Between these two there is first some reduction, with the internodes then remaining at about the same length.

Origin and relationships: As far as ear shape in general is concerned, there seems to exist no difference between the *Altiplano* ears collected at Humahuaca or anywhere in Bolivia and Peru. Since the region around Lake Titicaca belongs climatically to the Altiplano, it is not surprising that the archaeological remains, or rather clay imitations, of ears there found (Mangelsdorf and Reeves 1939) represent *Altiplano* type ears. This in itself cannot yet be taken as an indication that the Altiplano type must be especially ancient or primitive. It is in fact nothing else but an

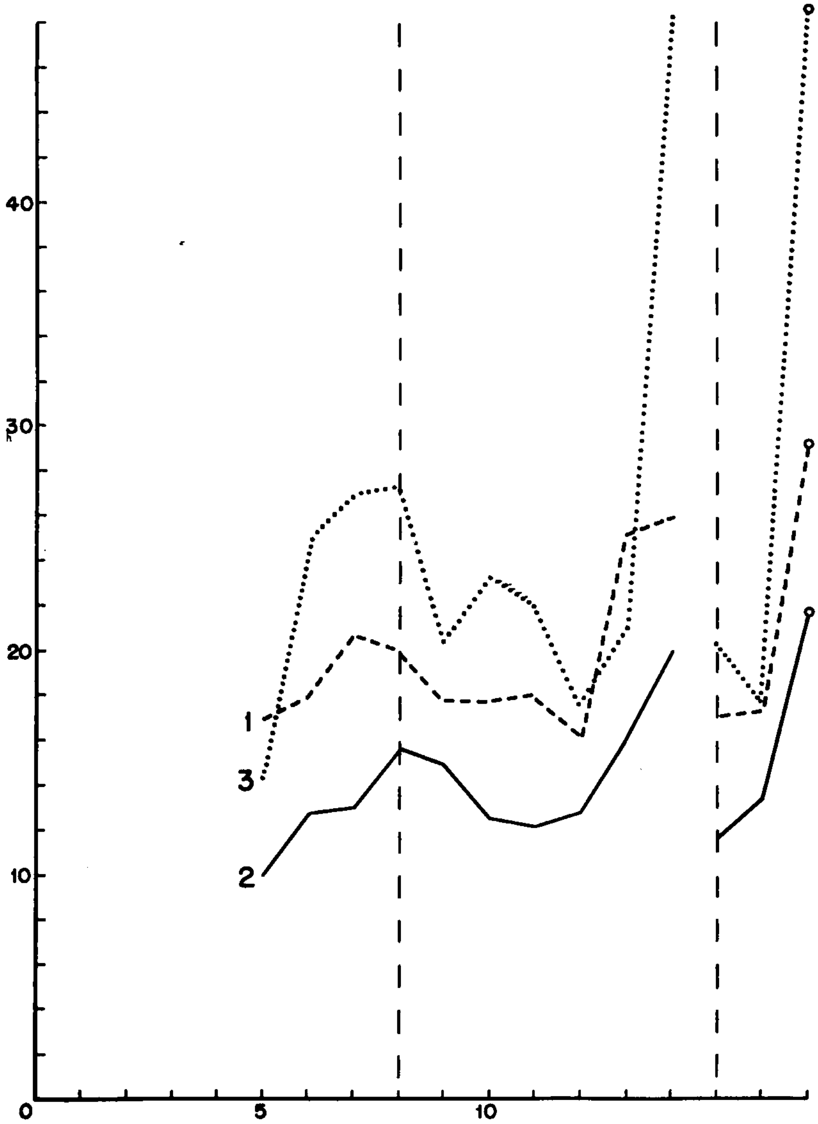

Fig. 46. Internode pattern of Valley Races of Humahuaca: 1) Capia Carrapata; 2) Capia Amarillo; 3) Chulpi.

adaptation to extreme climatic and edaphic conditions found on the high plateaus about 3,500 meters altitude, with their extreme temperature variations, low rainfall, great isolation, etc. Since on the one hand the civilization of Tihuanaco, in the Titicaca area, is rather old, and on the other hand large and well developed civilizations require initially a sound and productive agriculture, the *Altiplano* type of corn must be very old. But this in turn need not signify that it also must be primitive, and we must remember

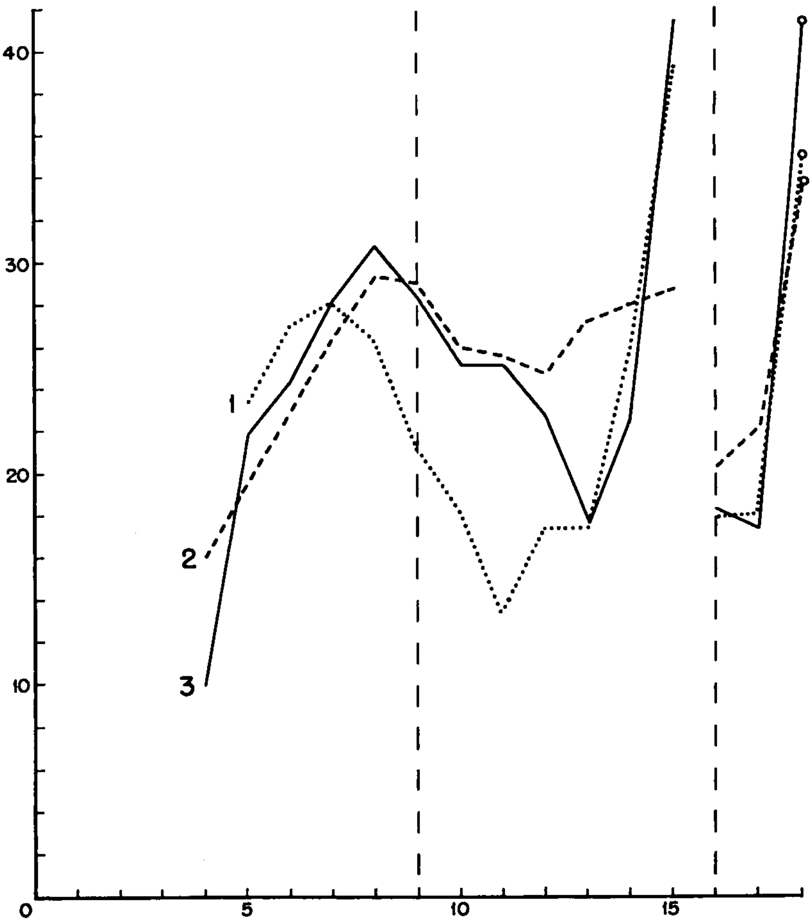

FIG. 47. Internode pattern of Valley Races of Humahuaca: 1) Morocho; 2) Oke; 3) Achilli.

that we consider its stunted form and the reduction in size of the ears as an adaptation and not as a primitive character. This adaptation process, which always represents a very slow procedure,

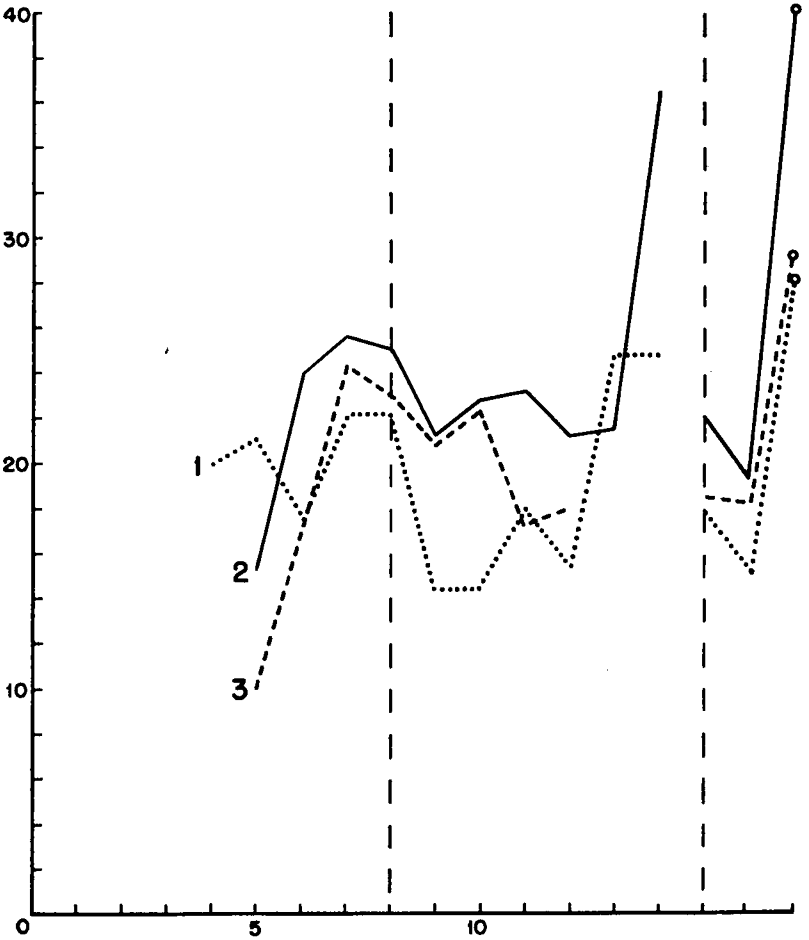

FIG. 48. Internode pattern of Altiplano Races of Humahuaca: 1) Culli; 2) Altiplano; 3) Pisincho.

must have been carried out successfully some time previous to the higher civilization for which the Altiplano maize served as the basic means of subsistence. Once the adaptation to the extreme conditions was successfully achieved, further improvement continued and was always possible by the new introduction of races from lower altitudes. In the subsequent formation of new synthetics, one can be certain that natural selection will have played a very strong part, considering the extreme conditions of the region, and must have favored very strongly all characters of adaptation and all genes responsible for this adaptation. Artificial selection should have only a slight effect, under such extreme conditions.

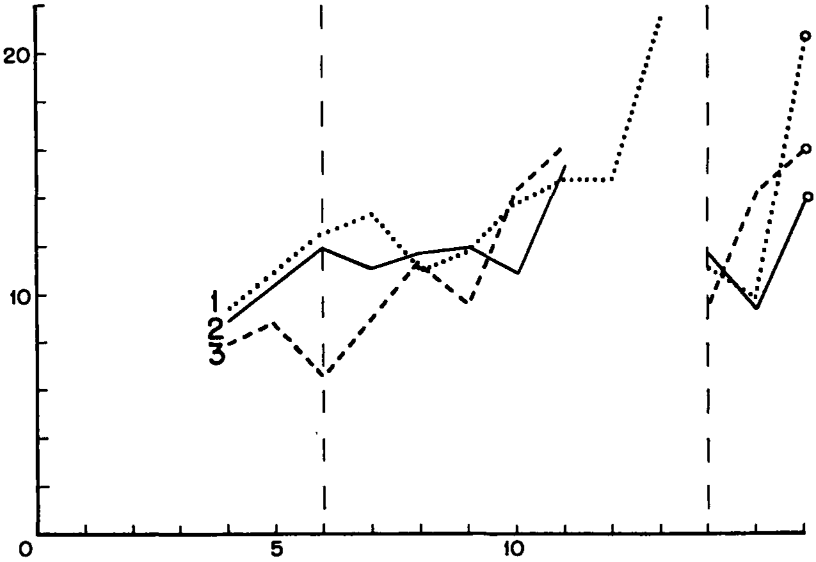

Fig. 49. Internode pattern of Races from Humahuaca: 1) Marron; 2) Amarillo de Ocho; 3) Bola Blanca

This may have consisted mainly in maintaining the kernel characters of the introduced races. The maintenance of these small ears over the whole Altiplano region proves that they represent adaptive and not simply primitive characters since if they were only primitive they would have been replaced in time by more productive forms.

There can be no doubt about the uniformity of ear size and shape of all the Altiplano maize. It must, however, be admitted that no such uniformity exists regarding plant characters. The description given above refers to the material collected on the Altiplano around the Valley of Humahuaca and then grown at the low altitudes of Piracicaba. Other material, received several years ago from Dr. Cardenas in Cochabama, when grown at Piracicaba gave quite different plants. They were still smaller than the ones described in this paper and matured very early. But they showed a pronounced tendency to tillering, which is absent in the material from Humahuaca. These tillers showed a slow transition until the earshoot was reached, which still had a very long shank and carried husks ending in flag-leaves. The aspect of these plants resembled somewhat that of some *Northeastern Little Flints* from Canada, which are also rather early maize, with small plants, high number of tillers, and flag-leaves on the husks.

The Altiplano maize is not a race but represents a large group of races with a common special adaptation to the climatic conditions of the extreme High Plateau. Regarding non-adaptive characters, as much differentiation into races exists as in the Valley or in lowland maize.

The origin of the adaptative characters, which in a large measure are probably physiological, cannot be attributed to the simple formation of synthetics, and we must refer now to the rather remote time when no maize at all existed at these high elevations. At some very remote time, then, the Indians of the High Plateau must have started to try to grow maize, but since we consider maize as a lowland plant, this was definitely a secondary step in breeding, which must have been preceded by the breeding of Valley races with their special adaptation. In both cases, in the High Valleys and in the Altiplano, initially the Indian breeder must have relied on the slow appearance of adaptative characters by mutation. The frequency of the mutated allele probably increased very rapidly, in consequence of the equally rapid elimination of the genes which lacked the necessary adaptation. As soon as one good Valley race or one good Altiplano race was obtained, everything became easier, since, after the introduction from the lowlands of any new race with new desirable characteristics, synthetics could immediately begin to appear as a result of accidental hybridization. These would, however, remain under the antagonistic action of natural selection in favor of the adaptative characters of the old race and artificial selection in favor of the desirable characters from the newly introduced race. The more

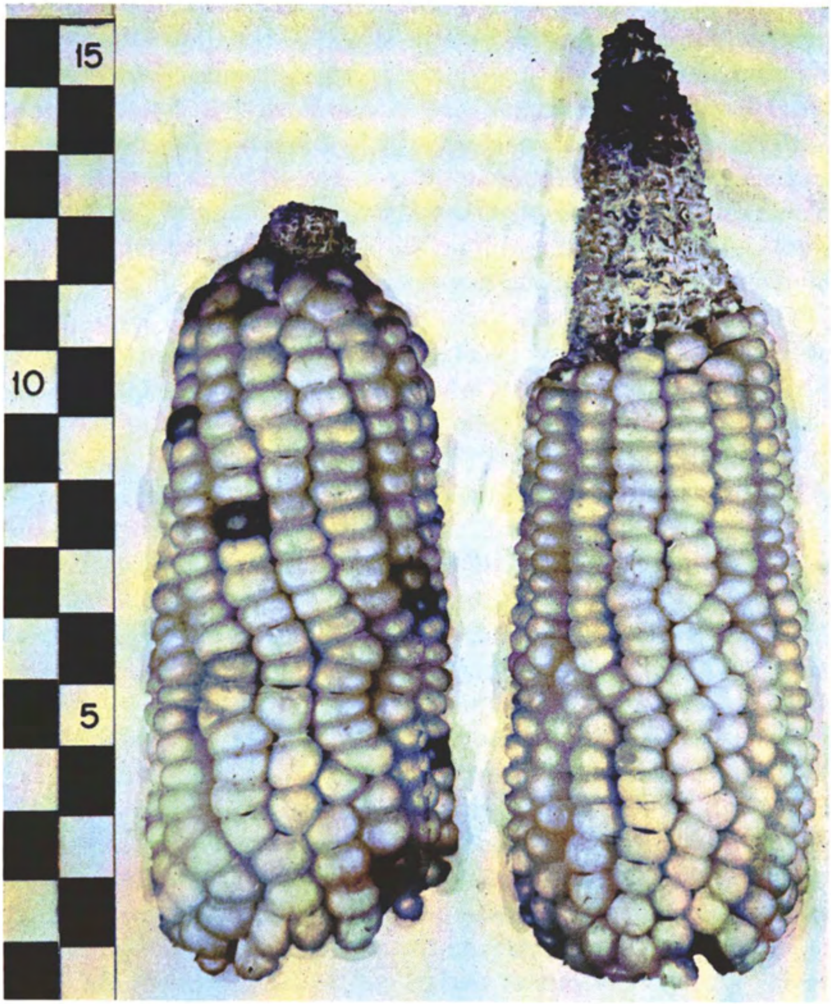

FIG. 50. Races from the High Valley in the Andes of northern Argentina, the "Quebrada de Humahuaca": Morocho, a hard white flint, considered a synthetic between Capia Blanco and Calchaqui White Flint, a characteristic race of northwestern Argentina and northern Chile, in the lower Andean regions and the neighboring lowlands, just south of the Humahuaca area. Morocho seems to be restricted to the Humahuaca area, and does not penetrate north into Bolivia.

extreme the ecological conditions, the stronger will be the action of natural selection, and consequently fewer genes from the newly introduced variety have a chance to be maintained in the new synthetic. This may explain the uniformity in ear, tassel, and plant characters in Altiplano races, with racial differences maintained only in kernel type, shape, and texture, because natural selection will be at a maximum in the Altiplano, leaving but little room for artificially directed selection.

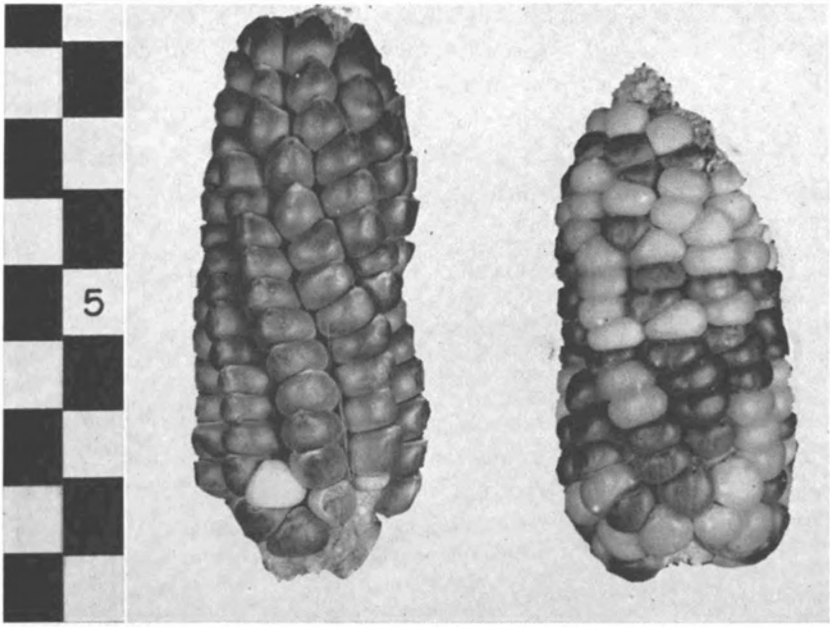

FIG. 51. Races from the High Valley in the Andes of northern Argentina, the "Quebrada de Humahuaca": Oke, a not too common race, segregating generally for black aleurone color over white endosperm.

9. OKE FROM HUMAHUACA

Oke is one of the races having ears which belong to the Altiplano group, while tassel and plant characters agree with those of races grown in the Valleys. We found only a few ears of this race and are not even sure whether it is grown in the Valleys or in the High Plateau.

Ear: Longer than those of the Altiplano type: 8 cm. on the average as against 6 cm. of the Altiplano type. Row number is smaller, with a mean of 10.7 rows as against 12.2.

Kernel: Round, not dented, sometimes with a somewhat pointed tip. Color mostly black (aleurone), though segregating ears appear. Pericarp and endosperm colorless.

Tassel: Table 13 shows that, for all measurements, no statistical differences exist between tassels from *Oke* and those of *Capia Blanco,* the main Valley race.

Plant: Some slight statistical differences exist between *Capia* and *Oke* plant characters, as shown in Table 14, *i.e.*, increase in the number of leaves below the ear and a decrease of those above the ear, and also a slight increase in leaf length.

Origin and relationships: The origin of *Oke* is rather obscure, and it must be remembered that it is the only type of maize at Humahuaca with predominantly black aleurone color.

10. BOLA BLANCA FROM HUMAHUACA

Ear photograph, Figure 52
Internode pattern, Figure 49.3
Tables 15 to 17

As explained above, when discussing the formation of synthetic races we consider *Bola Blanca* as a secondary synthetic: (*Calchaqui White Flint*×*Capia Blanco*=*Morocho*×*Altiplano*=*Bola Blanca*) (Fig. 14). But now in the general and comparative discussion, we can conclude that it agrees in most quantitative characters with the *Altiplano* type.

Ear: Small and nearly cylindrical, with regular rows. They are slightly longer than those of the common *Altiplano* type, with a higher number of rows (mean length 8 cm. and 15 rows). There are practically no differences in the diameters of the ear diagrams or in the cob/rachis index.

Kernel: Rather small: length 0.8 cm., width 0.6, thickness 0.5 cm., with a glume cover index of 27 per cent. In size and hardness, the kernels are of a nature which would be generally considered like those of a popcorn. However, it should again be emphasized that we cannot consider *Bola Blanca* as a primitive race of popcorn, but only as a recent synthetic which acquired the adaptive characters that make it appear primitive. Pericarp and endosperm are always colorless and aleurone only rarely colored.

Tassel: Practically identical with Altiplano maize, with no statistically significant difference, as shown by Table 16.

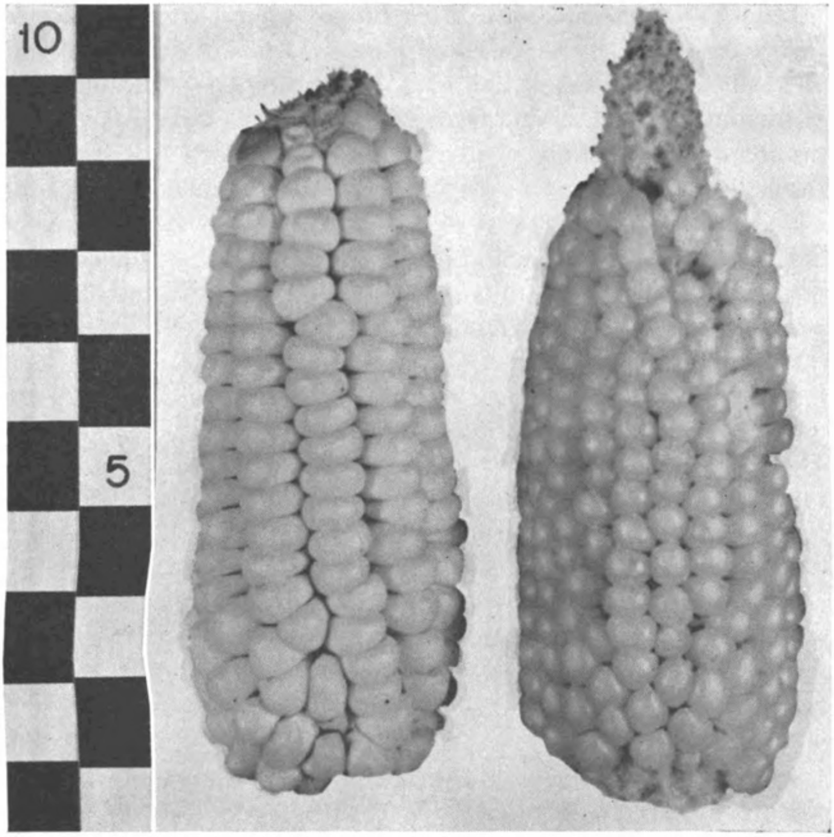

FIG. 52. Races from the High Valley in the Andes of northern Argentina, the "Quebrada de Humahuaca": Bola Blanca, a small-grained flint with white hard endosperm, sometimes slightly pointed. Interpreted to be a secondary synthetic between Altiplano and Morocho, which itself is considered as a synthetic between Capia Blanco and Calchaqui White Flint. As Morocho, Bola Blanca seems to be restricted to the Humahuaca area and does not penetrate into Bolivia.

Plant: The smallest among all the Altiplano races. The plants are only 132 cm. high, with the ear at 62 cm. There are about 4 leaves above and 4 below the ear.

Internode pattern: As shown by Figure 49.3, *Bola Blanca* is the most extreme example of a steady increase of internode length from base to the apex of the plant. There is one maximum of internode length between base and apex of the plant just below the tassel. There is no maximum of length at the internode just below the ear.

Origin and relationships: Bola Blanca seems to occur only in the general area of the Valley of Humahuaca just as was the case of *Morocho.* This restriction in distribution gives additional support to our hypothesis that we are dealing with a rather recent and progressive illustration. Morocho represents Valley type synthetic resulting from infiltration of *Calchaqui White Flint* into *Capia Blanco,* and the infiltration of *Morocho* into the *Altiplano* type (Fig. 14) is the second step. If this interpretation is correct, this would be the first case in which a race, very much resembling a popcorn, has originated rather recently as a synthetic from much more highly developed races. However, this certainly represents a rather isolated case, since the Indians tried quite generally to get away from the archaic popcorn type with its hard endosperm. They preferred mostly floury or dent corn. The white man after the Conquest, however, again gave preference to the hard flint maize, which was more easily stored and transported by sea without excessively deteriorating. Neither the hard work involved in milling nor the poor cooking qualities of flint bothered the white people, who did not use maize directly for food and had either slaves or a better developed milling industry to do the hard work of grinding.

11. PISINCHO OR ANDEAN POINTED POPCORN

Ear photograph, Figure 53
Ear diagram, Figure 45.4
Internode pattern, Figure 48.3
Tables 9 to 11

Ear: Slightly conical, with rows mostly regular, sometimes quite prominently paired. Irregularities in the row arrangement, either by the addition or discontinuation of some rows or by the formation of additional kernels from the normally sterile secondary flower of a spikelet, are not too rare. These additional kernels have of course an inverted position, as described in some detail by Cutler (1946) for Bolivian Pointed Popcorn of our collection. Average ear length 11 cm.; row number 18, with extremes from 12 to 22. Ear diagram: diameter of medulla 0.7 cm.; of rachis 1.5 cm.; at kernel base 2.0 cm.; of cob 2.5; of whole ear 3.6 cm.; cob/rachis index 1.69.

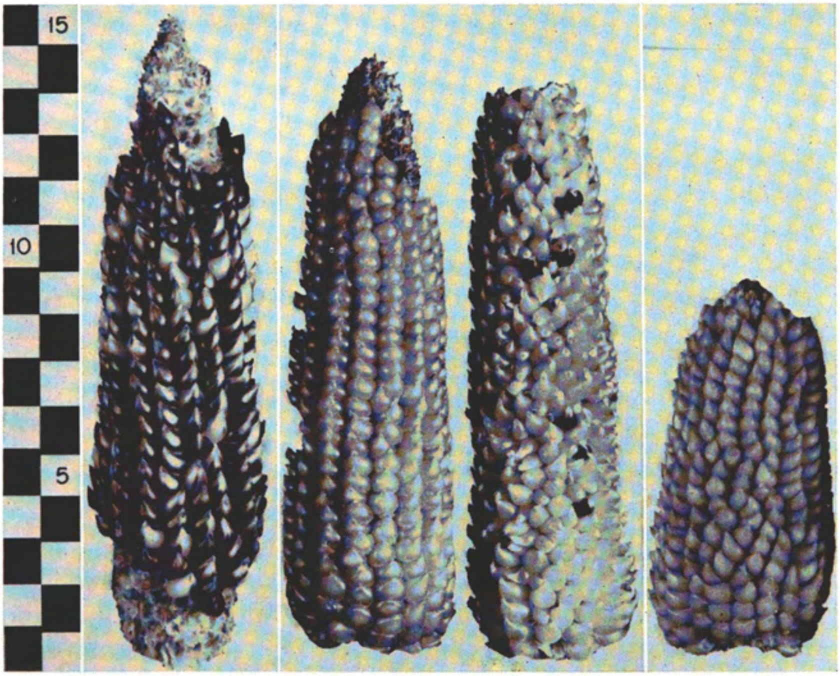

FIG. 53. Races from the High Valley in the Andes of northern Argentina, the "Quebrada de Humahuaca": Pisincho, the Andean pointed popcorn, sometimes with straight rows (ear on the left) and with strongly fasciated ear tips (ear on the right). The formation of double kernels, one pointing towards the tip of the ear and the other towards the base, is to be seen in the second ear from the right.

Kernel: Length 0.9 cm., width 0.5, and thickness 0.4 cm., width and thickness being nearly equal. The glumes cover about 27 per cent of the kernels.

Tassel: With respect to tassel and plant characters, it was necessary to divide the six samples studied into three groups, one of four samples and two of one sample each. Between these three groups of samples, statistically significant differences appeared only with regard to the tassel characters. For all others the samples were uniform: length of last leaf sheath with means of 18, 16, and 13 cm.; length of the last internode more or less the same for all samples, with a mean of 25 cm.; no significant differences for internode covering, the mean being 1.51. The length of the branched part of the tassel is more or less uniformly 8.6 cm. and that of the terminal spike 29 cm., with the branched part being 30 per cent of the total tassel length. Very significant variation was found in the number of tassel branches, with about 8.3 for 5 samples, while the last sample had about twice as many branches, with a mean of 15.6. There were practically no branches of second order.

Plant: Except for total plant height (mean 132 cm.) and for the number of leaves above the ear (mean 3.8), all variations are statistically significant. Ear height in one sample was 85 cm., while for the other five samples it was 55 cm. Consequently, in the first sample the ear was in the upper half of the plant, at a height of about 53 per cent of its total length, and below the middle, at about 41 per cent, for the other samples. There were 6.5, 5.2 or 4.1 leaves below the ear.

Internode pattern: This showed the ordinary behavior, with two maxima, one just below the ear and the other just below the tassel.

Origin and relationships: The *Pointed Popcorn* of Humahuaca is not completely identical with the main Andean popcorn type, from Bolivia for instance. The latter has generally not conical but slightly cylindrical ears, rounded both at the base and at the tip and quite frequently fasciated at the tip. Row arrangement is generally much more irregular than in the material from Humahuaca. Furthermore, the pointed kernels stand on the average at right angles to the cob surface, while in the Humahuaca material they point generally upward, towards the tip of the ear. All these differences, however, fall in one direction and seem to indicate some influence of the *Pointed Popcorn* from the Guaraní in the lowland, which will be described later (Fig. 69). Whether this probable infiltration of Guaraní Lowland Corn into the High Valley *Pointed Popcorn* of Humahuaca is pre- or post-Columbian is of course hard to say, but it seems rather more probable that it is of recent date.

RESUMÉ OF THE HUMAHUACA RACES

If we look over the tables which we discussed in detail and which contain the essential quantitative information, it becomes evident that there are really three main groups of races in this area:

(a) One which may be called the *Valley Group* and for which *Capia Blanco* is the typical representative,

(b) the type represented by *Pisincho,* and

(c) the *Altiplano group,* with the *Altiplano* type as the main representative.

To the *Valley group* belong without restrictions the races *Capia Blanco* and *Capia Amarillo* and their subraces, *Achilli* and *Chulpi.* To the *Altiplano group* belong *Altiplano* type and *Bola Blanca.*

Including all the remaining races outside of these two groups, we find the following situation:

Name of Race	*Valley Group*			*Altiplano Group*		
	Ear	*Tassel*	*Plant*	*Ear*	*Tassel*	*Plant*
Capia	+	+	+	—	—	—
Chulpi	+	+	+	—	—	—
Achilli	+	+	+	—	—	—
Morocho	(+)	+	+	—	—	—
Marron	+	+	—	—	—	+
Oke	—	+	+	+	—	—
Culli	—	+	—	+	—	+
Amarillo de Ocho	—	+	—	+	—	+
Bola Blanca	—	—	—	+	+	+
Altiplano	—	—	—	+	+	+

Thus we have a number of races which for some characters belong to the Valley type and for others to the Altiplano group. This term "belonging" is not completely correct from a statistical point of view, since within each group there are still some significant differences (Tables 9 to 11, and 12 to 14). But of a total of 54 error ratios "between races" tested we have the following distribution for the significance:

Levels:	*Valley Group*	*Altiplano Group*	*All*
Insignificant (> 5% limit)	19	15	34
Hardly significant (at the 5% limit)	—	3	3
Significant (at the 5% limit)	7	3	10
Significant (at the 1% limit)	3	4	7
Total of error ratios	29	25	54

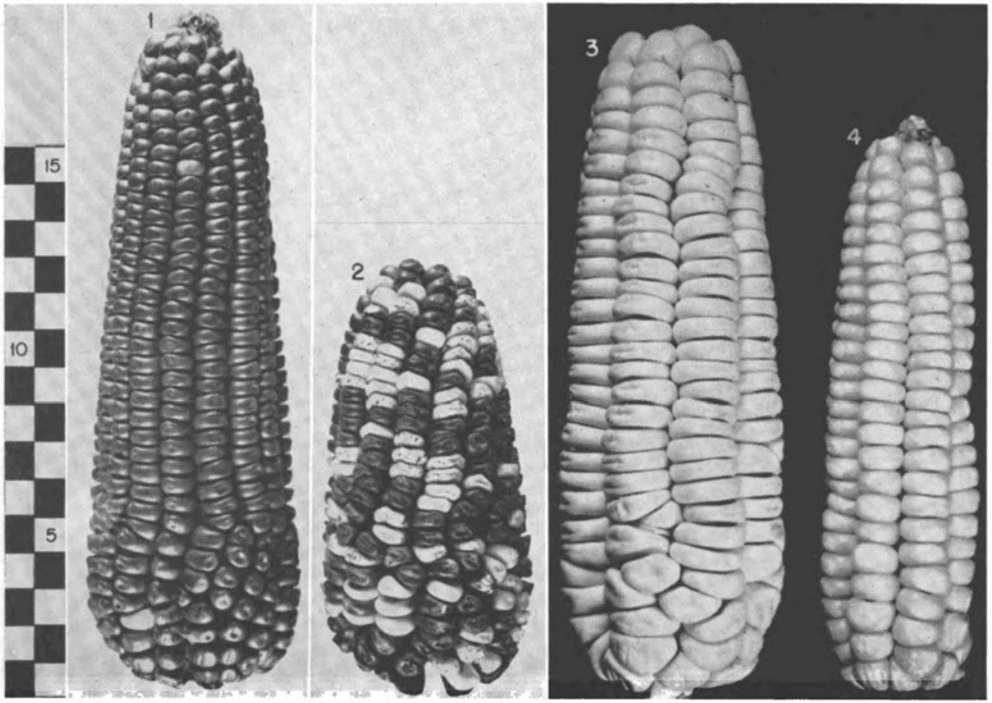

FIG. 54. The most important field corn races in the Andean High Valleys are Capia or Chechys (2) from the Yungas of La Paz to the "Quebrada de Humahuaca" and its many subraces—Huilcapara (1) is grown in the Valley of Cochabamba and the famous Large Grain Cuzco Corn, Palta Hulataca (3) is the main crop in the Urubamba Valley.

In 54 comparisons we may expect up to 3 error ratios which may go accidentally beyond the 5 per cent limit of significance, so the three values found may be attributed to chance and consequently can be considered as insignificant. We may have up to one error ratio (or more accurately 0.54 error ratio) which can go beyond the 1 per cent limit. Since there are in fact 10 error ratios of this size, almost all of them must be considered as significant and indicating the existence of some degree of heterogeneity within the groups. Finally, there should be no error ratios beyond the 1 per cent limit, but there were in fact 7. In all, there are about 17 error ratios out of the 54 tested which must be considered as statistically significant. This leaves the remaining 37 error ratios, which are quite insignificant statistically. Their high number is, however, rather astonishing. *A priori,* there really is no reason whatsoever why the races should fall into a few groups only if we leave *Pisincho* for the moment out of the discussion. The unexpected occurrence of so many insignificant error ratios proves, *a posteriori,* that there are factors limiting variation in such a way that two groups were formed. This in turn leads us to the conclusion that there are really two main ecological and agricultural habitats and that natural selection in the first place, and possibly some artificial selection as an additional element, tended to fix the races uniformly to one or the other of these two main habitats.

This "fitting into habitats" is, however, peculiar insofar as a number of races remain in a way intermediate, since they belong in some of their characters to one and in other characters to the other group. Thus, for instance, *Amarillo de Ocho* is a "Valley race" only in tassel characters, while both ear and plant characters agree more with the Atliplano group. Perhaps this may indicate that there are habitats or places of cultivation which are intermediate between the two extremes, High Valley and Altiplano.

Pisincho does not fit at all into these two groups, as far as ear characters are concerned and also to some extent regarding tassel characters. In plant characters, one of the subgroups of this race approaches the Altiplano group and another the Valley group.

The mean values for ear, tassel, and plant characters are summarized in Tables 18 to 20.

The following general discussion of some of the characters may have a bearing also on special problems.

We mentioned in the general section of this paper references in the literature relative to the existence of two basically different types of maize: the so-called "pure" maize and the Tripsacum-contaminated maize. We stated that, in spite of the importance of the problem, no author has yet published a clear list of characters which might be used to identify either one of these types. In fact, the Andean maize, sometimes considered as the prototype of the "pure maize," may have regular rows or irregular rows, it may have short or long ears, it may have any form or shape of the ear. Thus we must confirm the conclusion already drawn, that either this distinction does not exist or all Andean maize does not belong to one special or basic type of maize.

We mentioned also the importance that has been attributed recently to what we may call "tunicatoid" characters, and these are high values for the cob/rachis index, rachilla length, glume length, and glume coverage. In pod corn, the first is high, the second and third are long, and the third is again high, and for half-tunicate alleles these values may be smaller but still larger than for non-tunicate types. The respective values for these characters in the Humahuaca races may be summarized as follows:

Cob/rachis index quite low, from 1.54 to 1.65 on the average; *rachilla length* quite short, on the average from 2 to 3 mm.; *glume length* quite short, on the average from 3 to 4 mm.; glume coverage also low, on the average from 13 per cent to 27 per cent. Thus there is no indication of the presence of any "tunicatoid" characters in the Humahuaca races, not even in Pisincho, which always showed the relatively highest values.

The covering of the last internode and part of the tassel by the last leaf sheath is a character first described in Asiatic material, but it also occurs quite frequently in South American races. The Humahuaca races have a high index, over 1.50 on the average. This means that about one-third of the last internode is completely free from the sheath, and consequently in no case could any part of the tassel remain covered.

The relative position of the ear is also of general importance. In the *Valley group*, the ears are more or less in the middle of the plant (46 per cent to 50 per cent with mean 48 per cent of total plant height), while they are about at the end of the first third in the *Altiplano group* (31 per cent to 47 per cent of plant height, mean 39 per cent), and their position varies in the *Pisincho* (41 per cent, 43 per cent, and 53 per cent).

FIG. 55. The yellow flint Amarillo de Ocho (3) from Humahuaca is substituted in the High Valleys of Bolivia by two other flint races: the yellow flint Aizuma (1) and the white flint Uchuquilia (2).

We found the following two types of internode pattern: The majority of all races shows a bimodal pattern, with one maximum in the internode just below the ear and the other in the internode just below the tassel, with the second tending to be larger than the first. In three races (*Marron, Bola Blanca,* and *Amarillo de*

Ocho) there is a tendency toward another type, where the internode length increases more or less steadily from the base to the top of the plant, with the maximum at the last internode below the tassel.

The relationships between Humahuaca races and those of the neighboring areas are of interest.

There are practically no connections between the races of the lowland areas in the south (*Calchaqui*) and those in the east (*Guaraní Soft Corn* and *Interlocked Soft Corn*), with two or three exceptions: the infiltration of *Calchaqui White Flint*, which gave *Morocho* as primary and *Bola Blanca* as secondary synthetic, and some possible infiltration of *Guaraní Pointed Popcorn* into the Andean *Pisincho*. But with regard to these two, we came to the conclusion that they are the result of post-Columbian infiltration. Then there are the possible relations of *Amarillo de Ocho* to other 8-rowed races. On the other hand, we mentioned that the relation between races of the Humahuaca area and those of the Bolivian High Valleys and Altiplano is quite close, though there is no complete agreement in the racial composition. Some races such as *Capia* seem to extend over the whole area, while in other cases, such as *Pisincho*, the Humahuaca race and the Bolivian race are related but not identical. *Amarillo de Ocho* may represent a third case, since it appears to exist in its true form only in the Humahuaca area, and even there it seems nearing extinction. Thus we obtain the impression that the Humahuaca area is really the southern outpost of the Andean area of maize agriculture and breeding. If, furthermore, the migration of maize races into the highland territory as a whole really followed routes from north to south, as we believe, then Humahuaca may still contain the most original and the oldest complement of races. It seems even possible that, after a complete analysis of the races from Peru and Bolivia, it may be possible to establish a gradient, which in a way may permit drawing conclusions about the history of maize in the area, with the younger types not extending so much to the south because they have not yet gone that far, while the older types predominate there because they have not yet been replaced.

Finally, with regard to relations with the races in the low altitude areas on the Pacific coast, we came to the conclusion, after inspecting the material of the Peruvian collections of Drs. Grant and Grobman, that there is nearly always a fairly straight correlation between the races of the Andean Highland and the coastal lowlands of the same latitude. This correlation, if it really exists in Peru, certainly does not hold for Humahuaca, and most probably not for Bolivia. Here, the Andean races have no direct relation to the lowland races. Only the *Calchaqui* races entered the lowlands of northern Chile in pre-Columbian times, but of course northwest of the same latitude there have been post-Columbian introductions.

THE EASTERN SLOPES OF THE ANDES

The region covering the eastern slopes of the Andes, limited on the map shown in Figure 56 by two approximately parallel lines, is one of the most difficult to traverse, except perhaps in some special areas and then following the deep valleys of the main rivers, where rather special conditions may prevail. We have obtained only a few samples from this region, as indicated on the map, and only a few of them could be studied in any detail.

A very interesting ear was once obtained from the Territory of Acre, through Mr. Alves, a rubber planter and former student of the College at Piracicaba. He got it from an Indian who had arrived from somewhere "outside" the main Acre region, which belongs to the area of the *Interlocked Soft Corn.* The one ear received was almost spherical to egg-shaped, with yellow, small, and hard popcorn kernels, and the plants grown at Piracicaba were all fairly tall but typically brachytic, with very short internodes but large leaves. Unfortunately Dr. Kobal, who was studying this material, died prematurely, and he did not leave records or seed samples.

The first and third points on the map correspond approximately to the locality where samples of *Confite Morocho* were found, which we saw in the collection of Drs. Grant and Grobman. When collecting in the Yungas of La Paz and the adjoining regions, Dr. Gurgel found a number of ears which gave brachytic plants, and there was some indication of the existence of very short ears which may be interpreted as infiltrations from the *Brachytic Popcorn.*

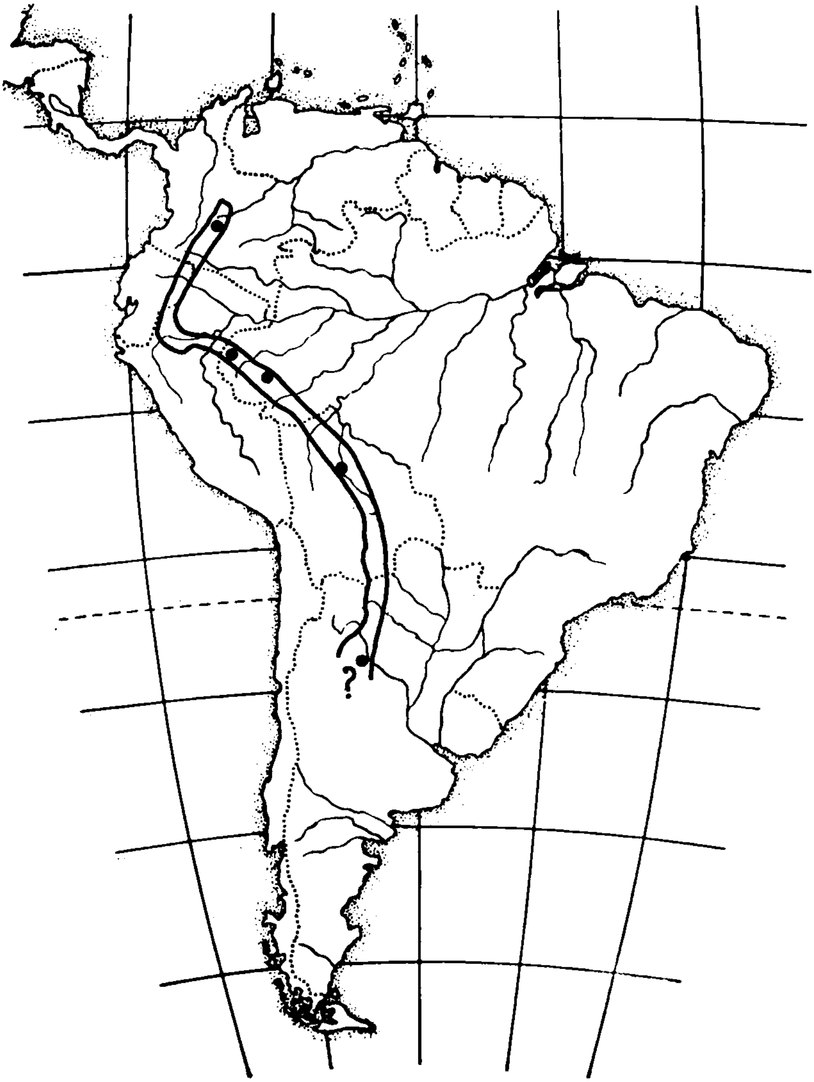

FIG. 56. Map of South America showing the regions in the mountain area of the eastern Andean slopes, where a peculiar popcorn occurs, with egg-shaped ears, generally, or brachytic plants.

The last indicated point at the southern margin of the zone, marked in Figure 56 with a question mark, indicates that somewhere there the type should occur which is known in collections as *Argentinian Rice Popcorn* and which exists in two forms: the *"strawberry form"* and the *"lady finger form."* Both always have rather small and brachytic plants with many tillers. The latter form was studied in some detail.

It would be very valuable if this region could be made the object of future special studies, in order to see if more material could be found and if *Brachytic Popcorn* is really the only race or only group of races in existence there.

As the basis for future work, a brief description of the only race of this group from which material was available follows.

12. BRACHYTIC POPCORN

Ear photographs, Figure 57
Ear diagram, Figure 58
Tables 21 to 23

Ear: (Lady finger form) Among the smallest corn ears which we know. Cylindrical in shape, mean length 8 cm. and quite frequently much less. Row number on the average 12.8 cm. with variations from 10 to 14 or 16. All measurements of the ear diagram show the reduced dimensions of the diameters: medulla 0.2 cm.; rachis 0.6 cm.; at kernel base 0.9 cm.; cob 1.3 cm.; whole ear 1.7 cm.; cob/rachis index is rather high, 2.1. Rachilla length about 2 mm. and glume length about 2 mm.

Kernel: Extremely small: length 0.5 cm., width 0.4, and thickness 0.2 cm. The glume cover index is 0.38, *i.e.*, slightly more than a third of the kernels are covered by the glumes. Thus there seems to us no reason to suppose that a gene for half-tunicate may be present. Outcrosses to other types of corn never gave any indication of anything but the non-tunicate alleles being present. Color is always deep red (pericarp) with colorless aleurone and colorless endosperm.

The dimensions for the "strawberry type" are slightly different. Kernel size is the same, but the ear is much shorter and broader, and row number is higher. Again, as in the case of the *Brachytic Yellow Popcorn* from Acre, unfortunately no data were available

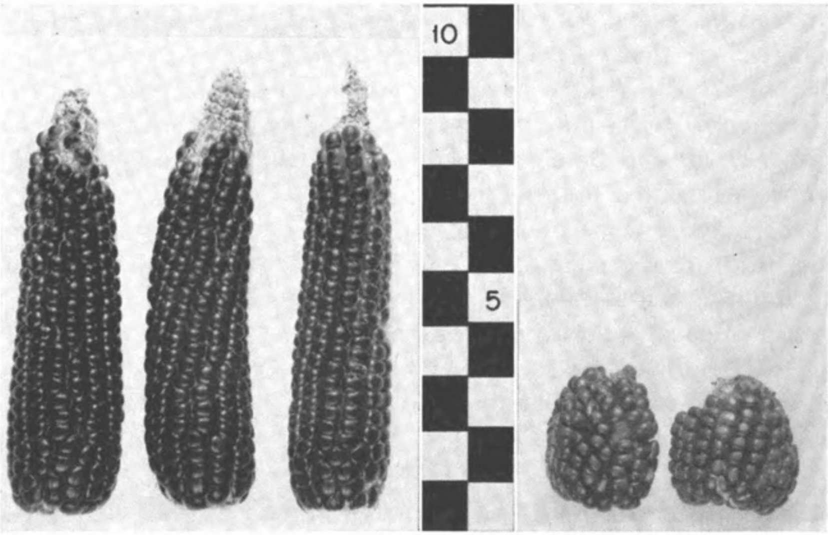

FIG. 57. In the mountain region in the eastern slopes of the Andes, a peculiar type of popcorn is grown, generally with brachytic plants and egg-shaped ears. The Pisankalla, with its *Strawberry Form* belongs to this group, while the *Lady Finger Form* must be caused by infiltration from some other popcorn race.

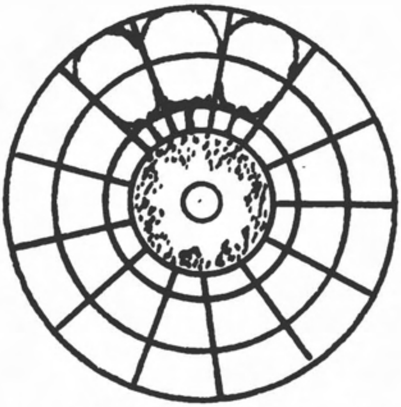

FIG. 58. Ear diagram of Pisankalla, Lady Finger Form, from Argentina.

when this manuscript was being written, and there was no time to grow another crop to collect new data.

Tassel and plant: Characters cannot be described in quantitative terms. Plants are always very small, with numerous short internodes and many tillers.

Origin and relationships: If our assumption is correct and the brachytic popcorn races are really limited to the eastern slopes of the Andes, *i.e.,* over a stretch very narrow but of considerable length, then we must conclude furthermore that for some reason, in this peculiar ecological region between the highly developed Andean tribes on the one hand and the lowland tribes on the other, there must have been a special group of Indians with their own peculiar type of agriculture, who preferred a stunted type of maize. But before such conclusions may be considered as justified and proven, new and more complete collections and subsequent detailed studies of this new material will be required.

THE LOWLANDS UNDER THE CAPRICORN, BETWEEN 15° AND 35° S.

This region is one of rather intensive maize cultivation and production, though the output could be considerably increased by modern methods of cultivation and of breeding. The basic material represented by the indigenous races, properly speaking, includes practically all major types of corn: the hard flints of the *Calchaqui* and of the *Cateto* group, the soft races of the southeastern *Guaraní,* the white dent of the *Caingang,* and the *Guaraní Popcorn,* from which apparently the North American variety called "South American Popcorn" has been derived. To this we can add a number of more recent synthetics, of which, under the present trends of agriculture, the synthetic hard white flints, *Cristal* and *Perola,* have less importance than the more recent orange-colored dent races of southern Brazil, which we shall discuss under the collective names: *Cateto-Dent,* or more specifically, *"Paulista Dent"* in the State of São Paulo and *"Rio Grande Dent"* in the State of Rio Grande do Sul, both in Brazil.

We can distinguish at least five groups of indigenous races in this area which still follow, at least to a considerable extent, a certain pattern in their geographical distribution and in connection with the agriculture of clearly defined groups of Indians. Among these we should mention especially the *White Soft Corn* of the Chavantes Opaia, which we received on two occasions some 20 years ago. This tribe is now practically extinct, *i.e.*, "absorbed by the civilization." Still other small tribes may have existed in this vast area, and we do not know how many tribes had disappeared before any collections of maize types attracted interest.

One of the indigenous groups of maize in the area is the *Orange Flints,* which we call the *Cateto* Group, using the name mostly applied in and around the State of São Paulo. We have not been able to find out where this name came from, although this should be known, since almost the same name is given to the principal residence of the President of Brazil in Rio de Janeiro (in the form of "Catete"). From the present distribution of *Cateto* maize, one may conclude that it was the main type of maize grown on the Atlantic coast, from at least the central part of the coast of Brazil down to the climatic southern limit of maize in Argentina. However, Indians living in coastal areas were always the first to receive the sometimes doubtful benefit of the progressive civilization of the white colonist, and thus they became rapidly "assimilated" and disappeared completely. This process has reached its end, and for quite a long time there have been no Indians in the area of the Southern Cateto, which we are discussing. Many or all of the Indians of the coastal area belonged to the coastal Guaraní. Thus *Cateto* is now known in the South only as ordinary field corn, but it must have once been indigenous.

There are several groups of flint synthetics, all evidently post-Columbian and possibly even of quite recent origin. There are at least two synthetics from infiltration of *Guaraní Soft Corn* into *Cateto, Canario de Ocho* and *Amarillo,* of which the last really forms a group. Next there are the infiltrations into the same Guaraní maize from the *Calchaqui White Flint* which have given the synthetics called *Cristal.* Finally we have the new *Brazilian Dents.*

It is not easy to find out when the introduction of dent types into Brazil really began, and everything points to repeated introductions of North American dent varieties into southern Brazil during the last century, probably since the first immigration, during the Civil War, when Southerners who were convinced that, without slaves, no profitable agriculture was possible in a hot climate. These three groups of synthetics represent in a certain way the change in the trends of corn breeding after the Conquest: first the flint corn types had priority, and much later the dent corn received more serious consideration.

We shall not attempt to give full data on geography or climatology of this vast area, since this would require the inclusion of a rather large geographic text book. Neither shall we enter into a discussion of the Indian tribes, still existing or extinct, which again would require a "Handbook." It may be enough to remember that the region is much too large to be uniform. It includes the vast plains of the Pampas of Argentina, the High Plateau of southern Brazil with an elevation within the general limits of 500 to 1,000 meters, the lowlands of Paraguay and some lower Andean Valleys, up to about 2,000 meters. It includes also the Atlantic coast from southern Brazil, more or less south of Baia, to Uruguay and Argentina, a short stretch of the Chilean coast on the Pacific, and all the regions with a more continental climate in between. There are three limitations: the region does not extend (a) beyond the climatic margin of corn cultivation at a latitude of about 35°; (b) beyond the altitude limit of the Andean High Valleys above 2,000 meters; nor (c) into the really tropical region of lower latitudes further north.

The Calchaqui Races

The Calchaqui Indians, or Diaguetta, are known to have had a well developed art, especially when measured by their surviving work in ceramics. At some time they became completely extinct. Though neighbors of the higher civilizations in the coastal area of Peru, they seem to have remained rather separate, perhaps because their main area was east of the Andes, in northern Argentina of today.

The material on which we shall base our descriptions was collected in part by Dr. Vallegas and his coworkers and in part by ourselves in the eastern Andean approaches of northwestern Argentina, where one large Valley is still today called the "Calchaqui Valley," because it is reported that it was there that these

Indians made their last stand against the white conquerors. The latter used a rather cruel method of warfare which we now know under the names of "total war" and "scorched earth," by invading the settlements of the Indians, where corn can be grown only with irrigation near the few river beds, and destroying all the crops. The Indians waited on higher elevations for a direct attack which never came, and they were left to slow but complete starvation after the Spaniards had finished their destructive work and had left.

From the material collected it was evident that at least three races had existed, one with large white kernels and the others with considerably smaller kernels, one white and the other yellow. Only from the former did we succeed in growing material for the more detailed analysis.

Later we were allowed to select from Dr. Grant's collection at Medellin, some material from northern Chile which certainly is identical with Calchaqui White Flint, showing that this race of white flint was grown by the Indians on both sides of the Andes, east and west.

13. CALCHAQUI WHITE FLINT

Ear photographs, Figure 59
Ear diagram, Figure 62
Internode pattern, Figure 63
Tables 22 to 24

Ear: Always cylindrical, without a pronounced butt at the base and with a mean length of 17 cm. Mean row number 13, with a range from 10 to 16. Ear diagram: medulla comparatively large, diameter 0.6 cm.; rachis only 1.1 cm.; diameter at kernel base 2.0 cm.; which means that the rachilla must be rather long, of the order of 4.5 mm. These rachillas are very stiff and are inserted in fairly deep cavities of the alveolus. The rachis flaps and the ridges at the base of each kernel pair, which represent the borders of these cavities, are also heavily sclerenchymatized. Cob diameter 2.7 cm. Since the glumes are inserted generally near the lower part of the rachilla, their length is of the order of 6 mm. The diameter of the whole ear is not too large and equals on the average 3.6 cm. Cob/rachis index 1.75.

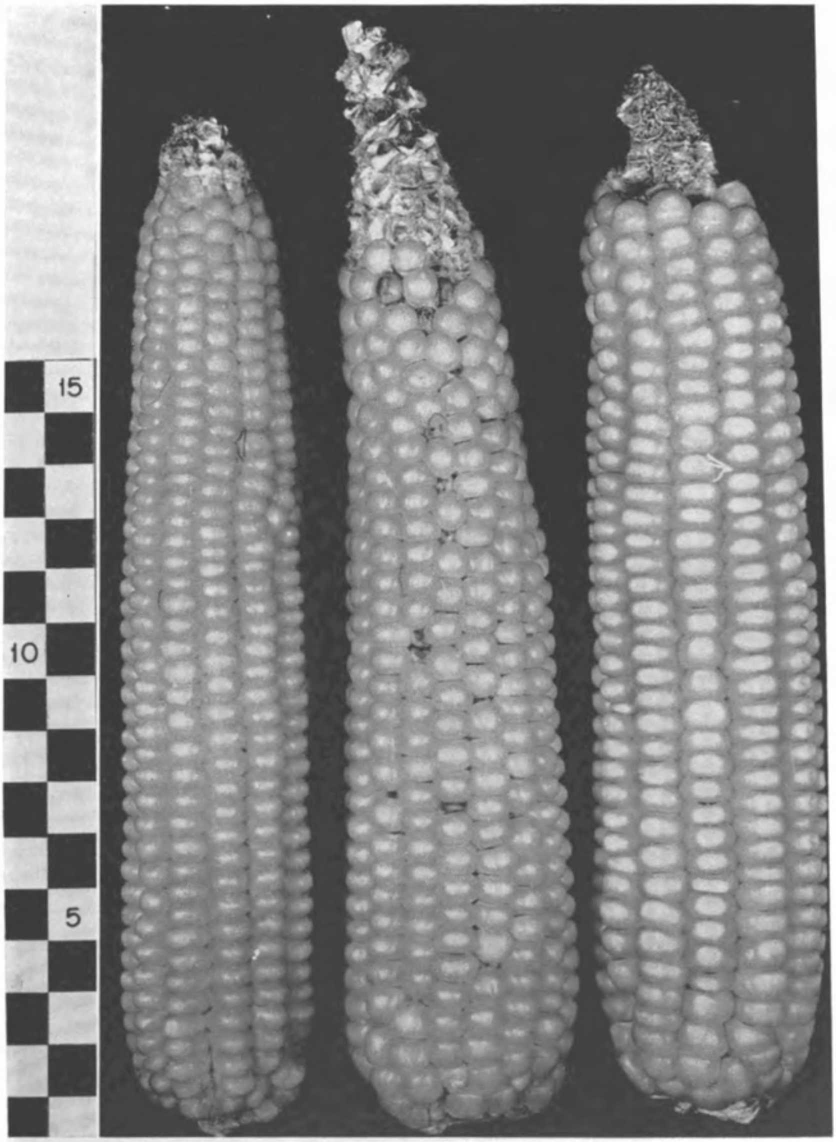

Fig. 59. Calchaqui White Flint is the most important race in northwestern Argentina, from the lowlands to about 2,000 meters.

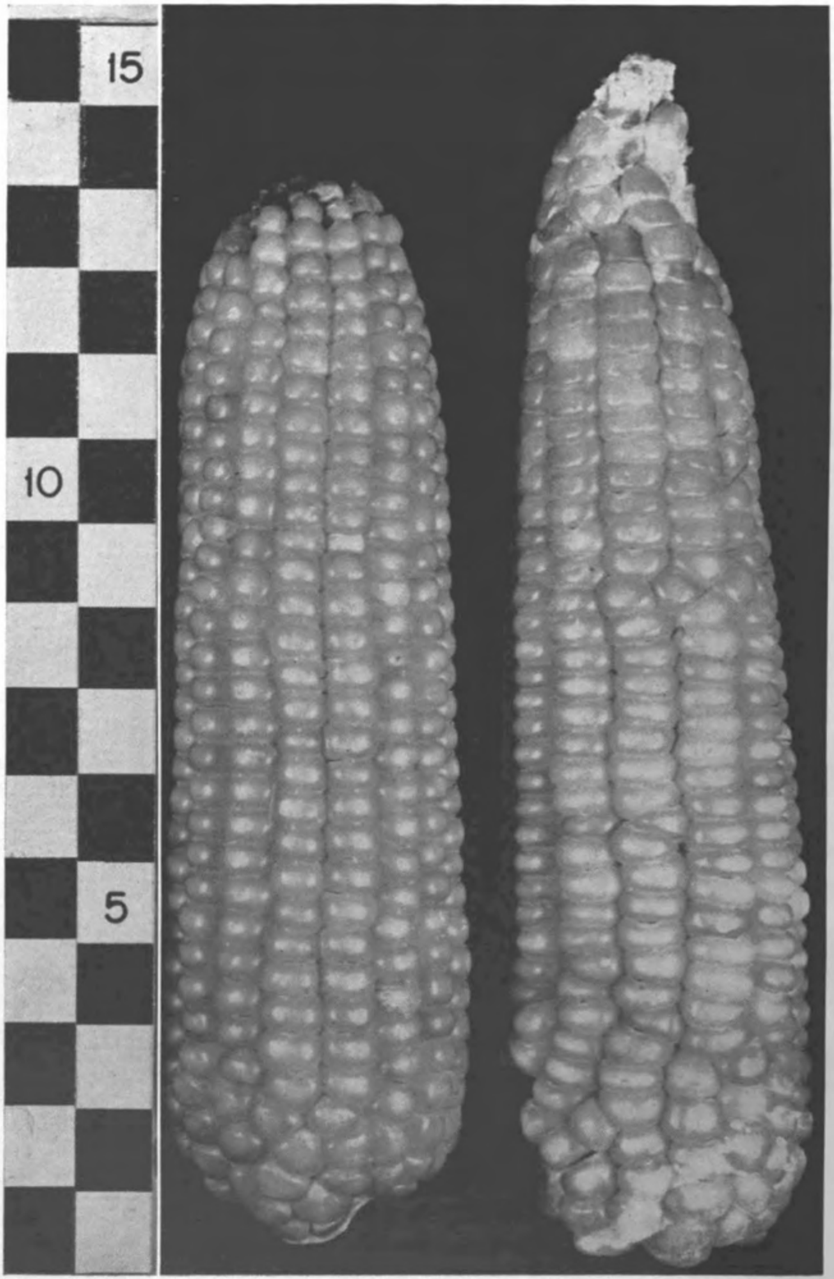

FIG. 60. Calchaqui Small White Flint is an almost extinct type in northwestern Argentina.

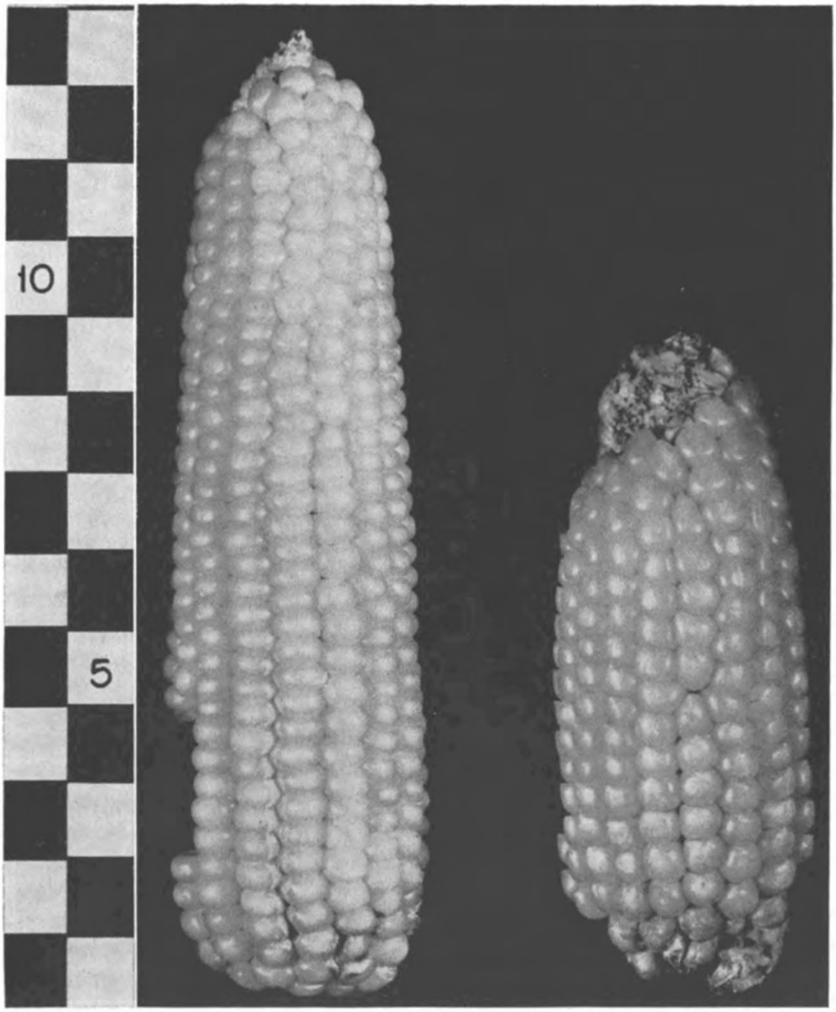

FIG. 61. Calchaqui Small Yellow Flint is an almost extinct type in northwestern Argentina.

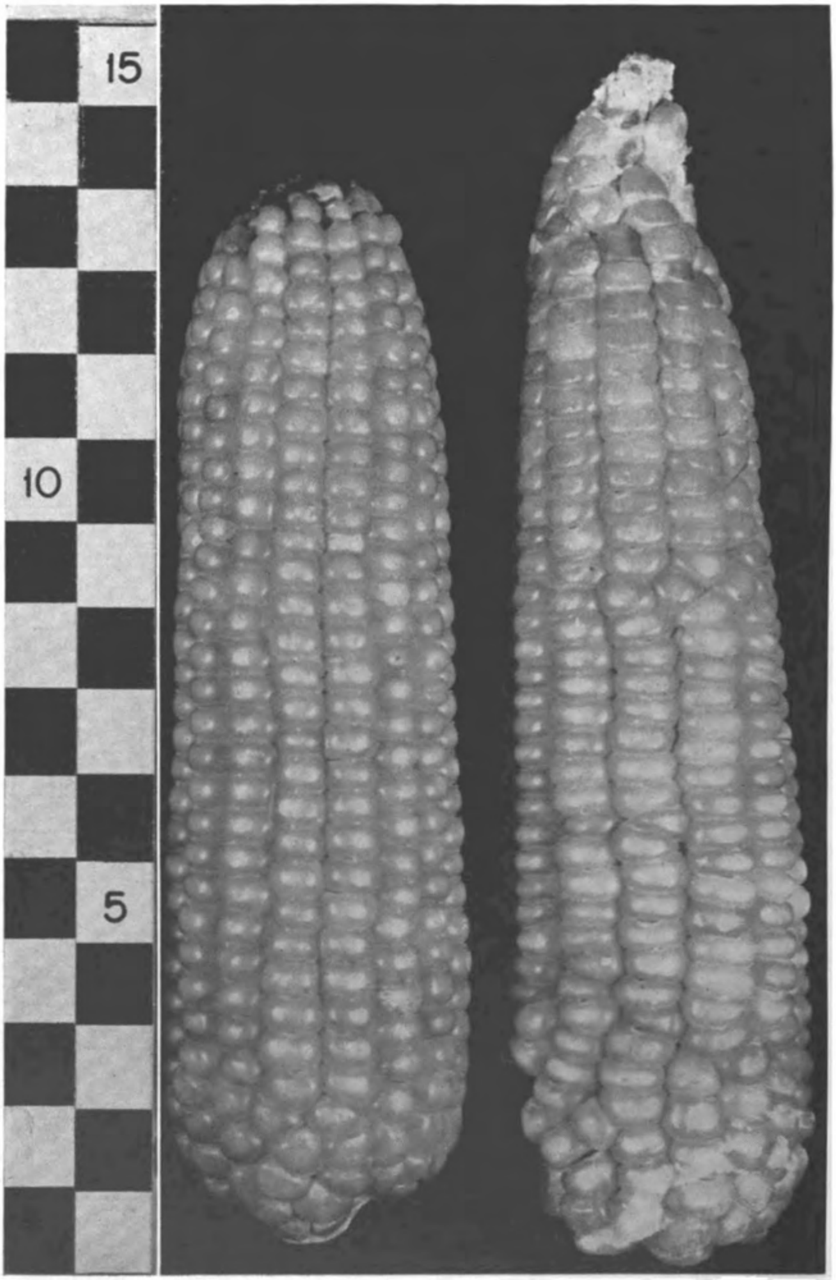

Fig. 60. Calchaqui Small White Flint is an almost extinct type in northwestern Argentina.

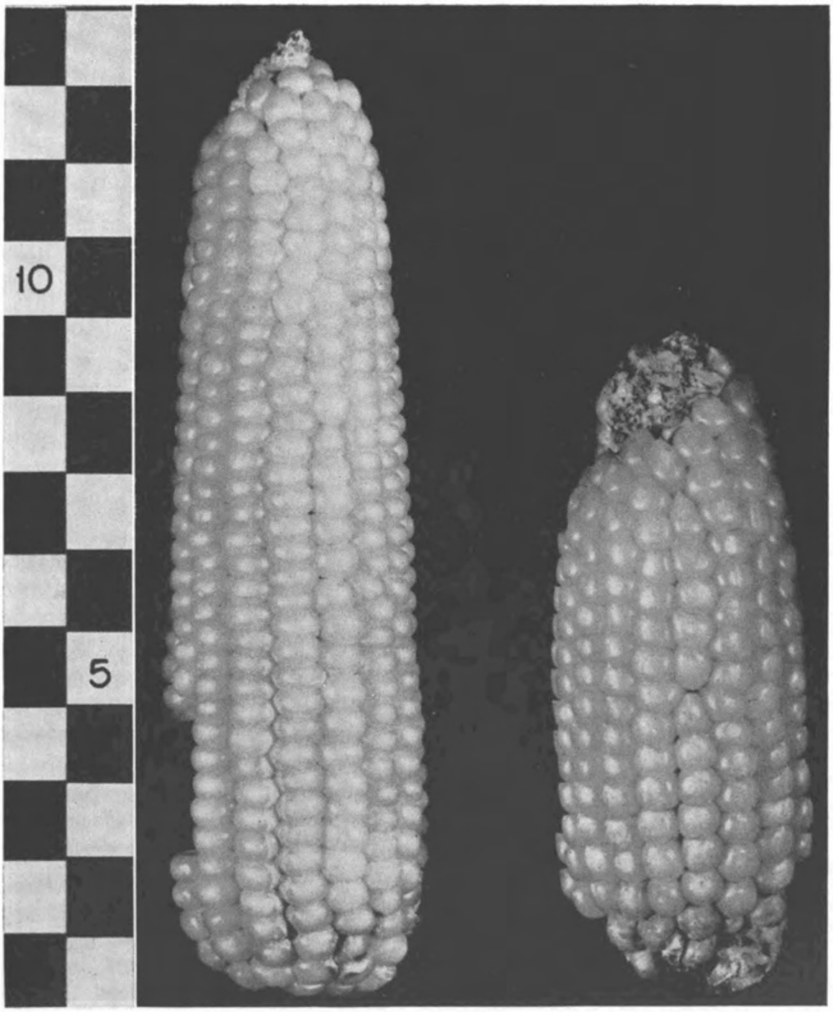

Fig. 61. Calchaqui Small Yellow Flint is an almost extinct type in northwestern Argentina.

Kernel: White kernels contain very hard corneous endosperm. Kernel length and width almost the same: 0.9 and 0.8 cm., respectively; thickness is one-half of this: 0.4 cm. The rather long glumes cover nearly one-half of the kernel (43 per cent). But there is no indication of the presence of half- or weak-tunicate gene in any of the many crosses in which we used Calchaqui Flint.

Tassel: Last leaf sheath about 14 cm. long and last internode about 21 cm., so that about two-thirds of the internode only is covered by the sheath. The branched part of the tassel, with mean length of 16 cm., forms a little more than one-third of the whole tassel (38 per cent) and the terminal spike of 25 cm. forms the other two-thirds (62 per cent). There are 20 tassel branches of first and about 6 of second order, *i.e.*, quite a heavy branching of the tassel.

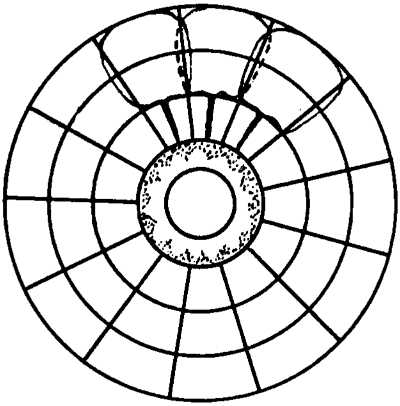

FIG. 62. Ear diagram of Calchaqui White Fint from northwestern Argentina.

There were in all 14 different original samples of this race, but as shown in Table 23 the component error ratios "between origins," with 13 degrees of freedom, are in 5 out of a total of 8 comparisons completely insignificant, in two just beyond the 5 per cent limit of probability, and in only one highly significant.

Plant: Samples were divided into three groups. These differ in five comparisons at the 1 per cent level, and are therefore highly significant. In these five cases, the variation "between three groups" is from about 4 (3.79) to nearly 9 (8.92) times greater than the residual variability. There is also much variation within samples, and this component amounts to about twice the normal residual variability. In four characters the variation "between groups of samples" is only of the same order as that "within groups." On the whole the three groups form an ascending series, the first one being the smallest in all respects and the third one the tallest. It is also interesting to note that in two of the groups the ears are slightly below the middle of the plant (at about 47 per cent of the total plant height), while in the third group the ears are near the end of the second third of the plant (at about 60 per cent of the total plant height). The number of leaves below the ear increases between extremes from 6.6 to 8.5, while that above the ear remains more or less constant at 4.7 leaves. Similarly, the length and width of the leaves increase from group to group, while the number of veins and the venation index are practically constant.

Internode pattern: As shown in Figure 63, there is a maximum, either of the last internode below the ear or, more frequently, above the ear, and there is of course again the other customary maximum of the last internode below the tassel.

Origin and relationships: Since Calchaqui White Flint occurs from the northwestern Argentinian lowlands up to Valleys of nearly 2,000 meters and descends again to lower altitudes in Chile, it is to be expected that there should exist a number of races or subraces with the same general ear and kernel characters as the result of artificial selection, but with different plant characters as the result of adaptation under natural selection. The existence of three groups can be explained in this way but even more variation could have been expected. Since the normal agricultural structure of the Calchaqui Indians has been destroyed and the situation in the area quite altered with the elimination of this Indian tribe, it remains doubtful whether more detailed and careful collections would allow separation of more old adaptive types or subraces.

Calchaqui Flint is far from being a primitive race. It is, on the contrary, a rather highly developed and productive field flint corn, and what may have been its primitive predecessors in some prehistoric period is completely unknown. The flint type must have satisfied completely the agricultural needs and preferences of the Calchaqui Indians, since they did not attempt to take over from their neighbors either floury or dent corn. Calchaqui Flint differs completely from all the Andean High Valley types and clearly belongs to the lowland complex of races.

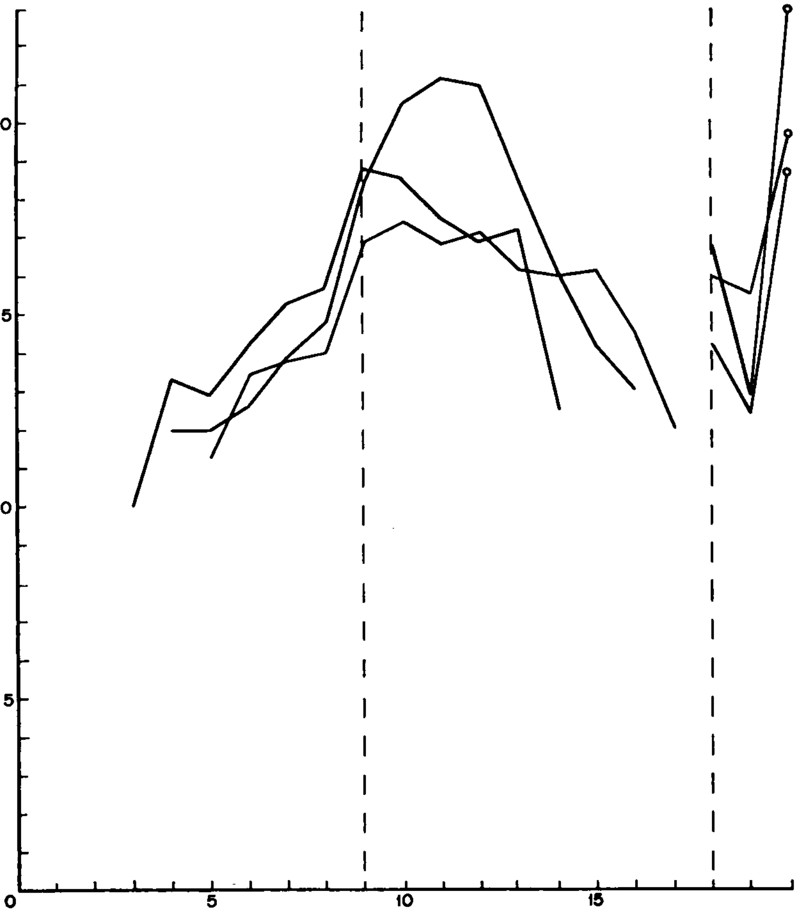

FIG. 63. Internode pattern of Calchaqui.

14. CALCHAQUI SMALL WHITE FLINT AND
15. CALCHAQUI SMALL YELLOW FLINT

For both these races we can show photographs of the original ears (Figs. 60 and 61), but no other detail. The ears are considerably shorter than in the ordinary White Flint of this area and have a higher row number and diameter. The kernels on the other hand are smaller and approach the size of popcorn. One of these two races has hard white endosperm and the other lemon yellow endosperm, quite different from that of the Cateto Flint. Whether these two should be considered as old and almost extinct races, as we believe, or whether we are dealing with some special synthetic, cannot be said with any certainty.

The Races of the Southwestern Guaraní

The Guaraní Indians of the southwestern area, who once occupied parts of the northern Argentina, of eastern Uruguay, of southern Brazil, nearly all of Paraguay, and the southern part of the Bolivian lowlands, must have had quite a distinguished position at the time of the Conquest. They not only formed the bulk of the population over a wide area of colonization, they also furnished the essential part of the labor force and population of the ecclesiastical empire which the Jesuit "Missiones" tried to organize. Their language became or remained the basic or general language ("lengua geral") in the lowlands. Among all the tribes of the area under Capricorn, they are distinguished by the fact that they cultivated more than one race of maize; besides a group of races which formed their ordinary field corn, all belonging to what we call the *Guaraní Yellow Soft Corn,* they had also a special ceremonial maize and two types of popcorn. The name used throughout for maize by these Guaraní Indians is *"Avatí" or "Abatí,"* which some believe to mean "white beard." There are at least four races, all with the typical yellow color, and they have in common the name *"Avatí Morotí."* Three of these races, which differ somewhat in their characters from the most common type, are characterized by the addition of a third name, such as *"Avatí Morotí Mitá"* for the smallest and most precocious race. The ceremonial maize is called *Avatí Djakaira.* The most common name for popcorn, used now all over Brazil, is *"Pipoca,"* which is supposed to be also a Guaraní word. However, the indigenous tribes seem to have called their popcorn *"Avatí Pichingá."* It may be remembered that most names for popcorn start with "pi . . .": *Pi*ra in Colombia, *Pi*sankalla or *Pi*sincho in the Bolivian and Argentinian Andes, *Pi*chinga or *Pi*poca in the Guaraní area.

16. AVATÍ MOROTÍ (GUARANÍ YELLOW SOFT CORN)

The common characteristics of all the races of the *Morotí* group are the large round kernels with soft endosperm and the deep lemon yellow coloration of the aleurone layer. *Avatí Morotí* is the most common field corn of the area.

Ear: Cylindrical and long, with regular rows; mean length 18 cm., mean row number 12.7, with a range from 10 to 16 more or less. Ear diagram: diameter of medulla rather large, 0.9 cm.; of rachis 1.5 cm.; at kernel base 2.2 cm.; mean rachilla length 3.5 mm.; cob diameter 2.8 cm., corresponding to an average glume length of about 5 mm. Total ear diameter 4.0 cm.; cob/rachis index 1.95.

Kernel: Rather large though not exceptionally so; round at the tip, containing only soft starch in the endosperm. Though occasionally some slight indentation of the kernels may be seen, *Morotí* is not a dent corn. On the other hand, we succeeded by simple selection and inbreeding in increasing the amount of denting in such a way as to obtain a typical "soft dent" as a final product. Evidently the Indian breeders were not and are not interested in accumulating modifiers for intense and constant denting of the kernels, but all the necessary modifiers are present in a random fashion. Kernel length 1.0 cm., width 0.9, and thickness 0.5 cm. The rather long glumes cover about one-third of the kernel (34 per cent). Pericarp sometimes colored (red, orange, or variegated). Very rarely, anthocyanin is present in the aleurone layer.

Tassel: Mean sheath length 12.8 cm.; internode length 15.9 cm. with the mean internode covering amounting to 1.24. If we remember that the coefficient of variation of this index is 16.5 per cent (4th column, bottom row, Table 26) and if we admit individual variations within samples up to 2.5 times the residual error or the coefficient of variation (approximately 1 per cent limit of chance variation), then the index may reach the following extremes:

$$1.24 \pm 2.5 \times 0.165 \text{ or}$$
$$0.83 < 1.24 < 1.65$$

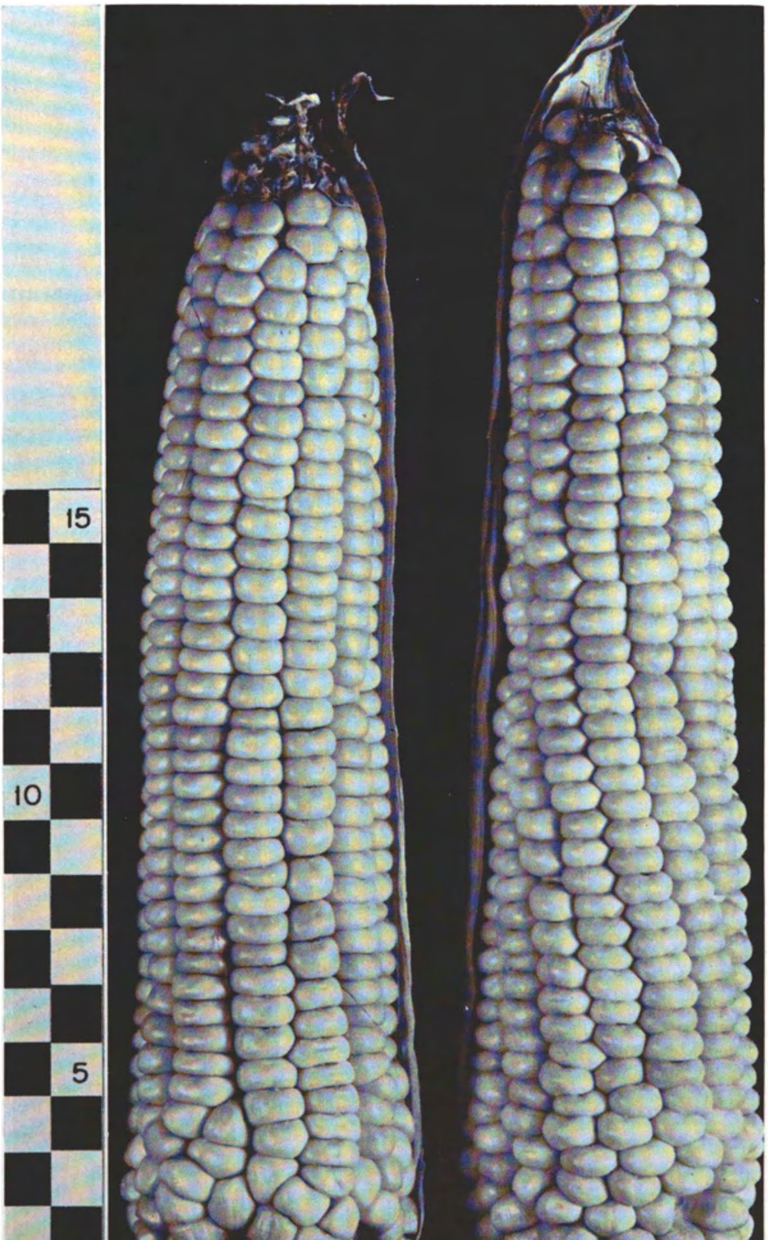

Fig. 64. The main field corn in the extensive Guaraní area in Paraguay, southwestern Bolivia, and southwestern Brazil is the Guaraní Yellow Soft Corn, of which the most common race is the Avatí Morotí.

If we accept the limit of the probable error (or quartil limit), the corresponding range would be:

$$0.97 < 1.24 < 1.51$$

This means that, if variation within the race is purely a question of chance variation, about one-quarter of all plants would have a coverage index between 0.83 and 0.97, while the value for the remaining three-quarters of the members of the sample would lie between 0.97 and 1.65. Thus one-quarter of all plants in a sample could have not only the whole internode but also a portion of the branched part of the tassel covered by the sheath. The values: internode length/sheath length = 15.9 cm. mean that a fraction of the tassel, equal to $(1.00-0.83=0.17)\times 15.9$ or 2.7 cm. would also be covered by the sheath. With a total length of the branched part of the tassel having a mean length of 17 cm., the enclosed portion is only a small part of the tassel, but it is just the one which carries most tassel branches.

The branched part of the tassel is, in the mean, 17.0 cm., and the terminal spike to 24.4 cm. Thus the branched part forms 41 per cent of the tassel, which is quite a considerable portion. The number of branches is also quite high: There are on the average twenty-two primary and nine secondary branches, while extreme deviates may have as many as thirty-four primary and nearly twenty secondary branches. These heavily branched tassels are quite frequently pendant.

Plant: With a mean plant height of 180 cm. and an ear height of 104 cm. the ears stand slightly above the middle of the plant (at about 55 per cent of its total height). There are on the average nine leaves below and six above the ear. Leaves are quite long: 93 cm., and of normal width: 10 cm. There are on the average twenty-six veins per leaf, giving a venation index of 2.6.

Internode pattern: There is one main maximum several nodes above the ear, and there may or may not again be an increase in the length of the last internode below the tassel. One of the two curves in Figure 71, which are constructed from the means of samples of ten plants each, shows a slight increase of the last internode, and the other a decrease (at the right of the diagram).

Origin and relationships: Avatí Morotí is the most southern representative of the large group of maize varieties characterized by nearly round kernels, very soft endosperm, and yellow aleurone. This group stretches through a wide part of South America east of the Andes, then appears in Ecuador and Colombia and even in the Andes. Its most northern representative is *Cariaco* from northern Colombia (Figs. 4 to 7). The type is absent in Central America and Mexico and is not found in the Andean High Valleys of Peru and Bolivia. We must assume that it originated in the lowlands of South America and became the main tropical or subtropical lowland type of maize, accepted by the majority of Indian tribes in the interior of South America. Whether this origin occurred more to the north or to the south is a question which probably never will be answered. The preference for soft endosperm by the Indian breeder can be understood, but there is nothing to explain a preference for yellow pigmentation of the aleurone layer. For this reason we believe in only one origin of this kernel type in the area and its subsequent expansion through the formation of synthetics.

17. AVANTÍ MOROTÍ TÍ

The main difference between the common *Avatí Morotí* and the *Avatí Morotí Tí* is the fact that the latter is generally larger in all respects. If it has other special characteristics, we do not know them.

Ear photograph, Figure 65
Ear diagram, Figure 79.2
Internode pattern, Figure 72
Tables 25 to 27

Ear: Length, with a mean of 19.2, is slightly longer and row number tends to be higher (mean 15) in this race than in the common *Avatí Morotí*. There are only slight differences in the ear diagram, as can be seen in Table 25. Rachilla length amounts to about 4 mm. and glume length to about 5 mm.

Kernel: Kernels hardly differ from *Avatí Morotí* and their coverage of 34 per cent by the glumes is the same.

Tassel: These are indistinguishable from tassels of *Avatí Morotí*.

Plant: Somewhat taller, with a mean plant height of nearly 2 meters (not including the tassel) with the ears, at a height of 123

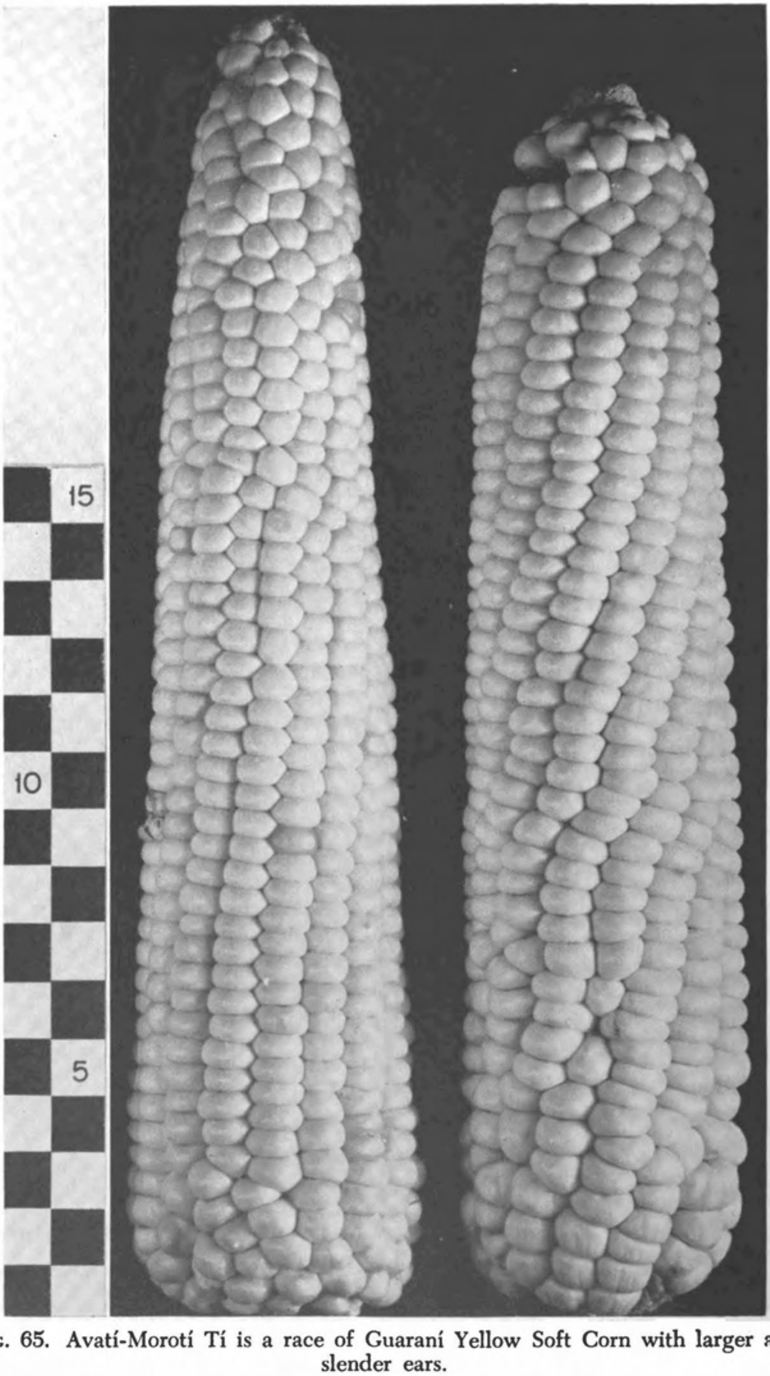

FIG. 65. Avatí-Morotí Tí is a race of Guaraní Yellow Soft Corn with larger and slender ears.

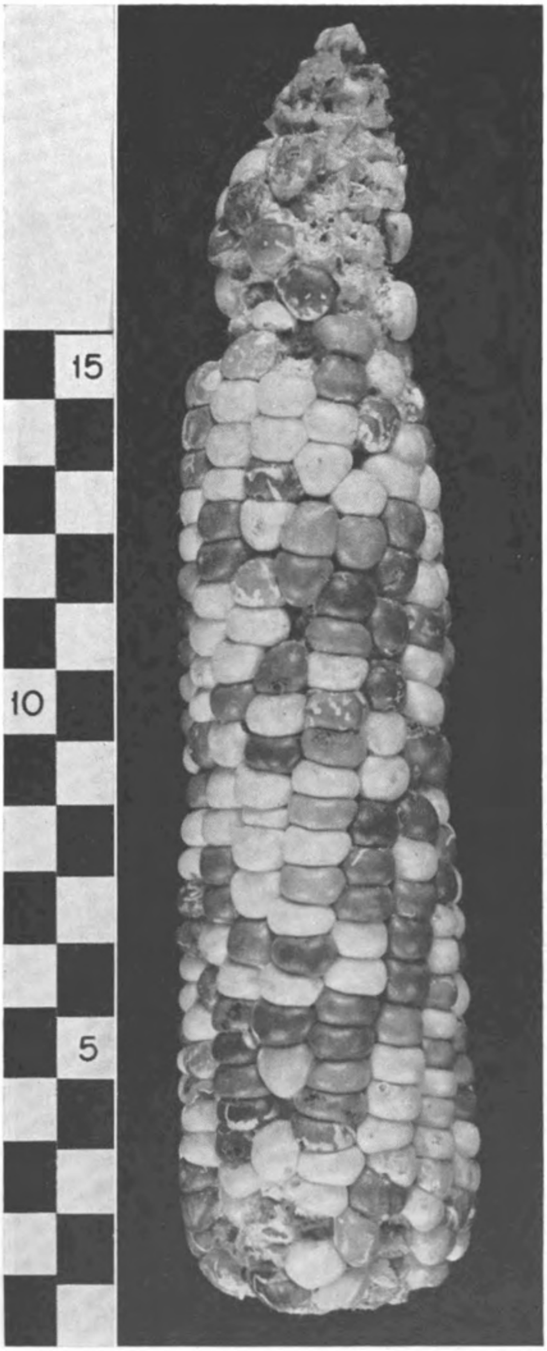

FIG. 66. Avatí Djakaira is the ceremonial corn of the Guaraní Indians. It has soft kernels with white endosperm and black, red, or colorless aleurone.

cm., almost at the end of the second third of the plant (59 per cent of plant height). The number of leaves is about the same, but the length and width are more extreme.

Internode pattern: The same tendency, though perhaps even more pronounced, can be seen. The longest internode is found well above the ear and then internode length decreases. There may or may not be a slight increase in the length of the last internode below the tassel.

FIG. 67. Avatí-Morotí-Guapí is a race of Guaraní Yellow Soft Corn with short and thick ears.

Origin and relationships: Avatí Morotí Tí seems simply a variant of the ordinary *Avatí* and could easily be a selection for larger plants and ears.

18. AVATÍ MOROTÍ GUAPÍ

Ear: Rather short and thick, with a pronounced butt. Ear length is the shortest of all *Morotí* races (mean only 13 cm.) and row number is the highest (mean 14.8, with a range from 10 to 18 or, rarely, even 20). The ear diagram shows that all diameters are considerably enlarged without a change in their relative proportions. Diameter of medulla 1.0 cm.; of rachis 1.9 cm.; at kernel base 2.7 cm.; main rachilla length about 4 mm.; cob diameter 3.36; average glume length about 6 mm.; total ear diameter 4.6 cm.; cob/rachis index 1.76.

Kernel: The kernels differ neither in size, texture, nor color from those of the other *Morotí* types. The glumes, owing to their large size, cover nearly 37 per cent of the kernels.

Tassel: On the average slightly smaller than those of the preceding races, but the proportion between branched part and terminal spike is about the same, and the number of branches is also of the same order. The coverage of the last internode is more pronounced and one-quarter of the plants of a normal sample may have a cover index between 0.74 and 0.88, while more than one-third of all plants will have portions of the branched part of the tassel included in the leaf sheath of the adult plant.

Plant: Considerably smaller than those of the preceding two races, and the leaves are shorter and very slightly narrower. Numbers of leaves and of veins do not vary.

Internode pattern: Of the two samples analyzed, one showed a maximum below the ear and the other several nodes above the ear. In one sample another maximum appeared just in the last internode below the tassel, while in the other the decrease of internode length continued to the tassel.

Origin and relationships: As is *Morotí-Tí, Morotí Guapí* must be just another variant due to some special trend in natural selection, in artificial selection, and possibly in accidental genetic drift.

19. AVATÍ MOROTÍ MITÁ

Ear photograph, Figure 68
Ear diagram, Figure 79.4
Internode pattern, Figure 74
Tables 25 to 27

Ear: Mean length of 15 cm. There are fewer rows mean (10.2 with range from 8 to 14). The shape is cylindrical, sometimes with a slight enlargement at the base. The ears are also relatively thin,

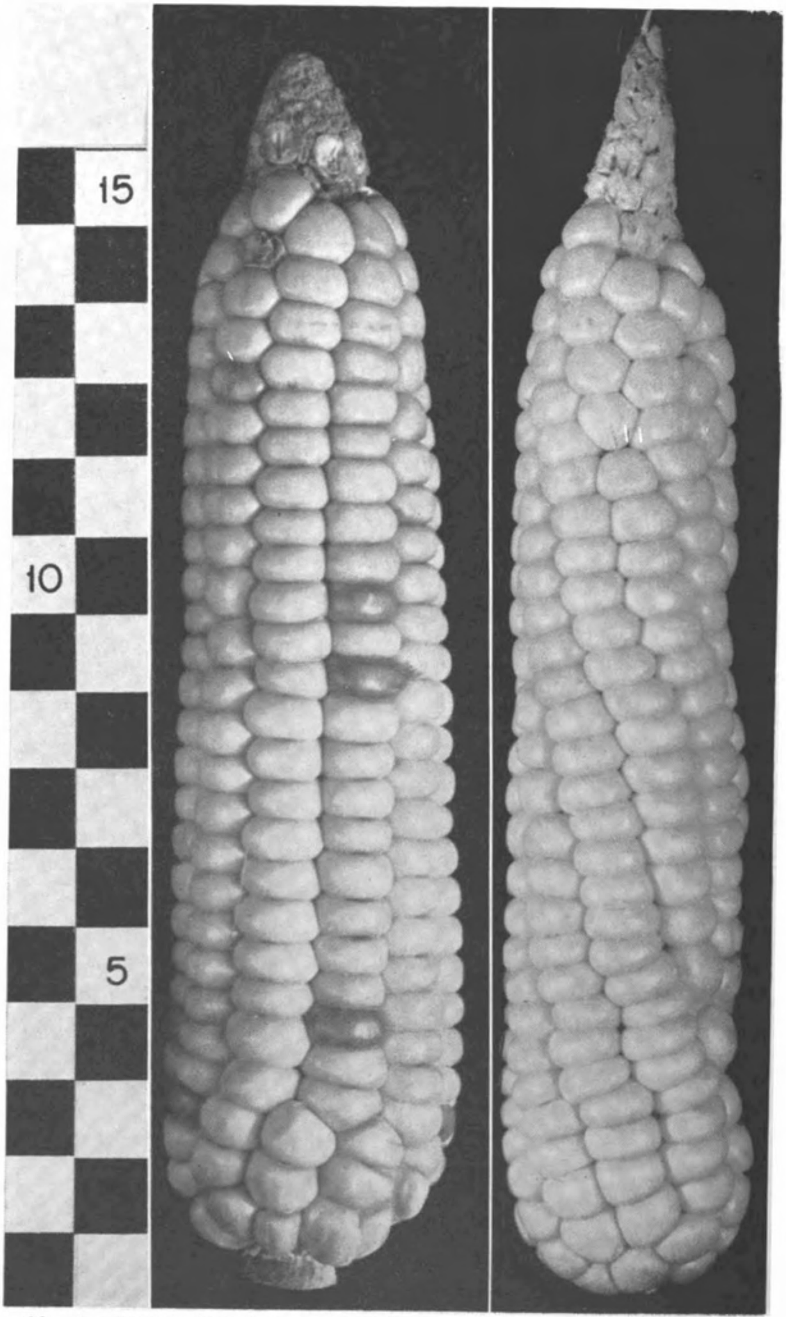

FIG. 68. Avatí-Morotí-Mitá is a race of Guaraní Yellow Soft Corn with small 8-rowed ears. It is very early in maturing.

as shown by the diameters of the ear diagram: of medulla 0.5 cm.; of rachis 1.0 cm.; at kernel base 1.6; rachilla about 3 mm. Diameter of cob 2.2 cm. which corresponds to an average glume length of 0.5 mm. Diameter of the whole ear 3.1 cm.; cob/rachis index 2.21.

Kernel: Somewhat smaller than in the preceding races of this group: mean kernel length 0.8 cm., width 0.8 cm., and thickness 0.5 cm. In consequence of the slightly reduced kernel size, kernel covering is more pronounced and amounts to about 42 per cent.

Tassel: Length of sheath and of last internode differs little from that of the preceding races, and the covering of the tassel by the last leaf sheath is slightly less pronounced. The branched part of the tassel is considerably shorter, amounting to only 33 per cent of the whole tassel. There are fewer tassel branches, with a mean of 15 for those of 1° order and of 5 for those of 2° order.

Plant: Considering the fact that *Mitá* is much earlier in flowering and maturing than the other races of the group, it is not surprising that the plants are considerably smaller, with a mean height to the first tassel branch of 113 cm. and to the ear of only 35 cm. The relative position of the ear is thus quite low, at about the end of the first third of the plant (36 per cent of its height). As shown in Table 27, there are fewer leaves (slightly more than 4 above or below the ear), and the leaves are shorter (61 cm.) and narrower (7 cm.), with fewer veins (19) but with a high venation index (3.2).

Internode pattern: For the other races of this group, we found that the internode below the ear is generally not the longest but that increase of internode length continues well beyond and above the ear-bearing node, while not very far from the last internode a reduction of internode size may begin. In *Mitá,* as shown in Figure 74, the increase in internode length seems to be almost continuous, with some fluctuations.

Origin and relationships: There cannot be any doubt that *Morotí Mitá* belongs in the group of the *Guaraní Soft Corn,* especially since kernel structure and color do not differ from any other race of this group. One might, however, ask where the reduction in ear size and in row number, the earliness, and the reduction of plant size and of tassel branching may have come from. There are no races nearby from which genes with such effects might have been introduced into the *Soft Corn* group, and we might assume that we are dealing with the result of a conscientious breeding effort by the Guaraní Indians to obtain an early maize in addition to the main type, which is normal in maturing.

But there is one very strong argument against this explanation. As we shall show later, all 8-rowed races of corn seem to have several traits in common which could only be understood if they were really related. There is thus the possibility that there was an old 8-rowed race, now extinct, into which the genes for *Avatí* kernels infiltrated.

Résumé of the Avatí Morotí Group

We have mentioned that the four races which we just described occupy a continuous area, and that no race shows any preference for any special part of it. Their cultivation is always associated with Indians belonging to one very large group, the southwestern Guaraní.

The foremost or basic character common to all the races of the *Avatí Morotí* group is the form, texture, and color of the kernels. It seems to us that uniformity of kernel characters is the main characteristic of a racial group. To show this, we may cite, in addition to the *Avatí Morotí*, the following groups: All members of the Mexican Dent group have white, rather hard, dented kernels; the members of the *Cateto* group have very hard orange-colored flint kernels, etc. It seemed interesting to us, however, to see whether there are other characters in common within the group.

Ear characters: Table 25 shows the results of a summarized statistical analysis. This analysis also includes the ceremonial corn *Avatí Djakaira,* but we shall not make further reference to this race in our present discussion.

The four races of *Avatí Morotí* clearly form three groups. The differences between *Morotí* and *Morotí-Tí* are to a large extent not significant, and the increase of variation is nil or small. However, the differences between these two on the one hand and both *Morotí Mitá* and *Morotí Guapí* on the other are so large that they correspond to an increase of variability by 6 times or more over the normal residual variability within samples.

Kernel characters: The differences in kernel size among the three groups are of the same order as those within the one group containing two races, and the latter error component is of about the same order as the residual variability.

There are some correlated facts which must be mentioned: the relative length of rachilla (3.6 mm.) and of glumes (4.9 mm.), the high cob/rachis index (1.95), and the fairly high percentage of kernel coverage by the glumes (37 per cent). We do not know what genetic factors may be responsible for these tendencies, but we can say that no indications were observed showing the presence of any special alleles such as alleles for "weak tunicate." Outcrosses did not give any support to such an hypothesis, although conclusive proof against the presence of weak-tunicate alleles would perhaps require linkage tests. It must also be remembered that phenotypic expression of any tunicate alleles is extremely variable, and this of course makes experimental proof still more difficult.

We may conclude that, except for kernel size, the races really form three groups, *i.e., Mitá* and *Guapí* are quite different between themselves and also from the other two races, which in turn differ little between themselves.

Tassel characters: Here it was possible to carry the breakdown of the error much further and we obtained, besides the estimate of residual variability within samples, four other error components. *Avatí Mitá* differs from all other races significantly in the branching of the tassel, which is reduced: the branched portion of the main axis is smaller both in absolute terms and proportionally, and there are also fewer branches. Otherwise tassel structure is uniform, and the variability between races, or between the different origins of the races, is of the same order as that within different samples of the same race and origin. The differences between the latter are statistically highly significant, in consequence of the large number of degrees of freedom which make the test quite sensitive, but actually they represent only a small increase in variability. The error ratio is increased by only about 1.8 times the residual variability.

It seems especially interesting to consider one character: the protection of the tassel by the last leaf sheath. In view of the uniformity among the four races, we may calculate the common general mean of the coverage index, which is 1.24, a value, incidentally, identical with the mean of *Avatí Morotí.* Thus we may use the calculations already made, and repeat that in any samples and in all races of *Avatí Morotí* we should expect that in nearly a quarter of all plants, not only the last internode below the tassel, but even a portion of the branched part of the tassel and its branches, will be enclosed within the last leaf sheath. These calculations and means refer to adult plants, but in still-growing plants this means that at the beginning of pollen shedding a still higher portion of plants may have protected tassels, covered partially by the last leaf sheath.

It is hard to say if this coverage has any very general pronounced advantage for the plant. We observed in several growing seasons, when during flowering time moisture was inadequate, that those tassels which were still mostly within the leaf sheath did not suffer and stretched normally after the rains began, giving a normal quantity of pollen, while those which had been pushed out of the protecting sheath by normal growth before the dry period set in became completely scorched. Thus we may be dealing with an adaptive character, resulting from natural selection over many generations.

If we disregard the reduction in branching of the *Mitá,* which evidently is either part of its adaptation to earliness or to the presence of an old character of the 8-rowed race, the uniformity of tassel characters for all four races of the group is quite striking. We should remember that, within the races of Humahuaca and in spite of the differences in ear structure between these races, there existed only two main types of tassel: those of the Valley group of races and those of the Altiplano group. We may perhaps conclude that tassel characters are mainly the result of natural selection, and if the representatives of a group of races occupy on the whole an area with a rather uniform climate, then tassel characters will become homogenized.

Plant characters: Table 27 shows the great heterogeneity with regard to all plant characters studied quantitatively. The difference of the precocious race *Mitá* from the others corresponds to an increase of variability by twenty times, more or less. The differences between the other four races, though also quite significant statistically, amount on the average to an increase of residual variability by about 6 times. The increase of variability shown by the component "within origins" is on the whole of the order of 2 times the residual variability. Thus it is clearly evident that *Mitá* differs very much, but that the other three races also differ in their plant characters, with one restriction only: the number of veins per leaf and the venation index. We may assume that there has been an intentional selective activity on the part of the indigenous breeder, which resulted in differences of the plant characters, while there is no reason to suppose that natural selection might have been different for the four races.

Internode pattern: If we study simultaneously all the diagrams shown in Figures 71, 72, 73, and 74, we can easily recognize the features common to all the races: from the base of the plant, internode length increases steadily, much beyond the internode which bears the ear. Mostly a decrease in internode then follows for a short distance, though both diagrams in Figure 74 and one in Figure 71 show that the point of decreasing length may not always be reached. As the diagrams at the right margins of these figures show, there may be an increase again at least in the last internode below the tassel, but this may also be absent, and the decrease of internode length may even continue. It would be very interesting to carry out more detailed studies about the growth rate of these internodes, which seem on the whole to continue growing even after flowering time, and to study in detail the physiological factors which control the growth rate of individual internodes.

We see that, in spite of their numerous differences, the races of the *Guaraní Yellow Soft Corn Group* have a considerable number of characters in common: the texture, shape and color of the kernels, the pronounced length of rachilla and glumes and consequently a high cob/rachis index and high percentage of glume cover of kernels, the tendency of the tassels to remain partially enclosed in the last leaf sheath, and the peculiar internode pattern.

20. AVATÍ DJAKAIRA, THE CEREMONIAL MAIZE OF THE GUARANÍ

Ear photograph, Figure 66
Ear diagram, Figure 79.3
Internode pattern, Figure 75
Tables 25 to 27

The main feature of this race is the fact that aleurone and endosperm do not contain any yellow pigments, but the former may or may not contain anthocyanin. Otherwise the kernels have the same shape and texture (floury) as those of *Avatí Morotí,* the ordinary Guaraní field corn.

Ear: The ceremonial race does not differ extensively from the ordinary *Avatí Morotí.*

Kernel: Slightly shorter than those of the *Morotí,* but otherwise show no significant differences.

Tassel: On the whole this shows the same aspect as that of *Avatí Morotí,* except that the coverage by the last leaf sheath is still more pronounced. With a mean of 1.09, almost half of the plants in any sample will have the tassels partially enclosed in the leaf sheath. There is a slight increase in the number of first order tassel branches.

Plant: Again the similarity, or even identity, between the ceremonial maize and the field corn of the Guaraní is quite evident.

Internode pattern: The same tendency as before is evident: increase in internode length well beyond the ear-bearing node, followed by a decrease in internode length. A new increase may or may not occur just below the tassel.

Origin and relationships: There can be no doubt that the ceremonial corn *Avatí Djakaira* belongs to the group of the *Guaraní Soft Corn.* We cannot explain why the Guaraní preferred as a ceremonial maize only material where the yellow coloration of the field corn is absent. It is also quite interesting that—at least in some Guaraní tribes—the ceremonial maize is maintained in two forms, one with completely colorless (white) kernels and the other with segregating black, red, and white kernels.

21 AND 22. AVATÍ PICHINGÁ AND PICHINGÁ IHÚ

(*Guaraní Popcorn*)

Ear photographs, Figures 69 and 70
Ear diagram, Figure 80
Internode pattern, Figures 76 to 78
Tables 28 to 30

There are two main types of *Guaraní Popcorn,* which are easily distinguished:

(a) one with pointed kernels, *i.e.,* with a sharp upturned beak

FIG. 69. Avatí Pichinga is the popcorn of the Guaraní area and is easily recognized by its pointed kernels and salient rows. The so-called "South American Popcorn" is derived from it.

at the tip of the kernel, which includes part of the base of the stigma, and frequently with salient rows, and

(b) another with closely packed kernels.

Though in general the Guaraní name for popcorn is pipoca, we also received the material with two special names: *Pichingá* for the pointed type and *Pichingá Ihú* for the round-seeded one.

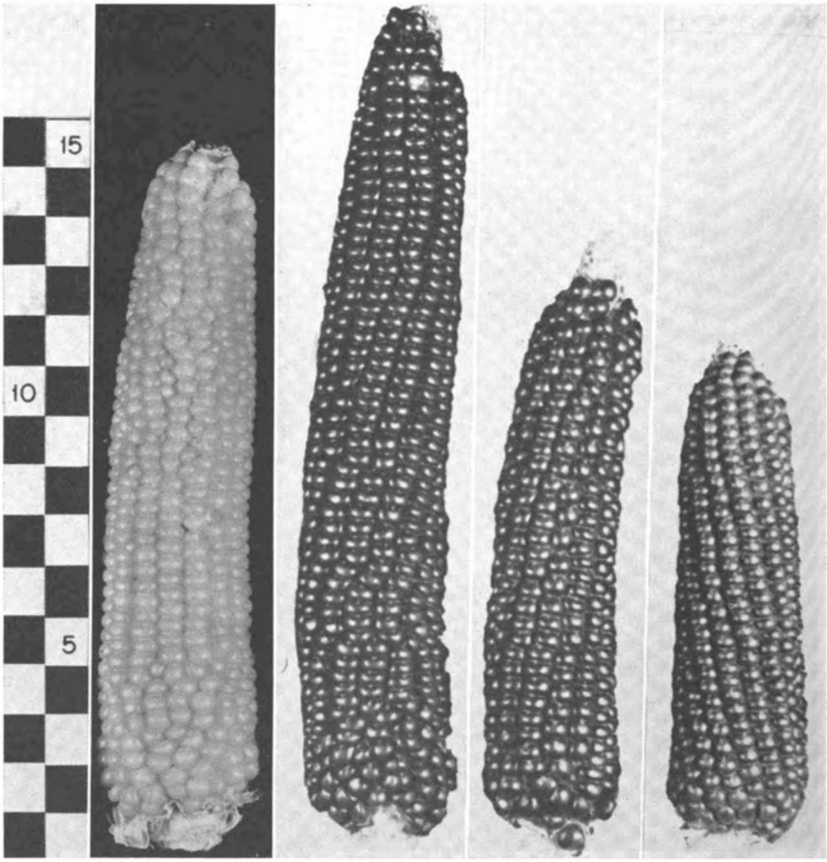

FIG. 70. Avatí-Pichinga-Ihú is a round-seeded popcorn of the Guaraní area. It has tightly packed kernels on cylindrical ears with regular rows.

There were in addition seed samples which, when cultivated, gave ears of either type plus some intermediate types, and this was repeated in subsequent generations. As the photographs show very clearly, the pointed *Pichingá* and the round-seeded *Pichingá*

Ihú are very distinct. However, most measurements showed up differences which might distinguish the races.

Ear and Kernel: Of the 12 comparisons of the error component "between races or subraces," all but three can be considered as statistically quite insignificant. *Round Popcorn* has longer ears (mean 15 cm.) than the *Pointed Popcorn* (mean 12.3). There is some difference in the thickness of the kernel and the glume cover index varies from 48 per cent for the *Pointed Popcorn* to 59 per cent for the *Round-Seeded Popcorn.*

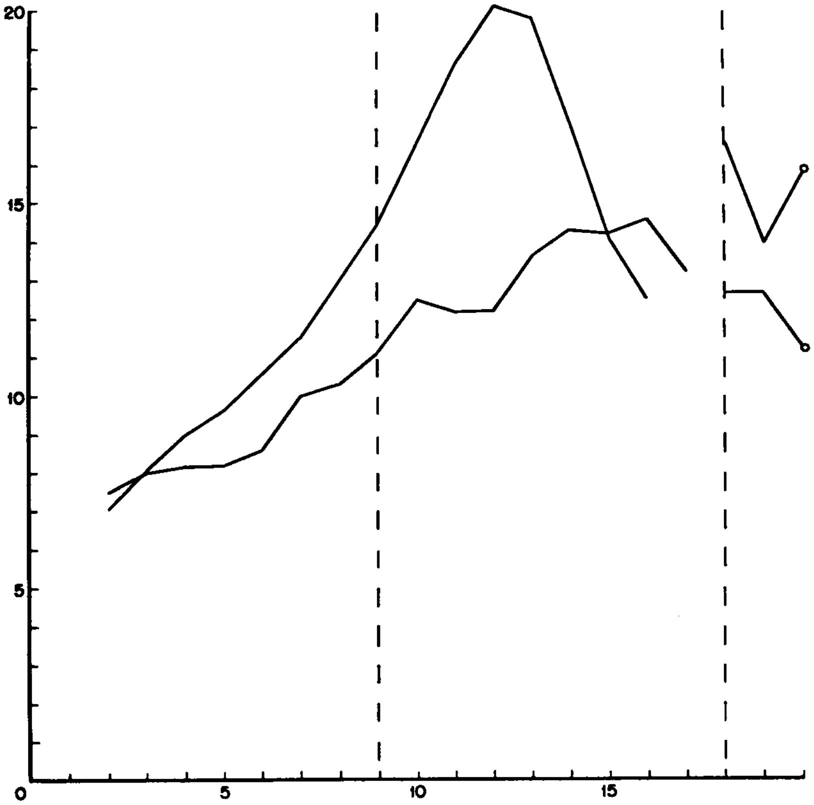

FIG. 71. Internode pattern of Avatí Morotí.

It should be added that the endosperm of this popcorn is predominantly colorless. There are ears which segregate for black, red, and white aleurone color, though the colorless type predominates in general. The pericarp may be colorless, red, orange, or variegated.

Tassel: These are in many respects quite similar to the tassels of the field corn *Avatí Morotí* and the ceremonial *Avatí Djakaira.* With an internode cover index of 1.1, it is evident that a large proportion of the plants will have the tassels partially enclosed in the leaf sheath. There is some variation in branching of the tassel, especially a tendency for less branching in the *Round-Seeded Popcorn* than in the *Pointed Popcorn.*

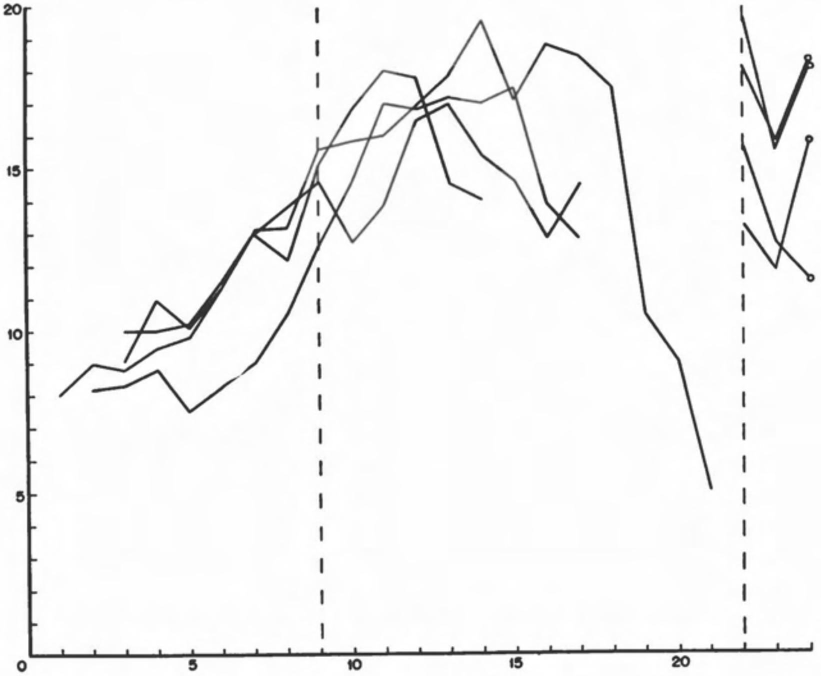

FIG. 72. Internode pattern of Avatí Morotí Tí.

There is a certain amount of heterogeneity, but the error components "between races" and "between origins of samples" are both of the same magnitude and augment the residual variation within samples only by about doubling it.

Plant: Again the two races and the segregating group do not differ statistically. The components "between races" and "be-

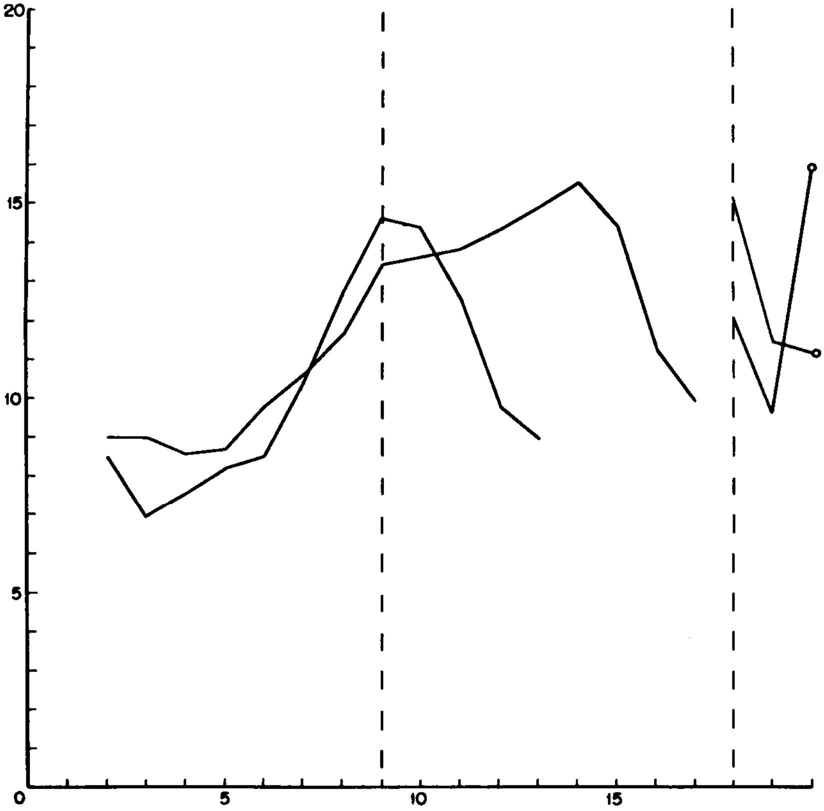

Fig. 73. Internode pattern of Avatí Morotí Guapí.

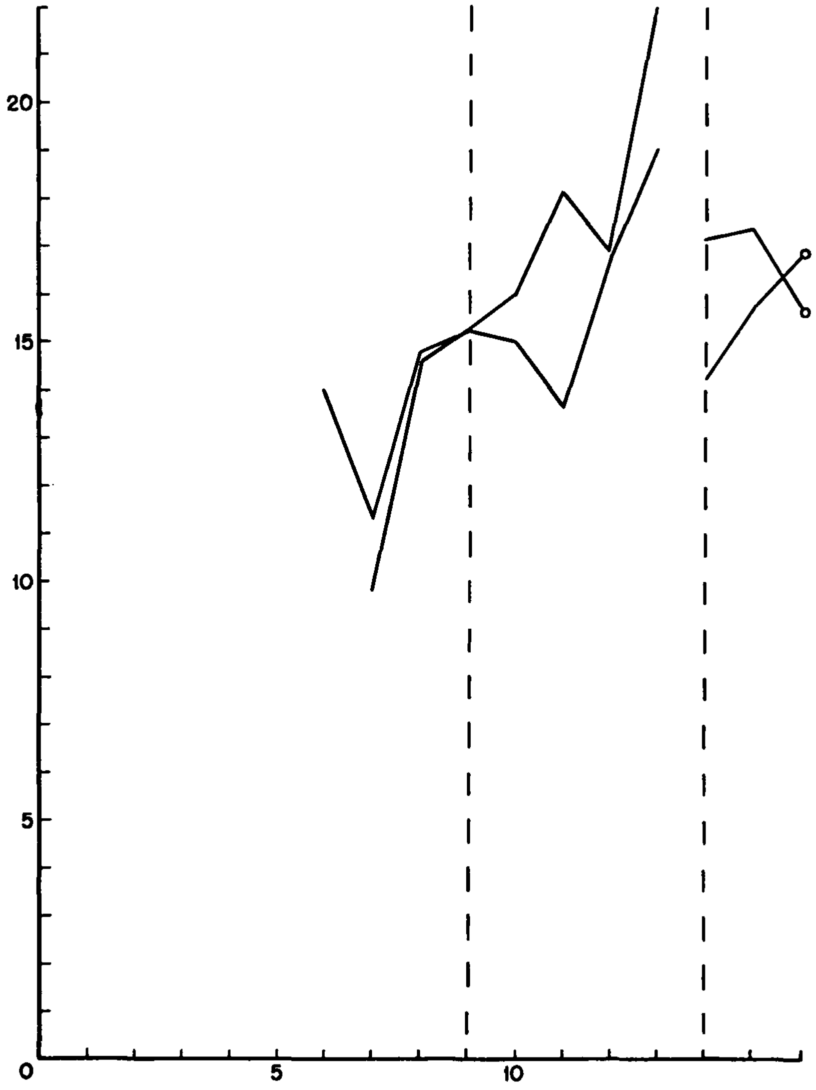

FIG. 74. Internode pattern of Avatí Morotí Mitá.

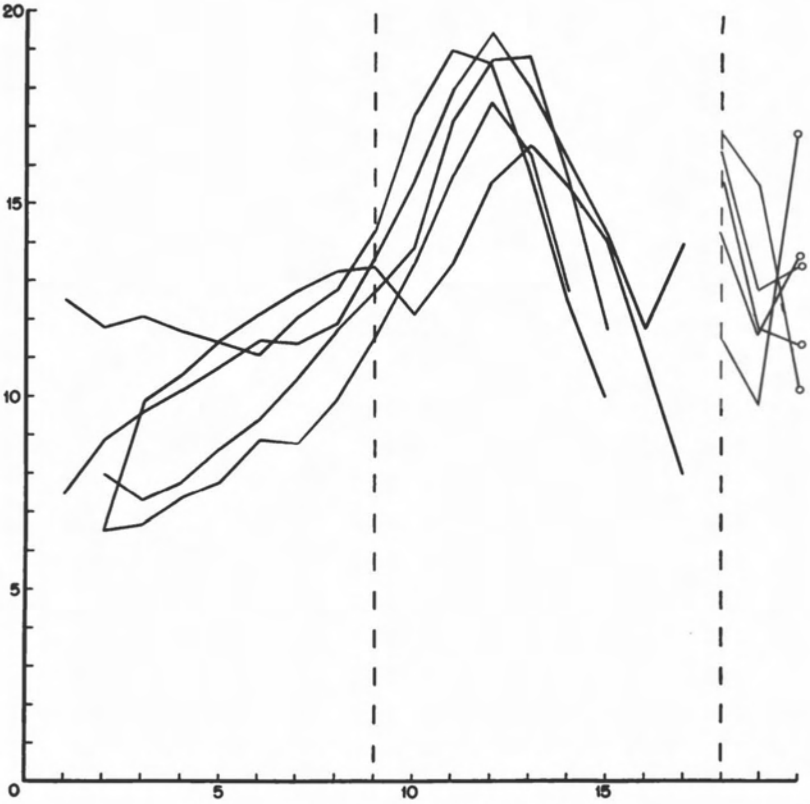

FIG. 75. Internode pattern of Avatí Djakaira.

tween origins of samples" vary to the same extent and this causes an increase of about 3 to 4 times in the general variability.

The ears are borne at about the end of the second third of the plant (58 per cent) and there are more leaves below than above the ear.

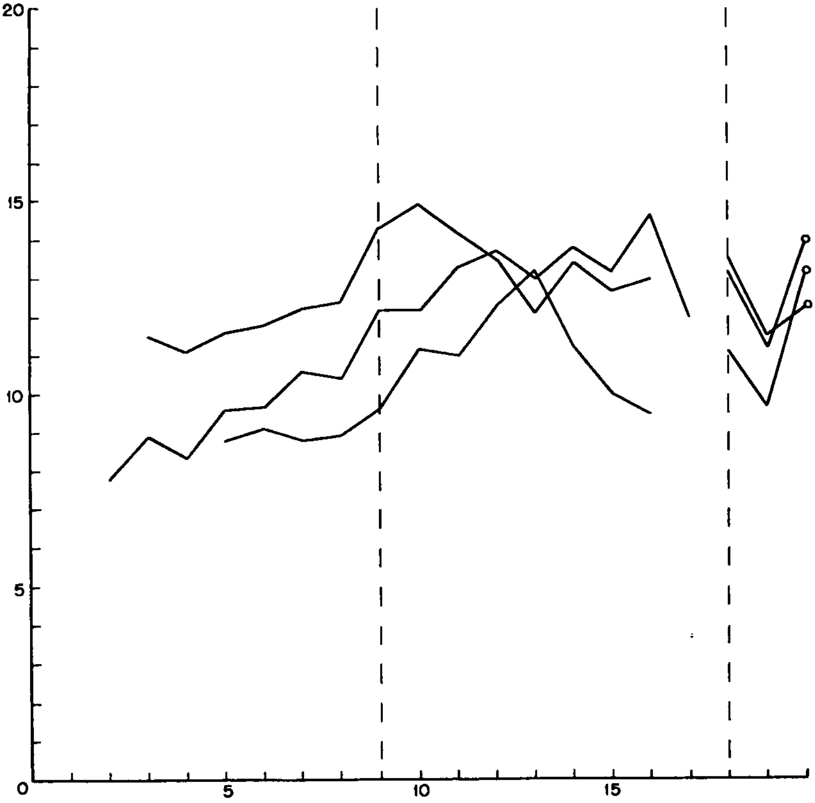

FIG. 76. Internode pattern of Pipóca Pontudo Avatí Pichingá.

Internode pattern: The diagrams in Figures 76 to 78 show the same general tendency as for all other Guaraní races: an increase of internode length well beyond the ear-bearing node, mostly followed by a decrease of internode length in the last few internodes. The last internode below the tassel always showed an increase in the popcorns.

Origin and relationships: These popcorn races have an aspect

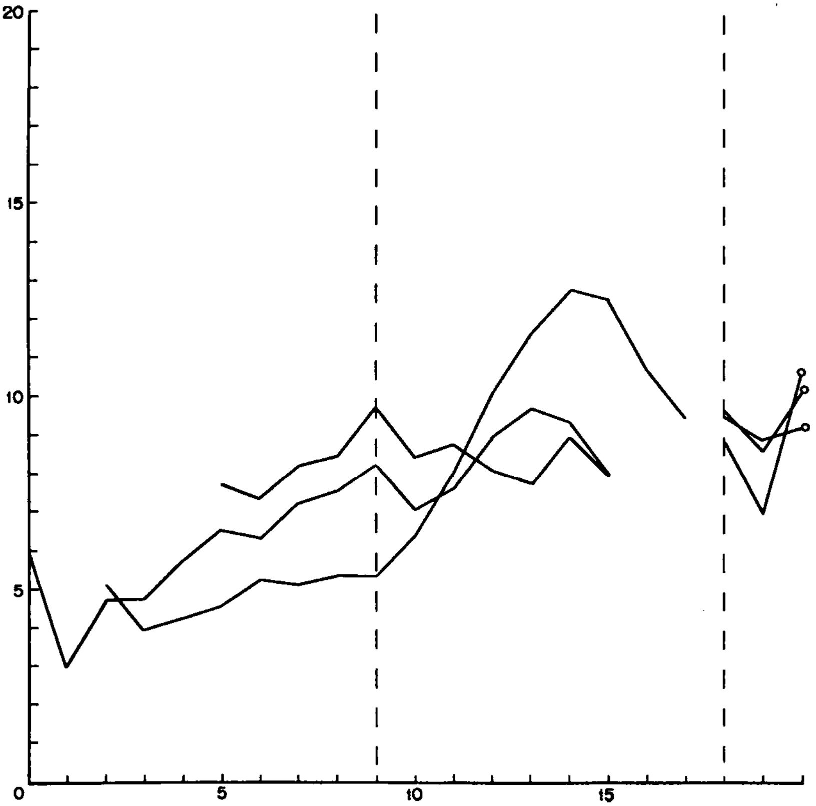

Fig. 77. Internode pattern of Pipóca Redondo Avatí Pichingá Ihú.

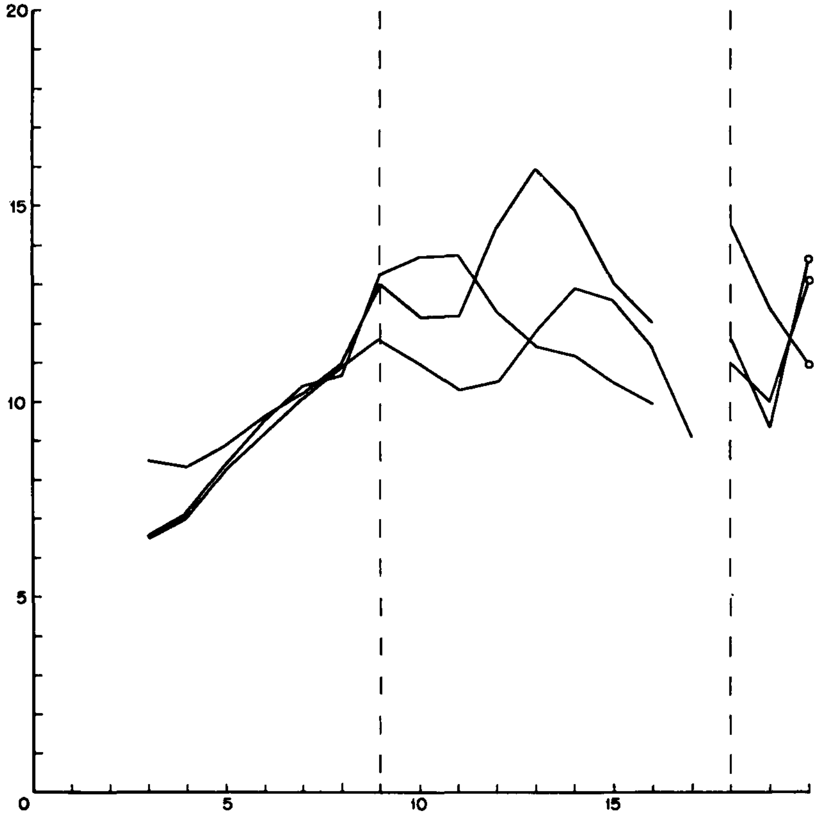

FIG. 78. Internode pattern of Pipóca Mixto.

of something rather "primitive," though it is quite difficult to state objectively in what this "something" consists. We may mention the strong tendency for the ears to terminate in a very thin rachis which carries only male flowers. One might also cite the "tunicatoid" characters, such as a high cob-rachis index (mean 2.0), the length of the glumes (about 4 mm.), and the high glume coverage of the kernels (from 48 to 59 per cent of the kernel). The last frequently becomes quite apparent in the Pointed Popcorn, owing to the shape of these kernels, which make the cob surface partially visible. But it must be remembered that practically all Guaraní races have these characters in common. Thus, if one should tend to consider these characters, not as a special racial peculiarity but as primitive, then the whole group of Guaraní maize must be considered as primitive, an opinion which hardly seems acceptable.

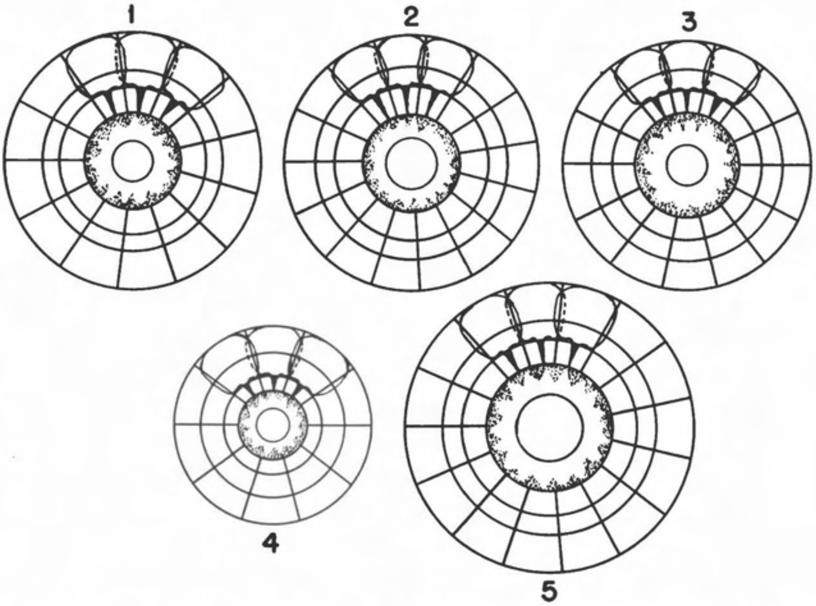

FIG. 79. Diagram, cross-section of: 1) Avatí Morotí; 2) Avatí Morotí Tí; 3) Avatí Djakaira; 4) Avatí Morotí Mitá; 5) Avatí Morotí Guapí.

The close association of two quite different popcorn types, the round-seeded and the pointed, is also peculiar. It must be remembered that both these popcorn races are geographically quite isolated and form part of what we called the "relict pattern" of the geographic distribution of the popcorn races. Thus we can only say that, for some reason of their own, the Guaraní Indians maintained two old popcorn races, different in ear pattern and kernel shape. They have become finally identical in all characters except some ear and kernel characters. They have also acquired many characters of the ordinary field corn.

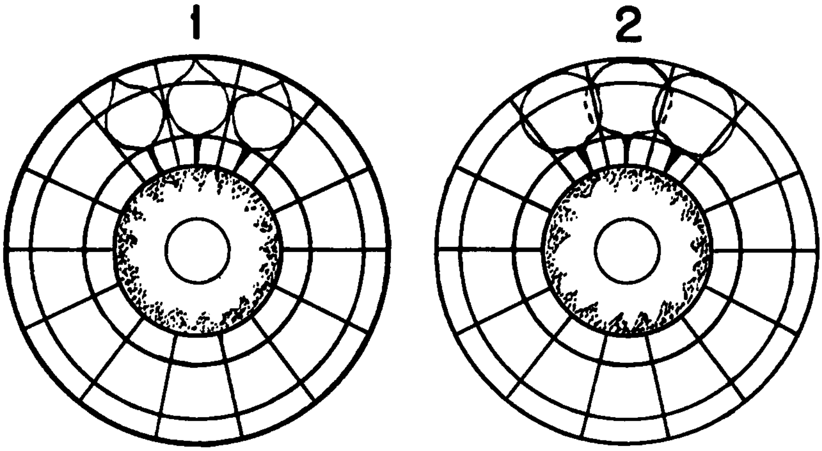

FIG. 80. Ear cross-section diagram of Avatí Pichingá.

Maize of the Chavantes Opaié

As mentioned earlier, the Chavantes Opaié are a tribe which has become extinct only during the last twenty years. Luckily we received some ears of their maize in time, though at a period before the creation of the "Maize Center," and thus before the methods of describing maize races became fully established.

23. CHAVANTES WHITE SOFT CORN

Ear photographs, Figure 81
Ear diagram, Figure 82
Table 31

Ear: Unusually long, on the average 25 cm. long but may reach a length of 40 cm. Row number rather low, with a mean of 14.8 and a range from 10 to 18. Ear diagram shows a slender narrow medulla (mean 0.6 cm.) and rachis (diameter 1.2); rachilla length

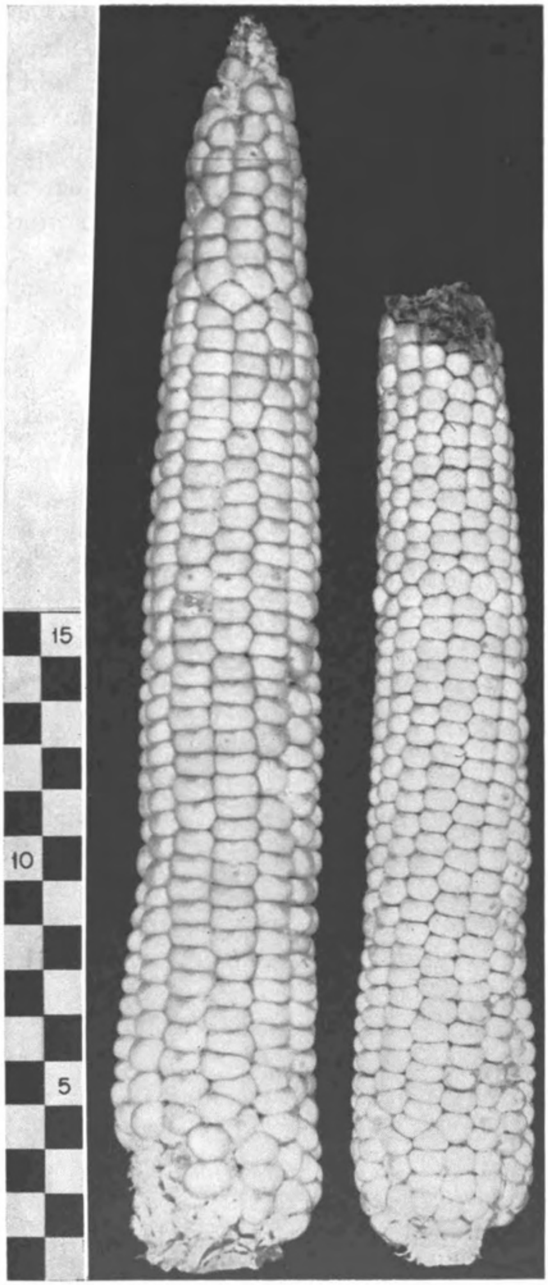

FIG. 81. The tribe of Chavantes Opaié was still an active group some 25 years ago on the border of the Brazilian States of São Paulo and Matto Grosso, but seems now to be extinct. They cultivated a very typical race of White Soft Corn, with very long ears and with no interlocking of the rows.

about 4 mm.; cob diameter 2.7 cm.; whole ear diameter 3.7 cm. Consequently the ears are rather slender. Glume length is about 6 mm.; cob/rachis index rather high, with a mean of 2.24.

Kernel: Fairly large, with a mean length of 1.0 cm., width of 0.9, and thickness of 0.6 cm. The glume coverage is quite considerable: 52 per cent of the kernel. Just as in Guaraní field corn, however, owing to the form of the kernels, which are tightly compressed, the glumes are not visible on the intact ear.

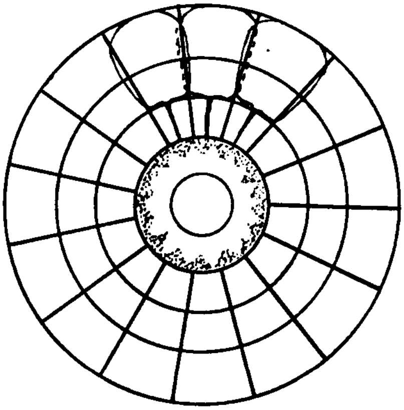

FIG. 82. Ear diagram of Opaié.

Tassel and plants: No measurements were available at the time of preparing this publication, and there was no time for growing a new crop. We may say, however, that this race has a strong tendency for the tassels to be partially covered by the last leaf sheath and that the tassels themselves are quite heavily branched. The plants were very tall and the ears were carried above the middle at about the end of the second third of the plant (about 60 per cent of plant height).

Origin and relationships: There cannot be any doubt that, as far as plant and tassel characters are concerned, the *Chavantes White Soft Corn* is related to the *Guaraní Soft Corn,* having about the same characters. We find again the long rachilla and the other "tunicatoid" characters, very high cob/rachis index, long glumes, and strong glume coverage on the kernels.

The general shape of the kernels and their texture are also the same as in the Guaraní field corn, but for some reason the Chavantes Opaié preferred white maize, without any color except occasional rare coloration of the pericarp, and never with the orange aleurone color of the Guaraní and many other South American races of soft corn.

Races With Very Thick Cob

During our collecting activities, it became evident that in the two southernmost States of Brazil, St. Catarina and Rio Grande do Sul, and also in Uruguay, a source must have existed which gave a very strong and thick cob. In this area all Indian tribes have become "assimilated," *i.e.*, they have disappeared completely, and the material with heavy cobs belonged in a general way to the *Cateto* group, at least as to kernel texture and coloration. There was, however, one exception: very uniform material which we found in cultivation in a small area in southern Brazil and to which we gave the name "Lenha" (which means firewood), since this is the use made of these cobs.

24. WHITE SOFT CORN LENHA

Ear photograph, Figure 83
Ear diagram, Figure 85
Internode pattern, Figure 84
Tables 32 to 34

Ear: Cylindrical or slightly tapering, generally with a large tip owing to a terminal fasciation. They are not very long in comparison with their thickness (mean length 18.5 cm.). Row number high, with a mean of 22.5 rows and a range from about 16 to 28 rows. The most remarkable feature, however, is the ear diagram. The very large medulla (diameter 1.9 cm. on the average) is for the most part hollow on fully mature or dry ears. The outer part of the rachis is rather thin: rachis diameter 2.8 cm. and difference between rachis and medulla only 0.45 cm. As can be clearly seen in the photographs, the rachilla is extremely long, with a mean diameter at kernel base of 3.9 and an average rachilla length of 5.5 mm., the highest value found for any race. The cob is not much enlarged, with a mean diameter of 4.4 cm., and a difference between cob surface and kernel base of only 2.5 mm. The diameter

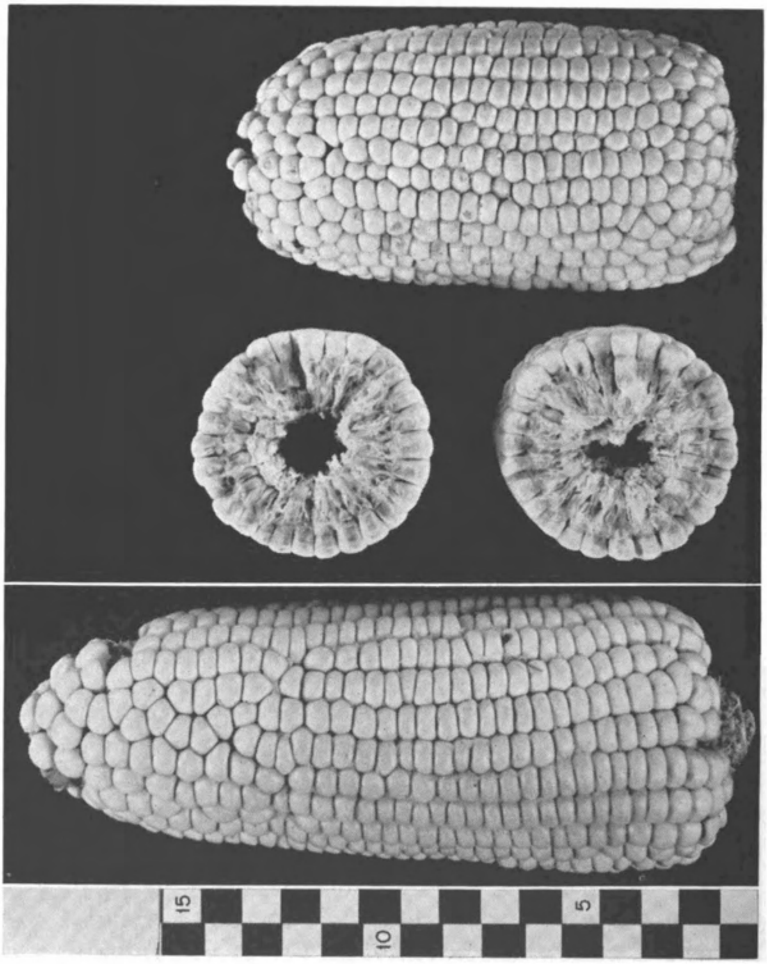

FIG. 83. Lenha—Sta. Catarina.

of the whole ear is 5.9 cm. on the average. Owing to the peculiar situation in these ears, we have a rather high cob/rachis index of nearly 2.0, mainly in consequence of the length of the rachilla. Though the glumes are rather long, on the average about 5.2 mm., they do not contribute very much to the cob diameter since they are, as usual, inserted on the very long rachillas, often rather near their base.

Kernel: The usual size of the South American soft corn, with mean length of about 1.1 cm., width of 0.8 cm., and thickness of 0.4 cm. Glume coverage is fairly pronounced, with about 32 per cent of the kernels protected by the glumes.

Tassel: Does not show anything extraordinary and the value of the means may be seen in Table 33 . It should be stated, however, that Lenha does not fit in with the other Soft Corn races just described. The internode covering index is rather high (mean 1.42) which means that about a third of the internode is free of the leaf sheath, and the tassel is thus completely free.

Plants: Fairly tall, with a mean height of more than two meters (mean 2.05 cm.) and having the ear borne about in the middle (51 per cent of plant height) of the plant. Leaves are rather numerous and large.

Internode pattern: Of the two samples illustrated in Figure 84, one shows the usual behavior, with two maxima of internode length, one just below the ear-bearing node and the other just below the tassel. The other diagram is rather abnormal since internode length remains rather constant above and below the ear, before the reduction in length between the ear and the tassel sets in.

Origin and relationships: Since we did not find *Lenha* in the hands of any existing Indian tribe, we cannot say much about it. However, it seems highly unlikely that any white settler would have carried out a special breeding project to obtain such an absurd type. Furthermore, the fact that similarly large ears are not too uncommon in the general area in question and were found only in this general area from southern Brazil to Uruguay makes us believe that we are dealing with the remains of an old indigenous race. According to the nature of its kernels, it belongs to the group of South American flour corn, but in its tassel and plant characters it agrees rather with the other races of the same geographical area in which *Lenha* occurs, namely the *Southern Cateto Flint.*

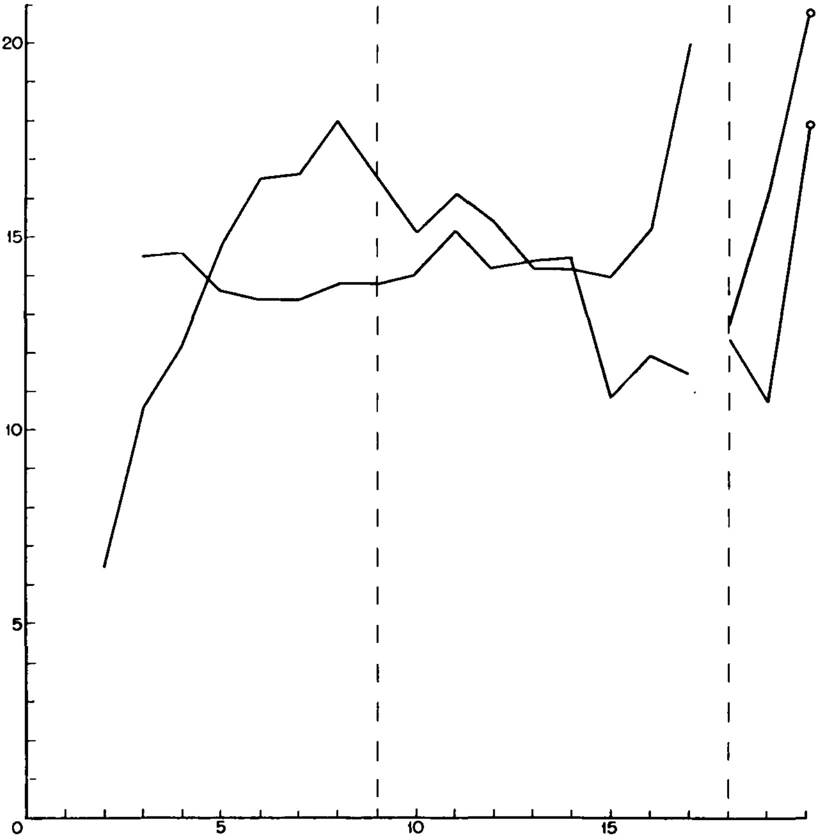

FIG. 84. Internode pattern of Lenha.

The Caingang Races

The races still grown by the Caingang Indians, the former inhabitants of the states of São Paulo, Paraná, and St. Catarina, have been fully described by Paterniani (1955) and the following description is based on his paper. The Caingang cultivate only one type of maize: a rather soft dent corn with white endosperm and aleurone, and sometimes with red or variegated pericarp. Another race was also collected which, as shown above, is clearly a synthetic between some *Guaraní Soft Corn* and *Caingang Dent.* These Indians also grow some *Cateto,* which they do not use themselves, but sell.

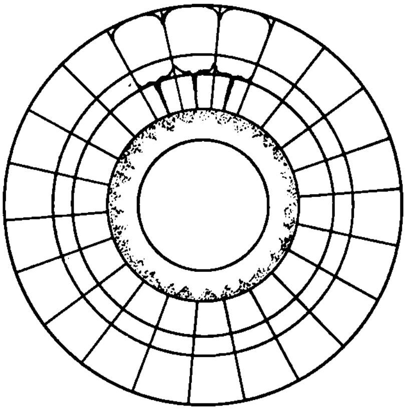

FIG. 85. Ear diagram of Lenha.

25. CAINGANG WHITE DENT AND ITS SUBRACES

Ear photographs, Figures 86 to 89
Ear diagram, Figure 91
Internode pattern, Figure 90
Tables 35 to 37

Ear: Rather perfect cylindrical ears, which are also quite long (mean length 19 to 20 cm.). Row number not high, with a mean of 11.8 for the subraces from São Paulo and of 12.6 for the subraces from Paraná, with a range roughly from 8 to 16.

The statistical analysis of subraces and geographic groups of races showed the following: The difference between ear characters of geographic groups is statistically highly significant and corresponds to an increase of variability by 5 to 10 times. The difference of subraces within groups is also statistically significant, but of a much smaller order, increasing variation only by about 3 to 6 times. Finally, there is also some heterogeneity within subraces, which increases variability at the most by 2 to 3 times. Since the differences between subraces are numerically not very great, we may limit the discussion to the data for geographic groups.

Paulista Caingang has a rather narrow medulla (mean 0.6 cm.); rachis diameter 1.36 cm.; at kernel base 1.98; rachilla about 3.5 mm.; cob diameter 2.63; glume length about 4.6 mm.; total ear diameter 4.1 cm.

Paraná Caingang has somewhat larger ears: medulla 0.7 cm.; rachis 1.5 cm.; rachilla length about 4 mm.; glume length about 5 mm.; cob/rachis index 1.95 for both groups.

Kernel: There is no difference between groups for kernel length and width and only a very slight difference in thickness: mean length 1.1 cm., width 1.0 cm., and mean thickness 0.5 cm. The glume covering of the kernel varies slightly from 30 to 36 per cent.

Tassel: Here the differences between groups are not quite so pronounced. Of the eight characters studied, the differences of these are statistically not significant, and in the remaining five, heterogeneity between groups corresponds to an increase in variability of about 3 to 7 times the residual error. Within groups, *i.e.*, "between subraces," there is on the average an increase of variability from 2 to 5 times. Thus there is perhaps not much justification for treating the groups separately, and one may perhaps better study the subraces directly. However, variation within subraces shows a slight heterogeneity, and the variability is at most about doubled.

It is interesting to note that *Paulista Caingang* has an internode covering index of about 1.19 while that of *Paraná Caingang* is slightly higher—1.31. If we would carry out calculations similar to those done with *Guaraní Soft Corn* we would find that for the *Paraná Caingang* about one-fourth of all plants of a sample have the last internode and in addition a portion of the tassel completely covered by the leaf sheath, while in *Paulista Caingang* nearly 40 per cent of the plants of a sample will have this condition. In both groups, the branched part of the tassel corresponds to about 40 per cent of the whole tassel and there are about twenty-one primary and eight to ten secondary tassel branches.

Plant: Again there is at least a partial difference between the two geographical groups, corresponding to an increase of variability by about 15 times, while the increase "between subraces" is only of the order of from 3 to 6 times and that "within subraces" is 5 to 10 times. The total plant height is about the same for all, but the ear stands much lower in Paraná races than in Paulista races. In the former it stands about in the middle of the plant (52 per cent) and in the latter about near the end of the second one-third (61 per cent).

Internode pattern: This is quite uniform for all subraces of *Caingang Dent,* as shown by Paterniani (1955), possessing the characteristic bimodal diagram, with one maximum in the internode just below the ear and the other just below the tassel (Fig. 90).

Origin and relationships: The origin of *Caingang White Soft Dent* is in a way a mystery. As we have pointed out on several occasions, genes for denting are scattered in many races, for instance in the *Guaraní Soft Corn* which is cultivated in an area quite near to that of the *Caingang Dent.* But why the Caingang Indians gave preference to this type of corn, and in white color, cannot be explained. Neither can the relative importance of the subraces be fully understood. Though they differ to some extent in quantitative characters, their appearance is also different, as can be seen in Figures 86 to 89. For instance, the denting in *Icatú* and *Ivaí* is quite different, and the denting is only slight in *Manguerinhos* or *Vanuirí.* These subraces could either be incipient new races, in an agriculture which did not develop further after the penetration of the white man, or they could be disappearing races in an agricultural organization which has broken down almost completely and is only maintained, more or less artificially, in Indian reservations.

The existence of the *Caingang Dent* in southern Brazil, while similar dents only reappear in northern Colombia, where they have perhaps been under the influence of the Mexican and Central American indigenous breeding activities, is in our opinion one of the most outstanding facts showing the efficiency of indigenous and pre-Columbian plant breeding.

Caingang Dent certainly belongs, at least in the following characters, to the group of South American Soft Corn: the enclosure of the last internode and even part of the tassel within the last leaf sheath and, in a lesser degree than the Guaraní races, the "tunicatoid" characters, *i.e.,* cob/rachis index near 2.0 and glume covering

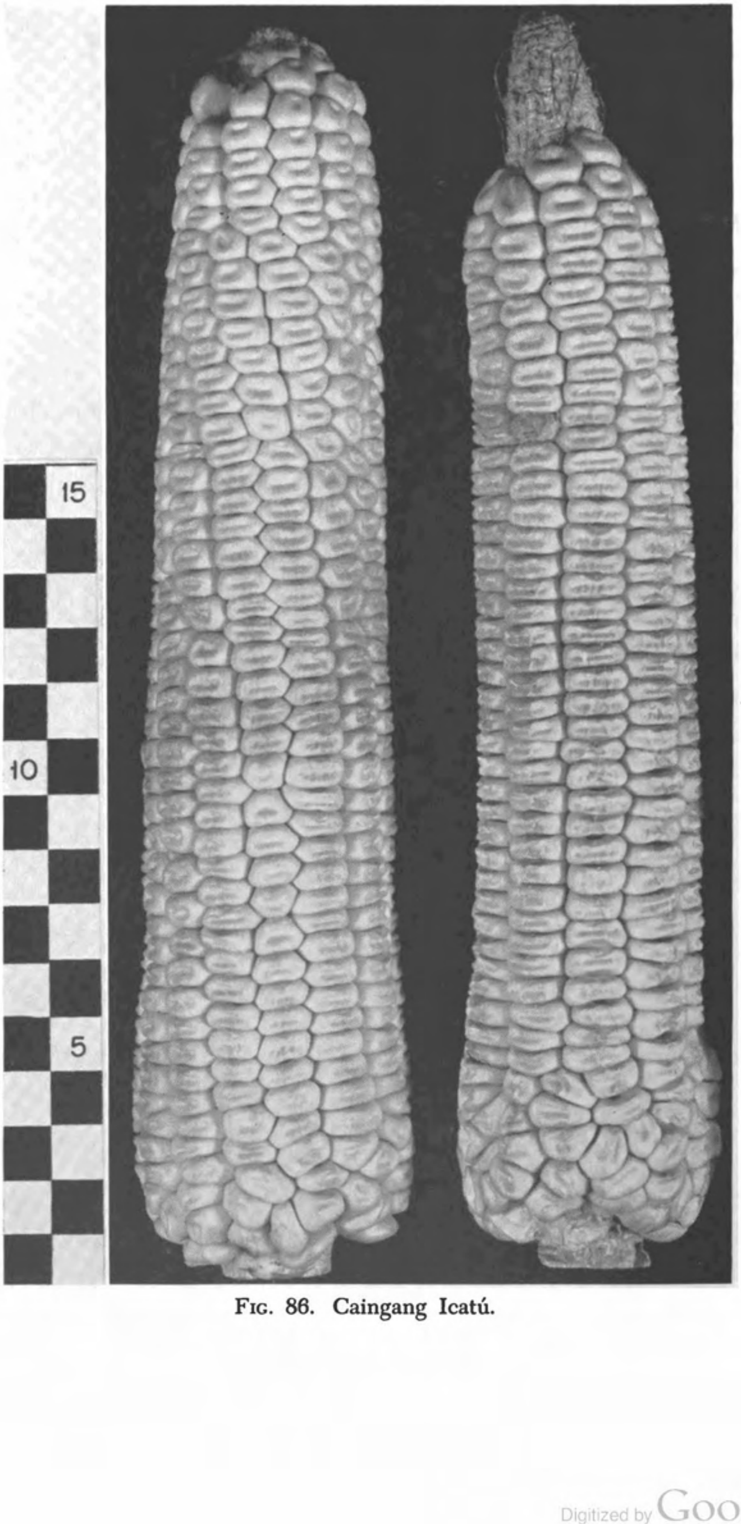

Fig. 86. Caingang Icatú.

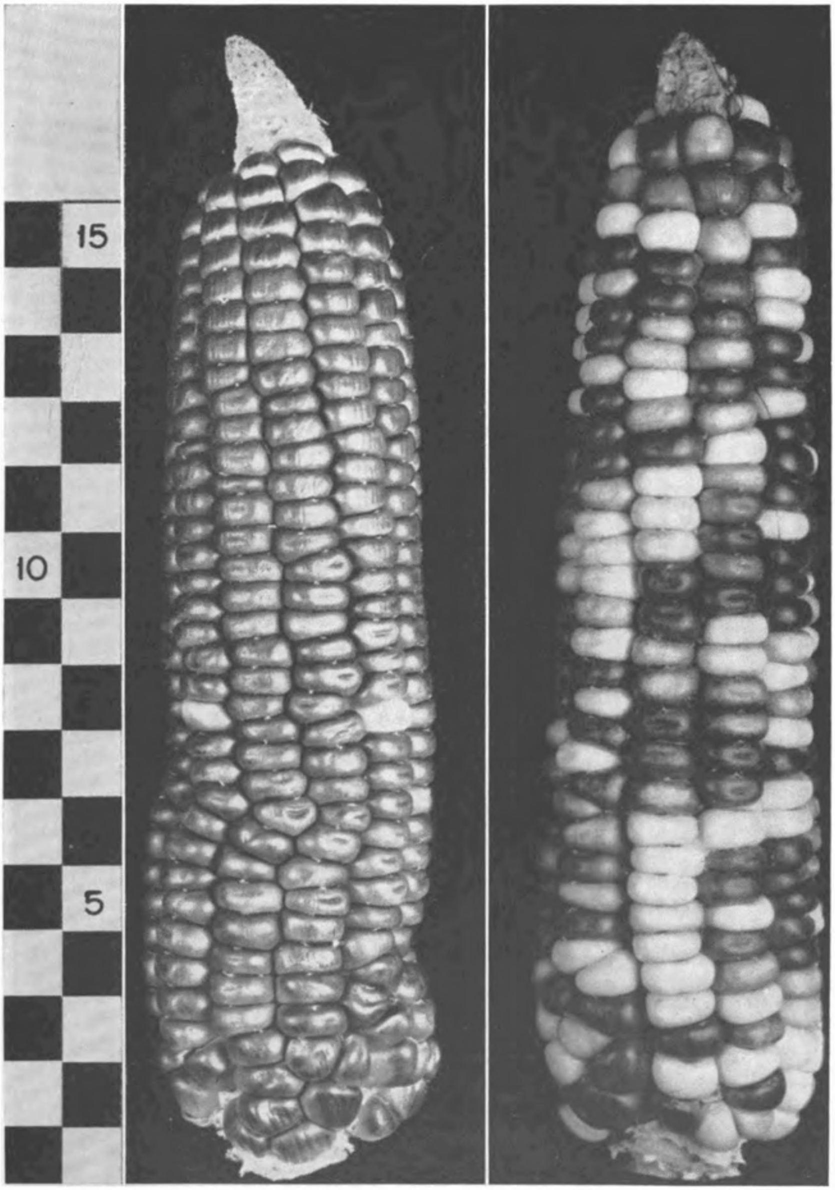

FIG. 87. Caingang Vanuirí.

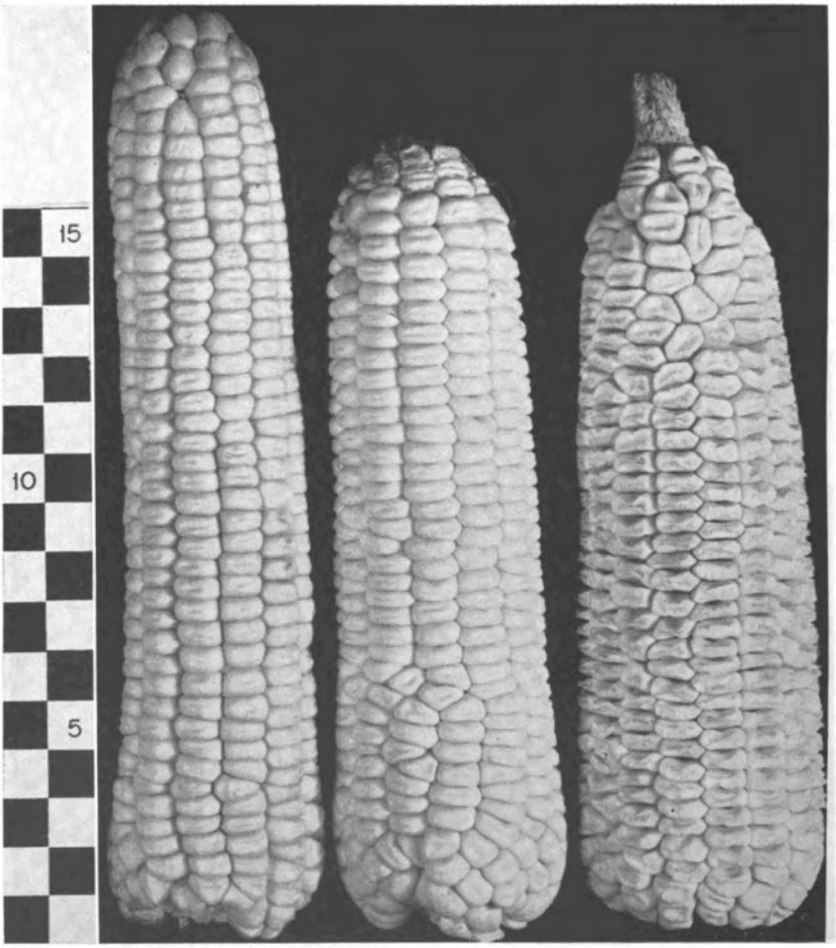

FIG. 88. Caingang Ivaí.

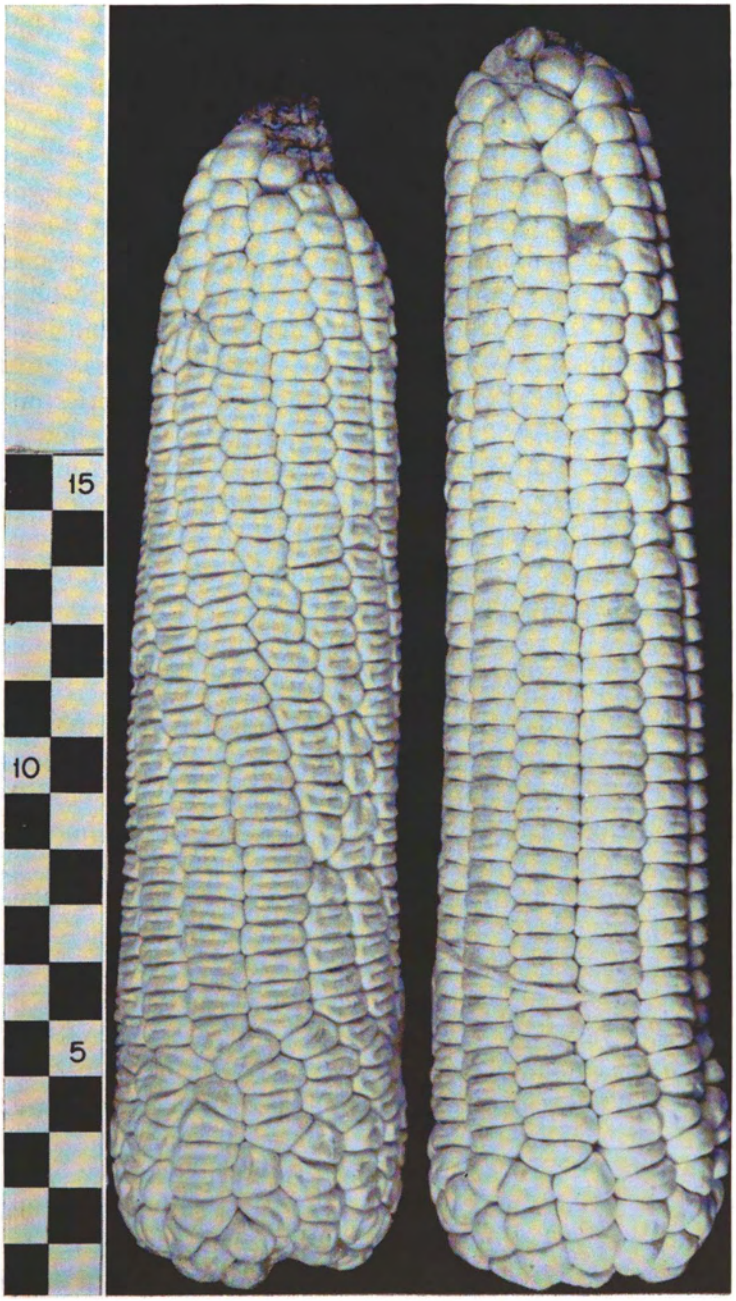

Fig. 89. Caingang Apucarana.

of about 30 to 35 per cent. Glume length is considerable (4.6 mm.) and so is rachilla length (3.5 mm.).

Caingang Dent is potentially very promising material for breeding work, though it has evidently never been used to any large extent. In former times it was the conviction that the main field corn should be a hard orange flint, and now when in southern Brazil the farmers prefer dent corn, they will insist that it must be as deeply orange colored as possible. Thus *Caingang Dent,* besides being too soft, has at the moment also the disadvantage of containing too many genes, not only for the inhibition of endosperm color, but also for the dilution of the color shades. Furthermore, there are already in existence fairly good varieties of synthetic *Paulista* or *Rio Grande Dent,* besides Mexican yellow dents of established value, from the tropical or subtropical area near San Luiz de Potosí, from which the Brazilian synthetics *Azteca* and *Piramex* have been derived. Thus as long as the yellow-orange dents are preferred, *Caingang* can occupy only a secondary position as breeding material.

26. SYNTHETIC IVAÍ AMARELLO

This is most probably a rather recent indigenous synthetic from the mixing of *Avatí Morotí* and *Caingang White Dent.* This synthetic has been fully described above, when we discussed the nature of synthetics in general. Since this race has no importance otherwise, we shall not go into any more detail here. If the organization and agriculture of the Caingang were still continuing, such synthetics might have attained some importance for the future.

The Southern Cateto Flints

We use the name Cateto in place of the many other names such as "Tropical Flint," "Caribbean Flint," etc. Up to a short time ago, we were fully convinced, as were the majority of authors, that this orange hard flint had originated in the Caribbean area and had expanded in pre-Columbian times along the Atlantic coast, finally reaching southern Brazil, Uruguay, and Argentina. However, this opinion can hardly be maintained any longer. It is in southern Brazil-Argentina that the group attains its maximum development and where it exists in pure form, while in the Caribbean area it seems to have a scattered distribution and is highly contaminated by other races. We have little doubt that there was in pre-Columbian times something which could be called "Caribbean Flint," but that this "Caribbean Flint" or "Northern Cateto" expanded from the south towards the north into the Caribbean area, along with Indian migrations. The Caribs, who probably migrated

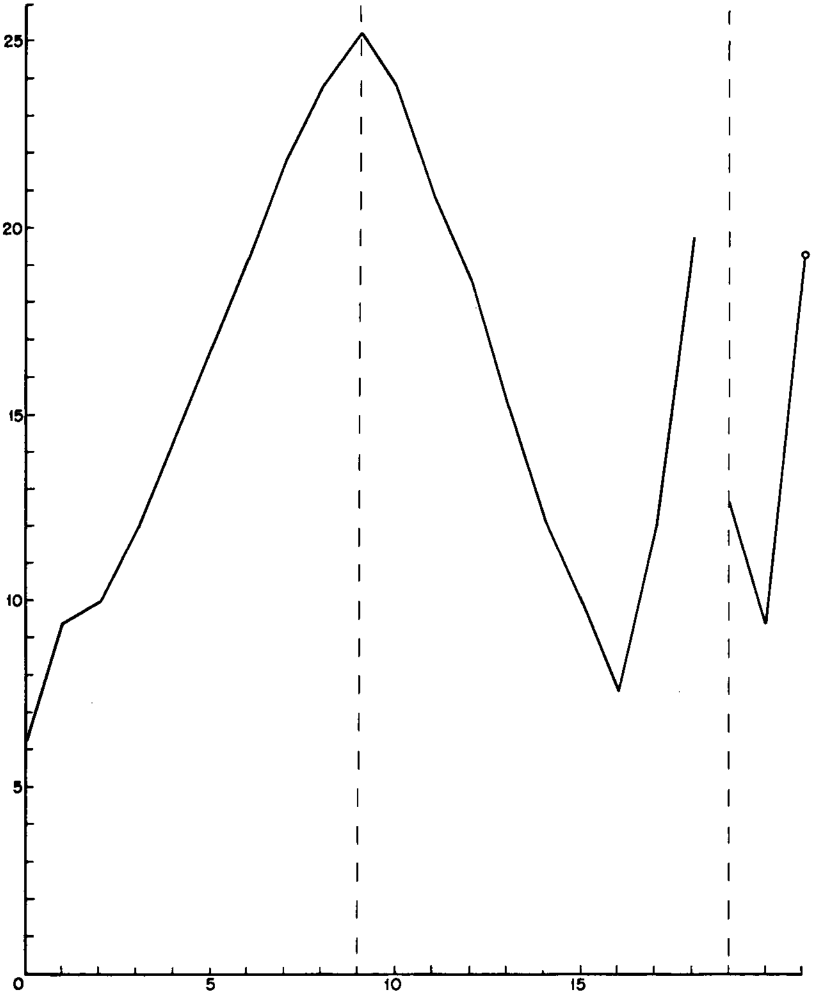

Fig. 90. Internode pattern of Caingang White Dent.

mainly from north to south, need not have been the principal elements of this expansion, though their participation is entirely possible. Such Indian migrations never were completely uniform in direction, and thus the Caribs, though on the whole migrating towards the more southern shores of the Atlantic, may, on finding there the *Southern Cateto*, have taken samples back north again.

There can also be little doubt that, at least for a long time, the maize grown in the area of the Mediterranean has been predominantly a hard orange flint, and the question of where this came from arises. Of course, up to now it was the general belief that this was "Caribbean Flint," but one should not overlook the facts: (a) that it cannot have been too easy to obtain good and at the same time rapid adaptation of the tropical material from the Caribbean area to the quite different conditions of southern Europe, while this would have been much easier with races from a southern area, Brazil or Argentina; (b) that Brazil was discovered very early and that not only the Spanish colonizer but also the Portuguese brought a lot of material from America to Europe, but that the Portuguese preferred the Brazilian shores where the *Southern Cateto* existed.

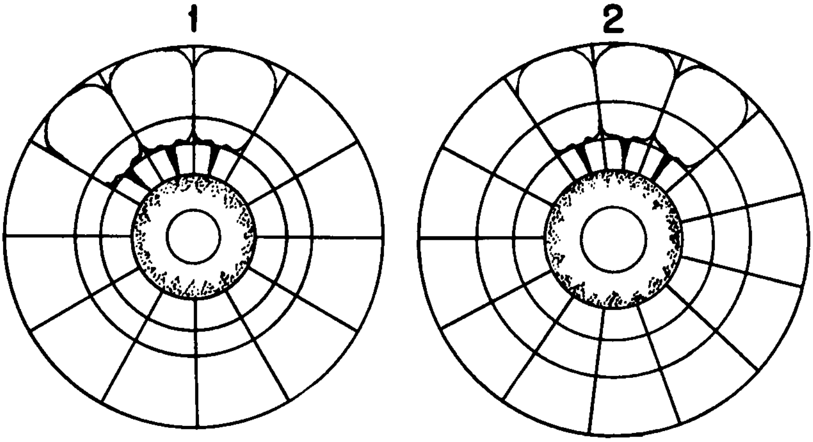

FIG. 91. Ear cross-section diagram of: 1) Caingang Paulista; 2) Caingang Paranaense.

We should also mention a belief, which has been quite generally accepted in southern Brazil and in Argentina without any substantial foundation, namely that *Southern Cateto* came originally from Italy to South America. Italian immigration started mainly during the last 50 years, and it would have been impossible that, in such a short time and over such a wide range, races so well adapted locally could have originated and become established. What probably happened is that these Italian settlers were astonished to find, in their new surroundings, types of maize so similar to that of Piedmont and other regions of Italy, and they came to the conclusion about its "Italian origin." Evidently they could not imagine that they themselves had come to the region from which the Italian races or varieties of maize had been imported in the first place.

In view of the alternative origins of the Cateto group, we shall divide the discussion and treat the *Southern Cateto* and the *Northern Cateto* as two groups.

27–32. SOUTHERN CATETO

In attempting to describe the representatives of the *Southern Cateto* group, we find a serious difficulty. There are so many commercial or agronomical types today that a complete description and classification of all of them and their arrangement into definite races would require an enormous amount of work, and also of paper, if we would try to put everything into print. In a future contribution to this problem, we intend to give as complete a description as desirable, but in the present paper we decided to limit ourselves to a few rather characteristic types, which may be considered as good races. We selected five races: *Cuarentón* and *Colorado,* both from Argentina-Uruguay, *Charua* from Rio Grande do Sul (Brazil) and *Cateto Fino* and *Cateto Grosso* from São Paulo. As far as we know, only one important type or race is lacking in this list: *Cateto Conico,* with rather short conical ears and a pronounced butt at the base.

Ear photographs, Figures 92 to 96
Ear diagrams, Figure 103
Internode pattern, Figure 101
Tables 38 to 40

Ear: The five selected races of *Southern Cateto* differ statistically only in ear length, diameter at kernel base, and diameter of

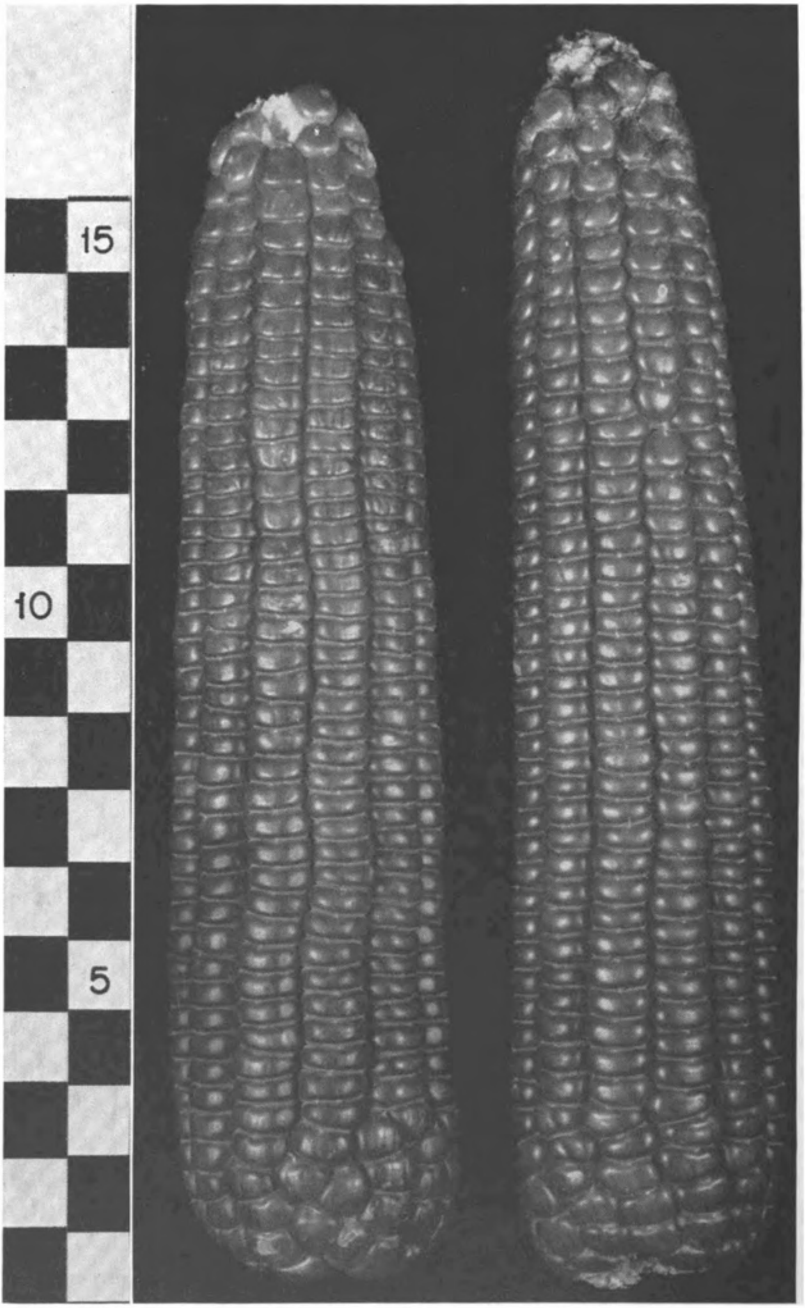

FIG. 92. The Orange Flint or Cateto group occupies nearly the whole coastal area from the La Plata to the Guianas, where it meets with the area of the Caribbean Flints. A number of races are shown in Figs. 92–97. Above is shown the very early race Cuarentino, from Argentina and Uruguay.

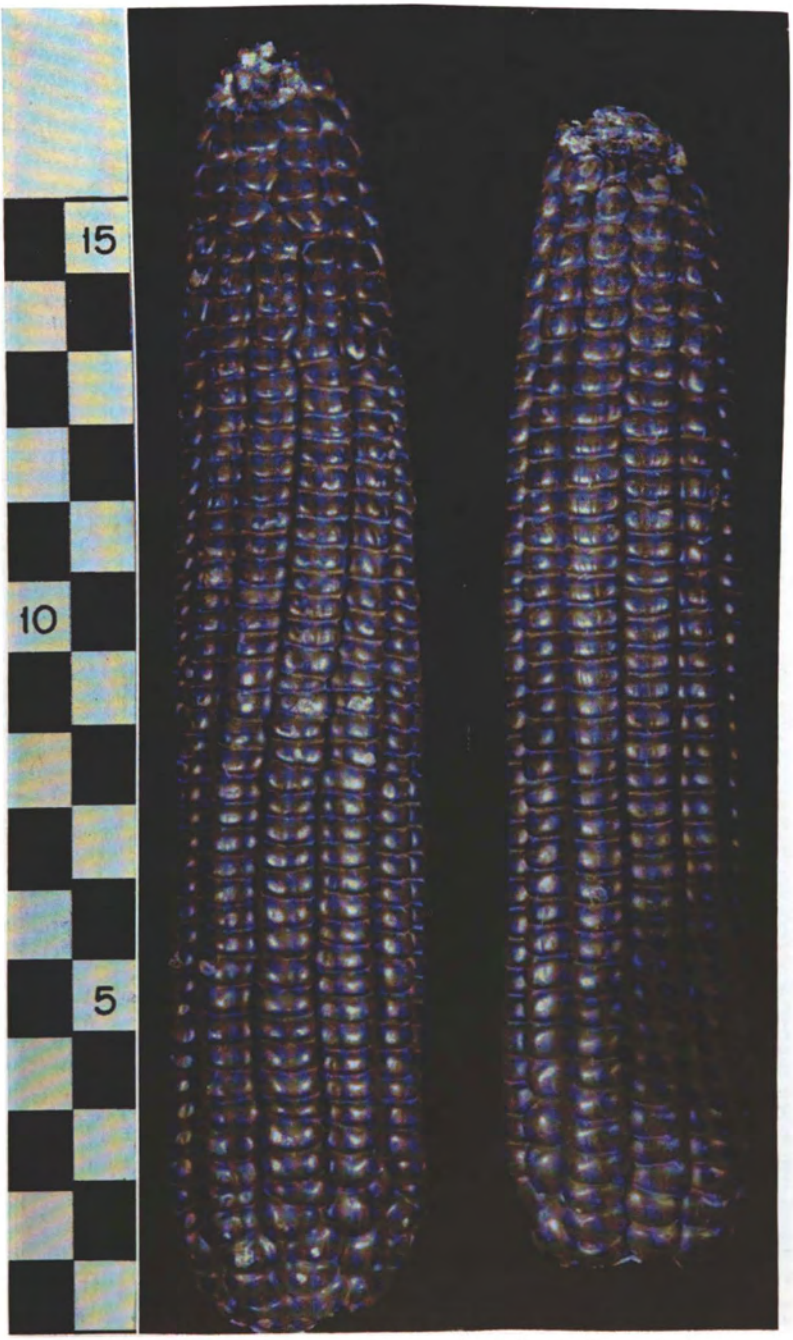

FIG. 93. Colorado, another race of Cateto from Argentina and Uruguay.

whole ear (Table 38). On the other hand, the diagrams in Figure 103 show that *Cateto Fino* especially has an aspect quite different from the others.

We have for 27, *Cuarentón*, ear length 15.3 cm.; row number 12.5, with a range from 10 to 14. Ear diagram: medulla 0.7 cm.; rachis 1.2; at kernel base 1.7; cob 2.6; whole ear 3.3; cob/rachis index 2.25. Rachilla length is about 3 mm. and glume length about 6 mm.

For the other four races, we have: medulla 0.7; rachis 1.5 cm.; diameter at kernel base 2.1 cm.; cob 2.8 cm.; whole ear 3.9. Thus, except for the medulla, all values are higher. Rachilla length is about 3 mm. and glume length about 5 mm. Cob/rachis index is only 1.86.

Kernel: Again *Cuarentón* represents the exception by having smaller kernels. Though the length is about the same for all five races (mean about 1 cm.), *Cuarentón* has a width and thickness of 0.76 cm. and 0.37 cm., while the mean for the other races is 0.94 cm. and 0.43. Glume coverage is 54 per cent for Cuarentón and for the other races 40 per cent.

Race 27: Cuarentón has extremely tightly packed kernels, so tight that the cobs dry with difficulty. The kernels are so pressed against each other that they appear almost to be angular. The orange color is intense and the endosperm extremely red.

Race 28: Colorado has tightly packed kernels, though less so than *Cuarentón*. The kernels are slightly larger, though still of the same thickness as in *Cuarentón*. The color is slightly less deep.

Race 29: Charua, from Rio Grande do Sul, is larger in all dimensions. The color is lighter and the kernels may sometimes have some soft starch.

Races 30 and 31: The two Catetos from São Paulo, *Cateto Fino* and *Cateto Grosso*, again have very hard orange kernels which appear larger than in the races from Argentina, and they are also not so tightly packed.

Race 32: Besides these five races, there are others, at least one of which was not included in the selection through an oversight: *Cateto Conico*, which has ears almost like those of *Avatí Morotí Guapí* and a very large butt at the base of the conical ear.

Tassel: As shown in Table 39, there is a certain amount of

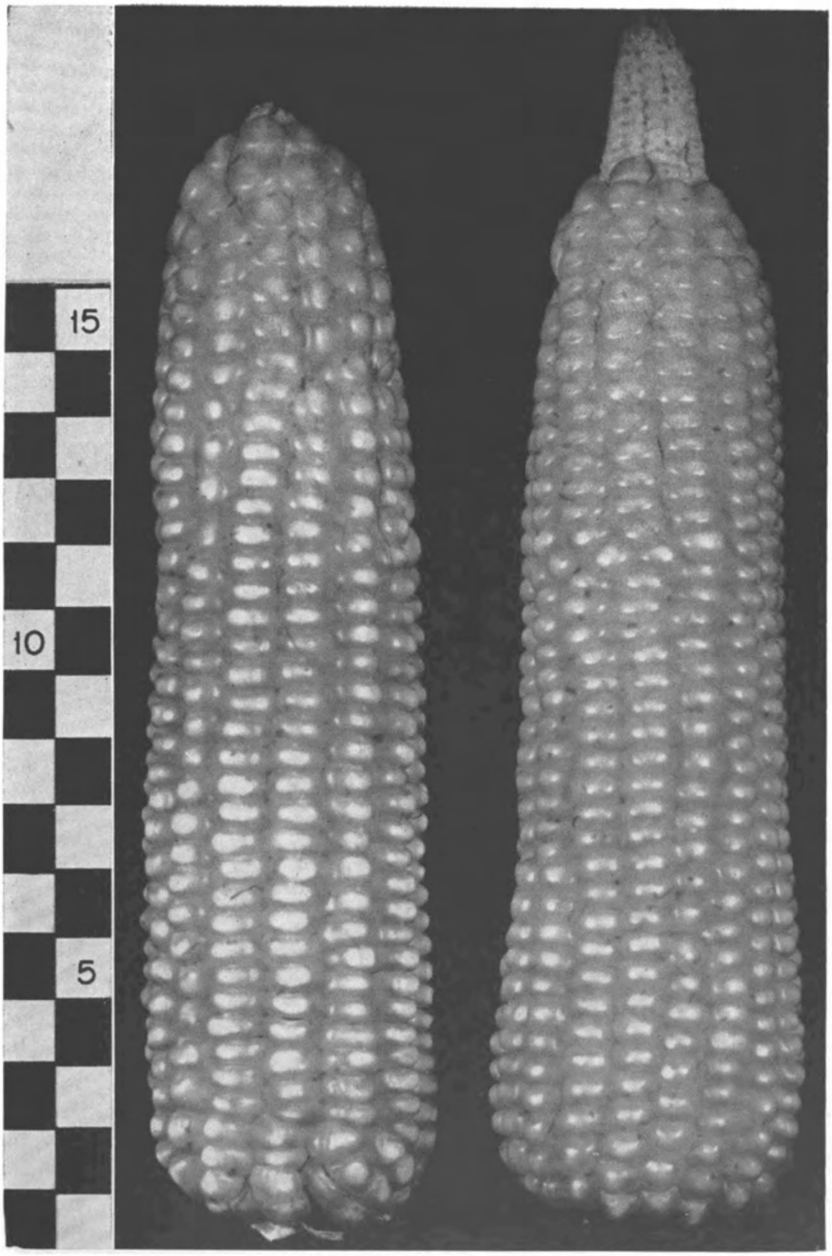

FIG. 94. Cateto Charua, from the Brazilian State of Rio Grande do Sul.

heterogeneity, though not too much. The internode covering index for the *Southern Cateto* races ranges from 1.45 (*Cateto Fino*) to 1.74 (*Colorado*), omitting the values for two synthetics, *Canario de Ocho* and *Amarillo,* which are also given in the same tables but which will be discussed separately later. These high values show that the upper part of the last internode, and thus also all the tassel, will be free of any sheath covering. The branched part of the tassel forms more or less uniformly a little more than a third of the tassel, but there is a good deal of variation in the number of tassel branches.

Plant: Whereas the tassels differ but little, each race has its special values for plant characters. Even the relative position of the ear varies from 44 per cent of plant height in *Cateto Grosso* to 63 per cent in the *Cateto Fino.* This means that the ear may be anywhere between the middle of the plant and the end of the second third. Plant height and also number of leaves are also variable characters.

Internode diagram: Here we found an astonishing uniformity as shown by the few diagrams given in Figure 101. There are two maxima, one several nodes below the ear and the other in the internode just below the tassel. Increase or decrease of internode length from these maxima is very pronounced.

Origin and relationships: We stated in the beginning of this section that we believe now that these *Southern Cateto* races originated in the southern coastal area, from Brazil to Argentina. Among the South American lowland races, the *Cateto* group is distinguished by the tassels, which are free of the last leaf sheath, by the presence of some "tunicatoid" characters such as fairly high cob/rachis ratio (from 1.89 for *Cateto Fino* to 2.25 for *Cuarentón*) and by considerable coverage of the kernels (from 34 per cent in *Charua* to 54 per cent in *Cuarentón*). The rachilla is generally rather short (about 3 mm.).

Cateto-Flint Synthetics

Considering the relatively large area over which *Cateto* races are grown, and in addition remembering the fact that we do not deal with races isolated by cultivation in indigenous agriculture but with modern commercial crops, it is to be expected that a

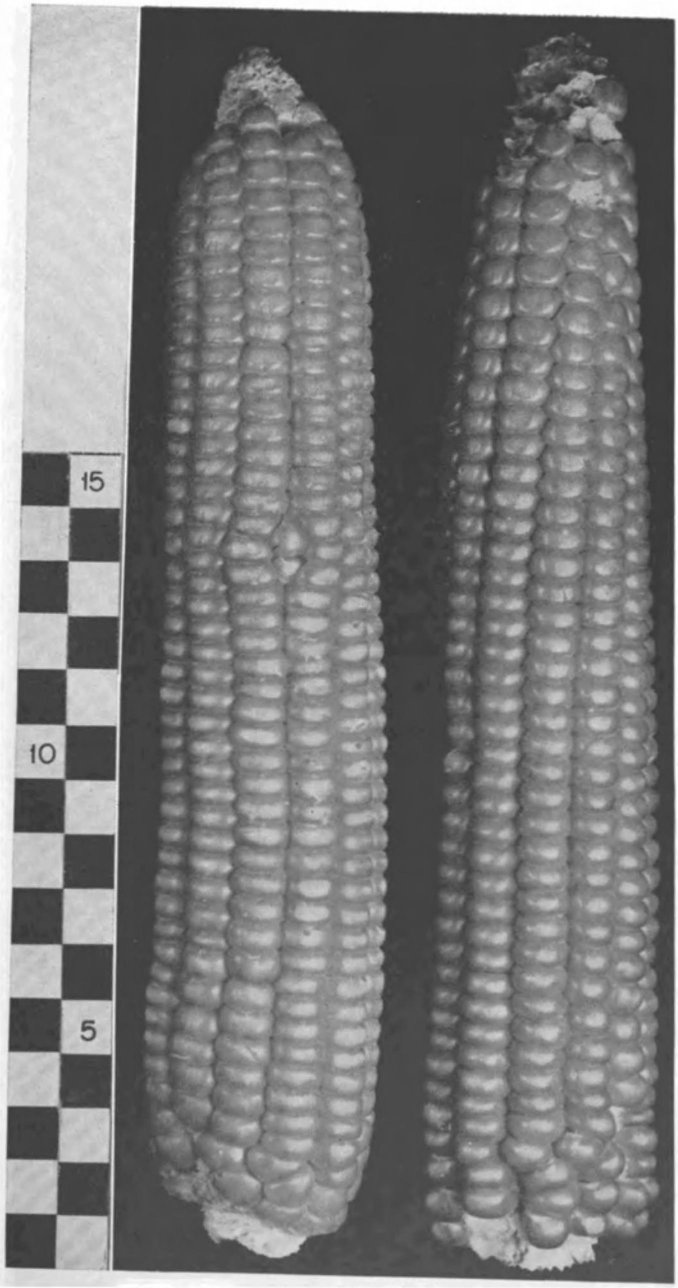

Fig. 95. Cateto Grosso from São Paulo.

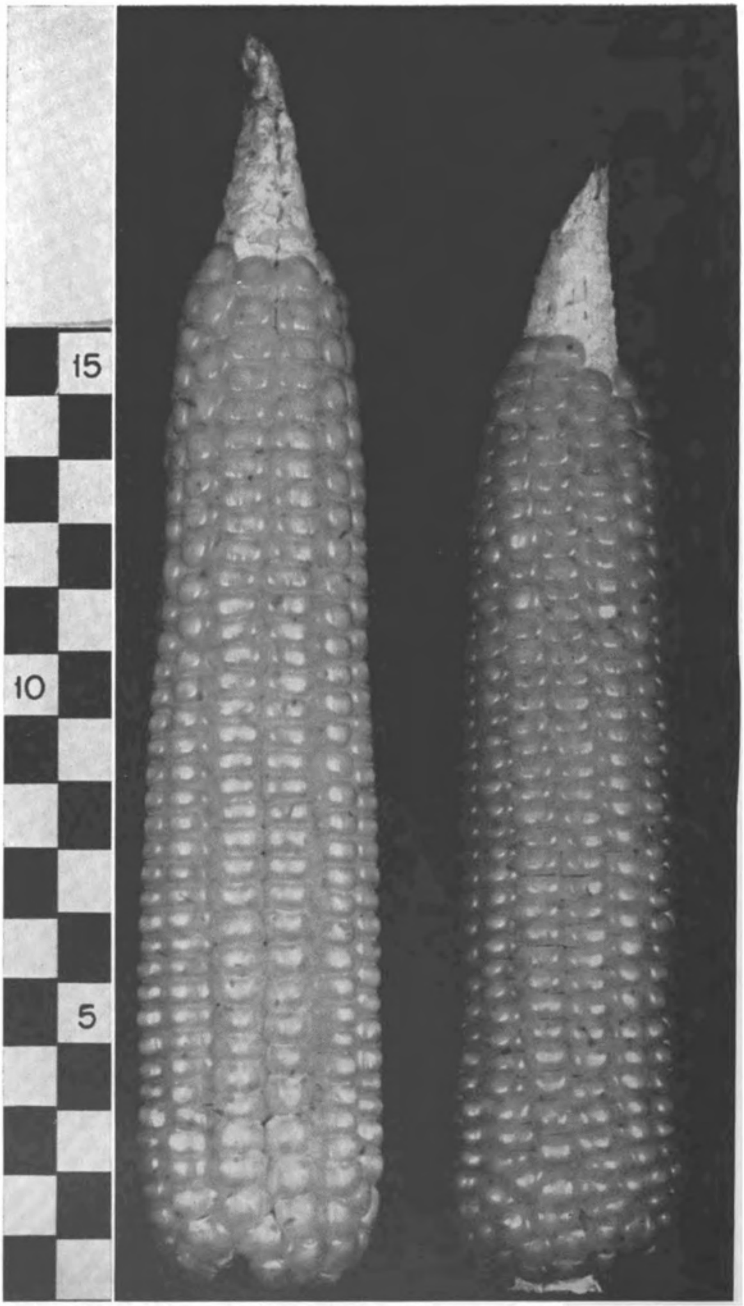

FIG. 96. Cateto Fino from São Paulo.

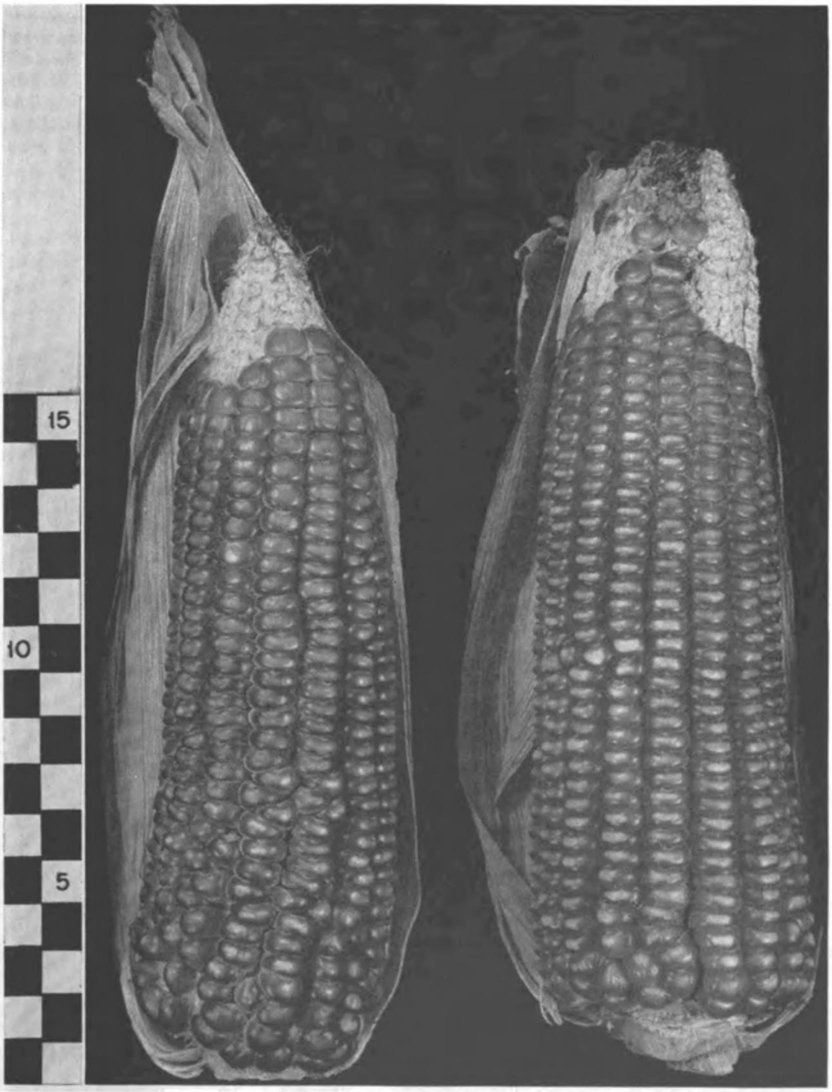

Fig. 97. A typical Cateto from the Guianas.

number of synthetics would have been formed. Only two such races will be described, both from the regions of Argentina and Uruguay, *Canario de Ocho* and *Amarillo,* but it must be emphasized that *Amarillo* may rather be regarded as a group than as a uniform synthetic race.

33. SYNTHETIC RACE CANARIO DE OCHO

Ear photograph, Figures 98 and 99
Ear diagrams, Figure 105
Internode pattern, Figure 102
Tables 38 to 40

Ear: Comparatively long, row number always 8.

Kernel: Length and thickness about the same as in the pure *Cateto* races, but kernels are considerably broader. There is more space available for expansion in this direction on ears with so few rows. Kernels are quite hard; color is a light bright yellow (canary yellow), not orange.

Tassel: Fairly low internode cover index of 1.32. With a coefficient of variation equal to 15 per cent of the mean, this means that a certain amount of the plants may have the last internode and even a small portion of the tassel covered by the last leaf sheath. The branched portion of the tassel amounts to 36 per cent of its total length, though branches are not very numerous: fifteen primary and four secondary branches on the average.

Plant: The data are contained in Table 40 and do not require any additional explanation.

Internode pattern: Differs completely from those of all the other *Cateto* types, since internodes increase steadily from the base to the tassel, with one maximum only in the last internode. In this respect, *Canario de Ocho* agrees completely with the other 8-rowed races from South America.

Origin and relationships: We came to the conclusion that *Canario de Ocho* must be a synthetic, since it represents a rather isolated flint type in the general area of the *Southern Cateto.* Furthermore, it has characters in common with *Avatí Morotí Mitá,* which has kernels of about the same shape and size, though with soft endosperm, and which has also slender 8-rowed ears. The partial enclosures of the tassel base in the last leaf sheath could

FIG. 98. Flint Amarillo, from Argentina and Uruguay, differs from Cateto in many aspects, such as heavier ears and yellow, not orange, pericarp.

easily be another character introduced from *Avatí Morotí* into *Cateto.* The internode pattern of *Canario de Ocho* is identical with that of *Avatí Morotí Mitá. Canario de Ocho* is probably a synthetic of fairly recent origin.

34. SYNTHETIC RACE CATETO-AMARILLO

Ear photographs, Figure 98
Ear diagram, Figure 103.3
Tables 38 to 40

Ear: Since measurements of only three ears were used to obtain the data contained in Table 38, it must be admitted that these ears may not be too typical as far as some quantitative characters are concerned, though they had otherwise all the necessary characteristics of this synthetic. As indicated in the photographs, the ears are generally larger than those of *Cateto,* especially for the Cateto races *Colorado* and *Cuarentón* of Uruguay and Argentina, and the kernels are often somewhat smaller and light yellow to pale orange in color.

Tassel: It should be emphasized that *Cateto Amarillo,* as does *Canario de Ocho,* has a low internode covering index (mean 1.28), and thus in some plants of a sample even part of the tassel will be enclosed in the leaf sheath, a character not found in the pure races of the *Cateto* group.

Plant: We may simply refer to the data in Table 40.

Origin and relationships: Though a more thorough analysis seems indicated, it can be considered as most probable that the *Cateto-Amarillo* group represents a group of synthetics which combine characters of *Cateto* races with other characters introduced from *Avatí Morotí,* with its light colored kernels, its pronounced sheath cover at the tassel base, etc.

If this interpretation is correct, then we have two infiltrations of *Avatí Morotí,* the main field corn of the southwestern Guaraní, into *Cateto,* the main corn of the coastal Guaraní. The differences between the two synthetics, the 8-rowed *Canario de Ocho* and the group of *Cateto Amarillo,* would result from the fact that the first originated from infiltration of genes of the 8-rowed *Avatí Morotí Mitá* and the other from the more common and more variable *Avatí Morotí.*

FIG. 99. Canario de Ocho, an 8-rowed flint with canary-yellow kernels, is grown to some extent in Argentina and Uruguay.

The Recent Cateto-Dent Synthetics

Dent corn has been introduced repeatedly, at least during the last 100 years and perhaps even earlier, into the general area of the Southern Cateto. But very few of these dents have maintained themselves without noticeable change. We have received from the State of St. Catarina, Brazil, alone a number of samples which look exactly like some of the old dent types used in the United States before the advent of the modern hybrid method. But in this State a rather special situation prevails in agriculture: small farms are in the hands of farmers of predominantly North European origin, *i.e.*, a type of immigrant similar to the original North American pioneers and farmers. Under their type of farming, with a certain isolation on farms or in villages, and a certain inherited training for seed selection, the maintenance of imported varieties seems quite possible. But in other regions, especially in the State of São Paulo where extremely large plantations predominate, either no need selection is carried out at all, or it is done in a very inefficient way, because the amount of seed required for planting is generally too large to allow efficient seed selection. Under such conditions the imported dent varieties, poorly adapted to the local climate, could not maintain themselves in a fairly pure state. The same thing occurred in the State of Rio Grande do Sul. However, the preference given to even partially indented types, with kernels better suited for the feeding of animals than those of the pure *Cateto* with their very hard endosperm, made the situation quite favorable for the formation of *Cateto-Dent* synthetics. Many dent varieties have been imported and there still are many races and more subraces of *Cateto.* Consequently we must expect to find not one or only a few *Cateto-Dent* synthetics, but rather a large group of synthetics. All of them have some characteristics in common: They are typical dent corn, with a hard corneous outer layer at the base of the kernel and soft endosperm within this outer layer and below the dent; and their color is deep-orange yellow except for the soft endosperm which is lighter yellow.

35–36. CATETO DENTS

Figure 100 shows three ears of *Paulista Cateto-Dent* (35), and *Rio Grande Cateto-Dent* (36) is not very different. As far as tassel and plant characters are concerned, these recent synthetics seem to differ very little from their *Cateto* parents, and it is in fact to be expected that in these respects natural selection will tend to increase the frequency of the *Cateto* genes, *i.e.,* the genes of the better adapted parent.

FIG. 100. Dent Paulista forms a group of recent or even incipient synthetics, between Cateto races and U.S.A. Dents, imported into Brazil on many occasions during the last 100 years.

The *Cateto-Dent* synthetics will, we believe, have considerable importance in future breeding work, and in a recent census, carried out in São Paulo by our "Maize Center," we found that in 60 per cent of the farms today some form of *Cateto-Dent* is grown. It should be pointed out that the ceiling of productivity of the *Southern Cateto* is rather low, while it is much higher in the dents and also in the *Cateto Dents*. Thus it is not surprising that, in a test of a few hundred samples of *Cateto-Dent*, about 30, or approximately 10 per cent of the samples, produced as much as the best *Cateto* double hybrids then (1954) available. These *Cateto-Dent* samples came from ordinary farms, from open-pollinated seed and not from any specially selected material, and they were collected without selection on these farms, in cooperation with the State Extension Service and County Agents. There cannot be any doubt that there must still be a considerable margin for their improvement by modern breeding methods. These synthetics are especially valuable, since natural selection and repeated crossing without control, but on a practically unlimited scale, have assembled in the synthetics many genes of *Cateto*, guaranteeing a fairly good adaptation to the local climatic conditions and even to the extreme variations which occur only occasionally during decades of uncontrolled natural selection. But on the other hand, enough genes for dent characters have evidently also been preserved by a certain selection carried out by farmers. But most *Cateto-Dent* synthetics are not yet sufficiently stabilized as to kernel type.

White Flint Synthetics

When discussing the problem of the formation of synthetic races, we gave details of two groups of rather recent synthetics, obtained from the accidental hybridization of *Calchaqui White Flint* with either *Guaraní Soft Corn* or *Interlocked Soft Corn*. The first is generally known by the name of *Cristal*, and for the second we shall use the name *Cristal-Perola*. We are presently studying a third group of *White Flint* synthetics which we collected farther north in the State of Minas Gerais. This material will be called "*Cristal Minas.*" Before concluding these studies, we cannot say which indigenous race has been combined either directly with *Calchaqui Flint*, for which there is only a very small probability, or with *Cristal* from São Paulo, to give the *Cristal Mineiro*.

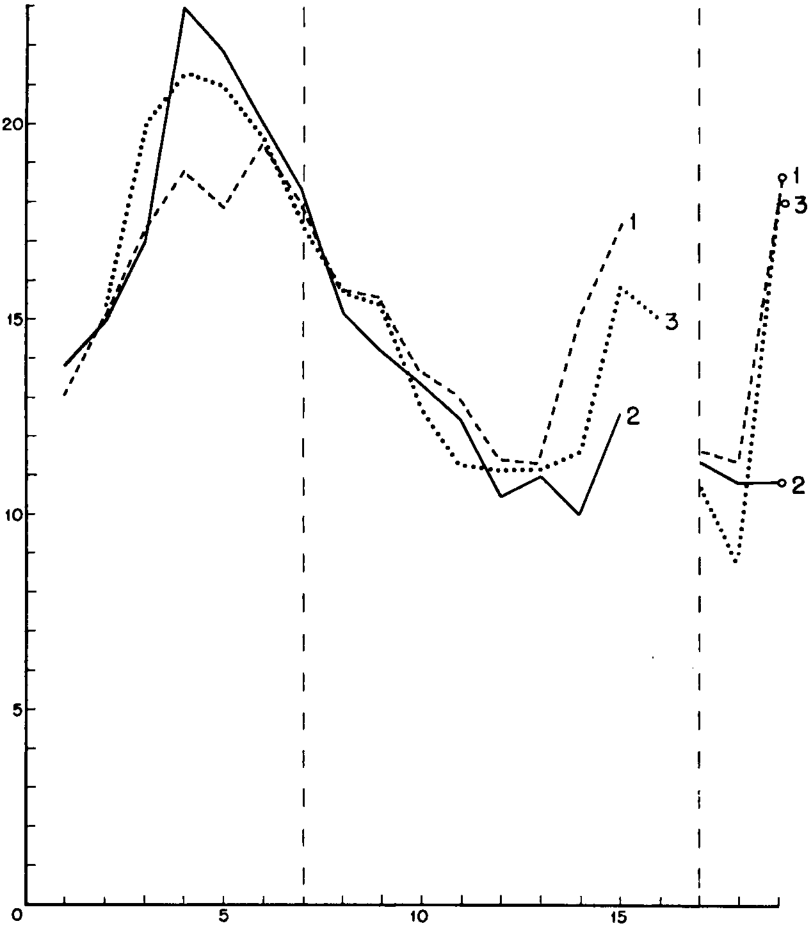

FIG. 101. Internode pattern of Southern Cateto: 1) Colorado; 2) Cateto Paulista Fino; 3) Northern Cateto Froes.

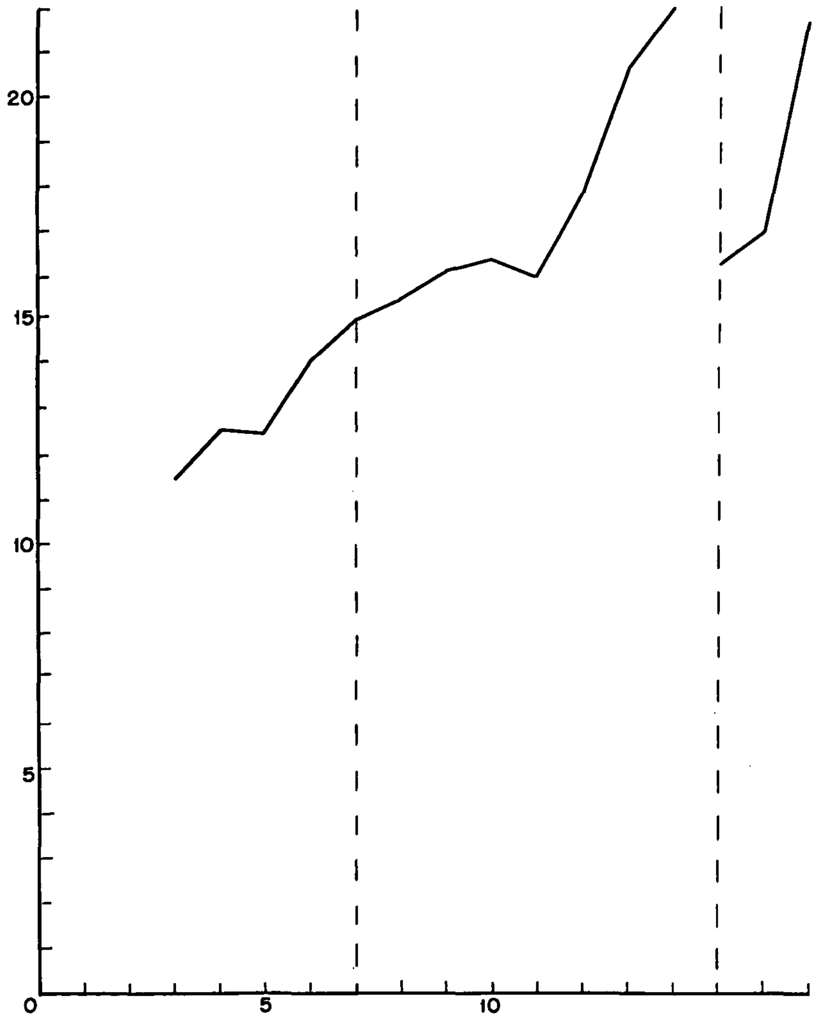

Fig. 102. Internode pattern of Canario de Ocho.

Instead of repeating the data already discussed, we shall only cite the following references:

37. SYNTHETIC WHITE FLINT CRISTAL (SÃO PAULO-PARAGUAY)

Ear photographs, Figures 18 and 19
Ear, tassel, and plant diagrams, Figures 20–23
Tables 2 to 4

(see discussions above, on pp. 34–35)

38. SYNTHETIC WHITE FLINT CRISTAL-PEROLA (FROM BOLIVIA)

Ear photographs, Figures 24–26
Ear, tassel, and plant diagrams, Figures 20–23
Tables 2 to 4

THE AMAZON BASIN AND ITS MARGINS

The last area to be considered in this paper is the fully tropical lowland area of the Amazon Basin, wherein the term "lowland" must be understood, as before, in contrast to the Andean slopes, the Andean High Valleys, and the Andean Altiplano.

Actually these "lowlands" include hilly country and even a number of mountain ranges with altitudes going beyond 1,000 meters, and which may reach even 2,000 meters. This whole region is characterized by its fully tropical climate, at least during the rainy growing season for maize. To what extent the winter period may be drier or wetter seems of little importance. As far as we know, maize is always grown in one season per year only, and this is always the season of the tropical rains.

In the study of this region we met with a number of serious difficulties. To begin with, the collecting requires extensive travel or even the organization of expeditions. It must also be remembered that most of the Indian tribes, especially in this area, seem neither to be fixed in definite places nor to be completely nomadic. The agricultural tribes remain in one spot during a number of years, and prepare their fields in the surrounding forest areas. But from time to time they decide to move to new surroundings, and cases are known where an Indian tribe, known to the Brazilian Indian Service as living in some region, may disappear for a number of years until discovered far away, generally by accident.

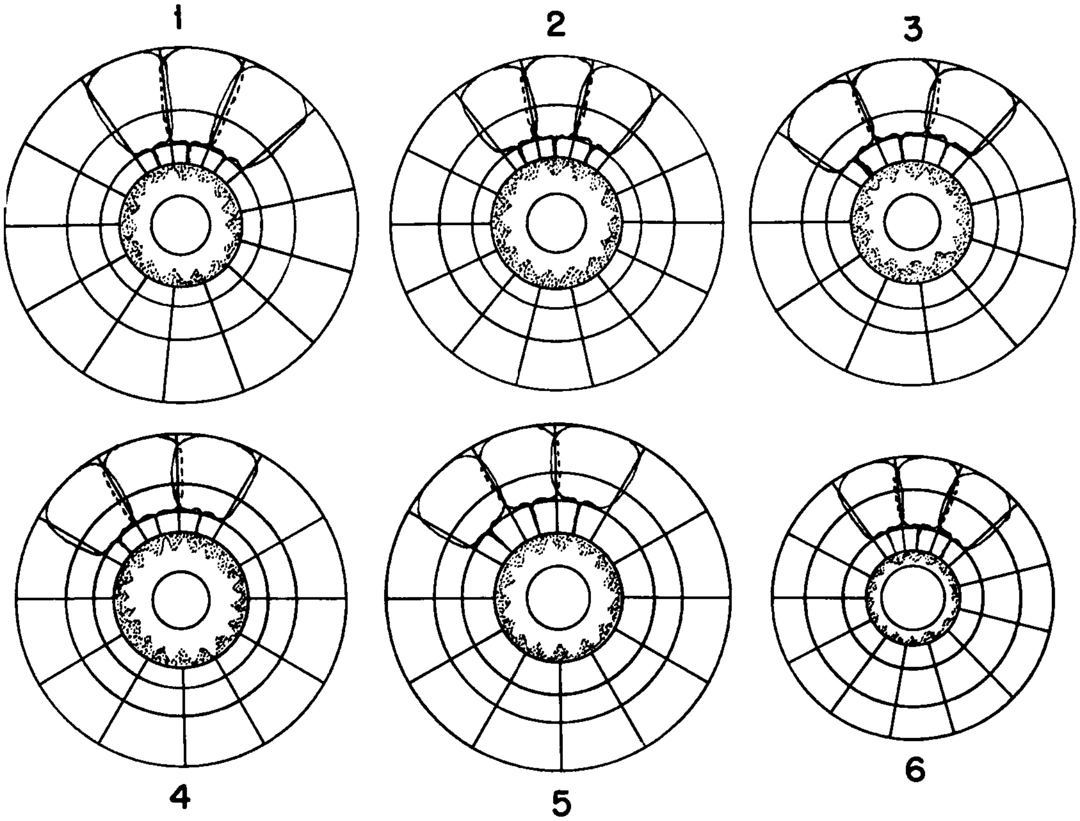

Fig. 103. Ear diagram of Southern Cateto Orange Flint: 1) Cuarenton; 2) Colorado; 3) Amarillo; 4) Cateto Paulista Grosso; 5) Charrua; 6) Cateto Paulista Fino.

When the Indians go on these migrations, they take with them all their belongings, which of course include principally their seed reserve and cuttings of all their other crop plants.

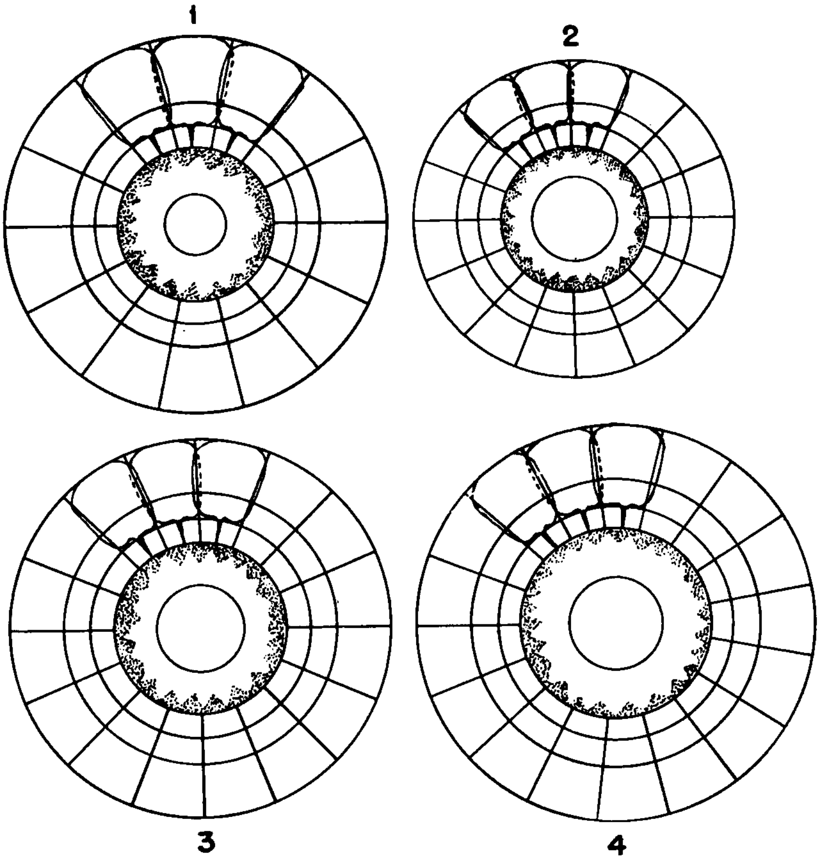

FIG. 104. Ear diagram of the Northern Cateto. 1 and 2, Type Froes; 3 and 4, Type Guiana.

Next there is the difficulty of growing the material, since fully tropical maize generally does not do well at the latitude and altitude of Piracicaba.

Thirdly, a number of races were collected and studied before the organization of the "Maize Center," at a time when the annotations were not yet completely organized.

For these reasons we must admit that in many respects our report on this area will remain incomplete, which is unfortunate since we have the impression that just in this area there may be still in existence a number of old races, preserved by Indian tribes which remained in a state of stagnation for centuries and thus kept their old races, which they may have produced themselves or taken over from still other and possibly already extinct tribes. The relative lack of geographic fixation must have also opened up interesting possibilities for the formation of synthetic races.

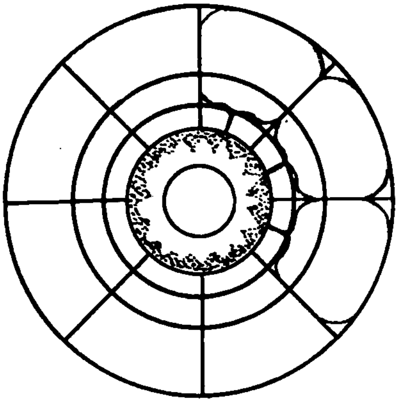

Fig. 105. Ear diagram of Canario de Ocho.

It should be remembered that in the Amazon Basin we are near what seems to be a climatic limit for maize. We have already discussed other such climatic limits. We stated at extreme latitudes, both north in the United States and Canada or south in Chile and Argentina, the marginal races are always races of flint corn, and that neither floury nor dent types appear as indigenous races there. Respective of the altitude limit in the Andes, the situation was different. We tried to show that there adaptation to the ecological-climatic conditions must have favored either the maintenance, through selection principally, of old races, or the production of new synthetics with a very high number of the genes, and thus of the characters, of the old adapted races which have entered into the newer synthetics. It now seems quite possible that the fully tropical climate also may represent an extreme area of adaptation, favoring either the maintenance of old races or at least the preservation of many of their characters in synthetics.

In short, we are sure that a more complete knowledge of the races in the Amazon area might contribute considerably to the knowledge about maize and its development, and the following description of races should be considered only as a first attempt in this direction.

In our collections we found that the western and southern margin of the Amazon Basin, a region indicated by "1" in the map of Figure 106, contains exclusively representatives of one group of races, and we call this group the *"Interlocked Soft Corn,"* since one of their main characteristics is the interlocking of ranks, first correctly described by Cutler (1946). Cutler used the name *"Coroico"* for this racial group, but this name is not really correct. *Coroico* in eastern Bolivia is a locality at a rather high altitude, and the *Interlocked Maize* may be grown there, but its real habitat is at much lower altitudes.

The sample "2" in Figure 106 was sent through missionaries from a place near the Colombian border. It resembles somewhat the Colombian race *Andaqui,* and in fact we may have reached a new geographical region which stretches from Colombia through Venezuela, south of the zone of the Llanos, for which types like *Andaqui* seem to be characteristic.

The materials of "3" and "4" in the map represent samples of shelled seed received through the "Service of Indian Protection" and are typical of the eastern Amazon Basin.

Finally we come to region "5" and we shall discuss the *Northern Cateto Flints* from the Guianas.

39–43. INTERLOCKED SOFT CORN

Ear photographs, Figures 107–114
Ear diagram, Figure 116
Internode pattern, Figure 115
Tables 44 to 46

The general characteristics of this group are:

(a) the interlocked rows, the nature of which has been fully explained on page 8, and (b) the fairly large kernels, with soft endosperm and with yellow-orange-brown pigments in the aleurone.

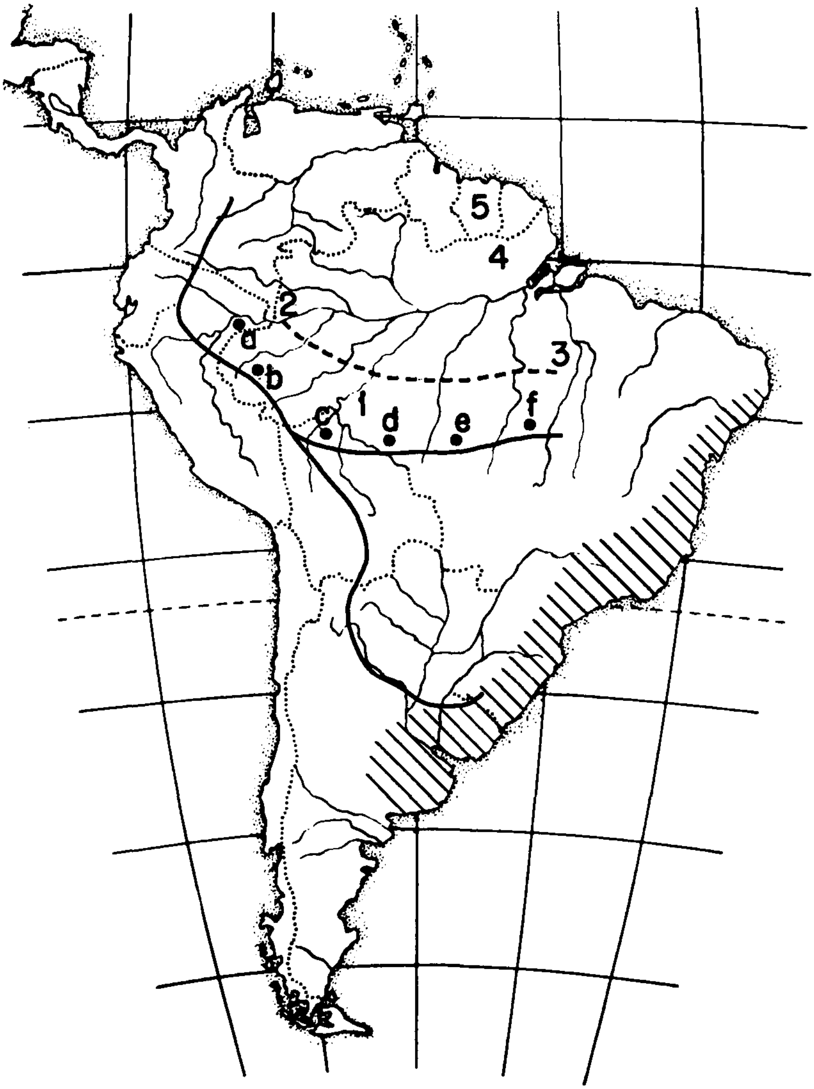

FIG. 106. Map of the *Amazon Basin* area with a tropical climate. The large area from eastern Peru to the Araguaia River in Central Brazil is occupied by the races of the group Interlocked Soft Corn (1)—from the northern part we had only one sample: Iauarete, (2) from the Amazon-Rio-Negro area.—In the eastern part of the Amazon Basin many races may still exist, of which we know only two: Carajá do Sul, (3) and Emerilhon (4). In the coastal areas one finds among both Aruak and Caraibe Indians the tropical Orange Flints (5) Interlocked races: a) Ticuna; b) Acre; c) Reyes; d) Bororó; e) Tapirape; f) Chavantes.

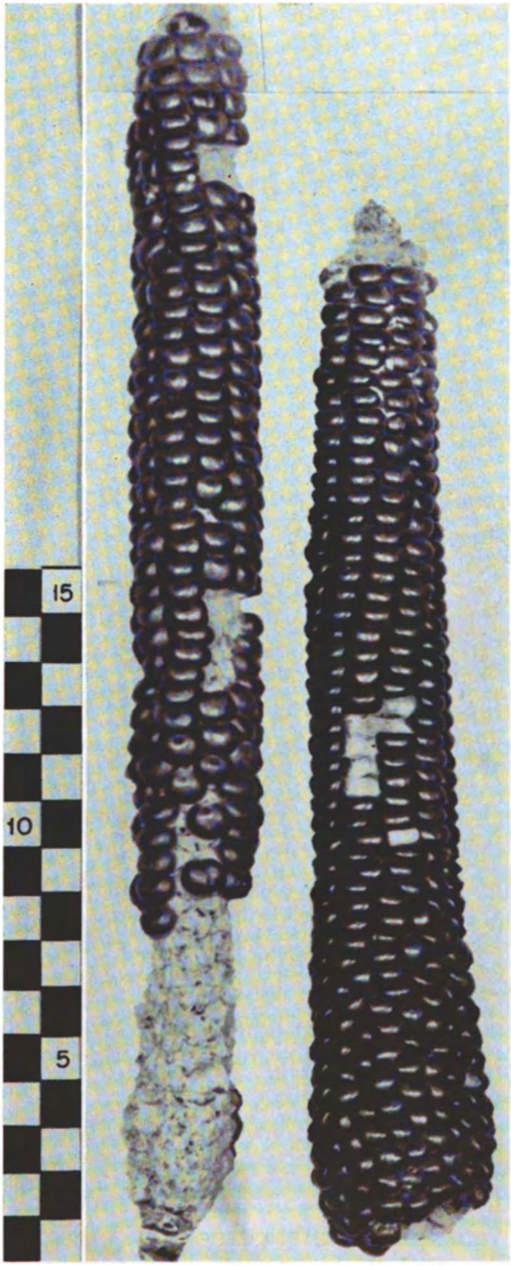

FIG. 107. The races of the *Interlocked Soft Corn* occupy the extensive tropical area which forms the western and part of the southern margin of the Amazon Basin, from about Iquitos in Peru to the Araguia in Central Brazil. It is divided into many races, of which one, from the territory of *Acre* in Brazil, is shown above.

There are certainly a number of well defined races in this group, and the photographs of the ears may give a fairly good picture of the situation. We may add some general observations:

Race 39. Acre Interlocked Soft Corn: The ears are on the whole exceedingly long and slender, only a short portion at its base showing ranks which are not completely interlocked. Black aleurone color is not uncommon, combined with the always present yellow aleurone color.

Race 40. Bolivian Interlocked Soft Corn: Santa Cruz. The ears are not quite so slender as in the preceding race, and the zone with irregularities, before interlocking becomes complete, is much longer. The kernels have many shades of color from deep orange-yellow to bronze and are sometimes segregated for the latter shade of aleurone color.

Reyes. Similar to the preceding one.

Race 41. Bororó Interlocked Soft Corn: Very slender ears with a short region of incomplete interlocking. Aleurone colors of lighter shades, with black aleurone also present.

Race 42. Tapirapé Interlocked Soft Corn: Very long and slender ears with light aleurone color shades.

Race 43. Chavantes Interlocked Soft Corn: It appears that the Chavantes grow at least two races of the Interlocked Group, one rather slender with brown to orange aleurone, and the other much shorter and with black pigment in the aleurone in addition to the yellow ones.

The data given in the tables refer only to two of these races and to two original samples ("origins") of each one.

Ear: Since ears were measured which had been harvested at Piracicaba, they did not reach the extreme length quite frequent in the original indigenous material. The row number, as given in the table, refers to the counts made in the upper half, which is perfectly interlocked. In order to know the "real" row number, the numbers given must be multiplied by 2. Thus we have a mean row number of about 24 (mean of rows after interlocking, 12.1) with a range of variation from 16 (8 ranks or interlocked rows) to about 30 rows (15 ranks or 15 interlocked rows). Ear diagram: The diameter of the medulla is fairly large, with a mean of 0.7 cm., and the rachis is less than twice as thick (diameter 1.2 cm.). Since

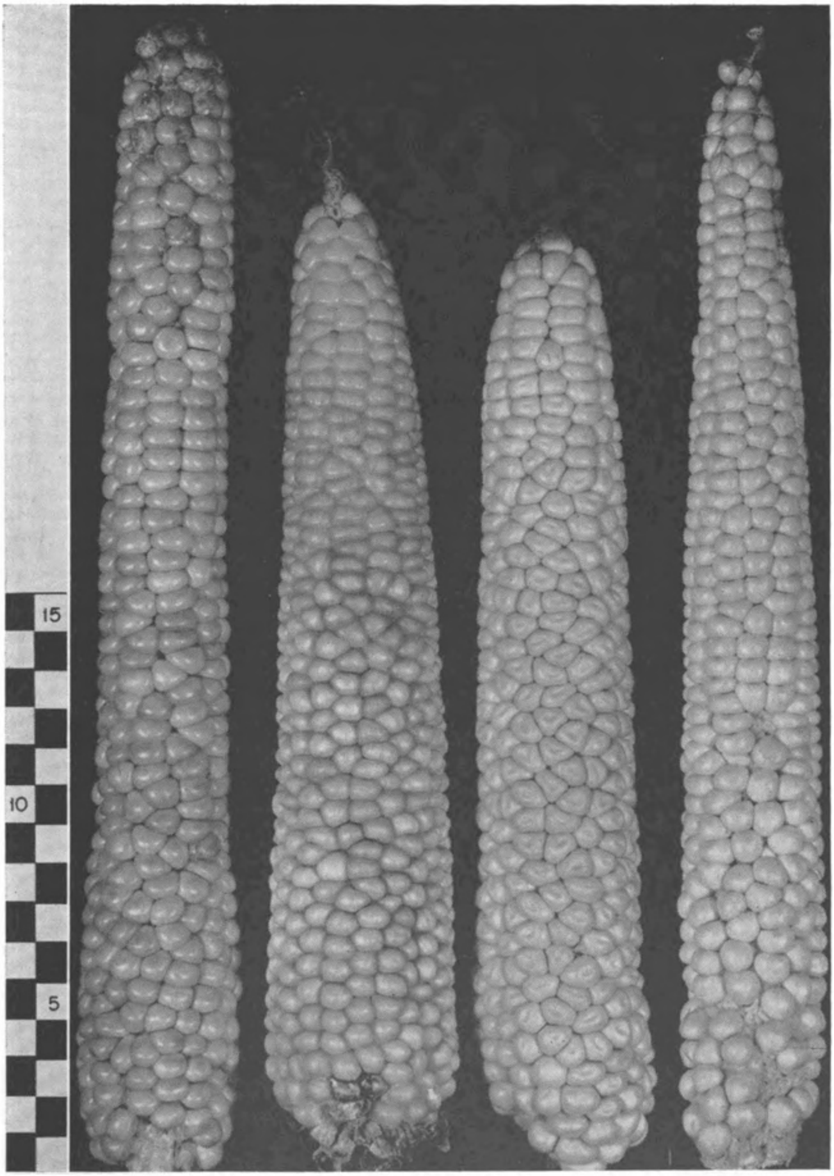

FIG. 108. A race of the Interlocked Soft Corn group from eastern Bolivia near Reyes, collected in 1957.

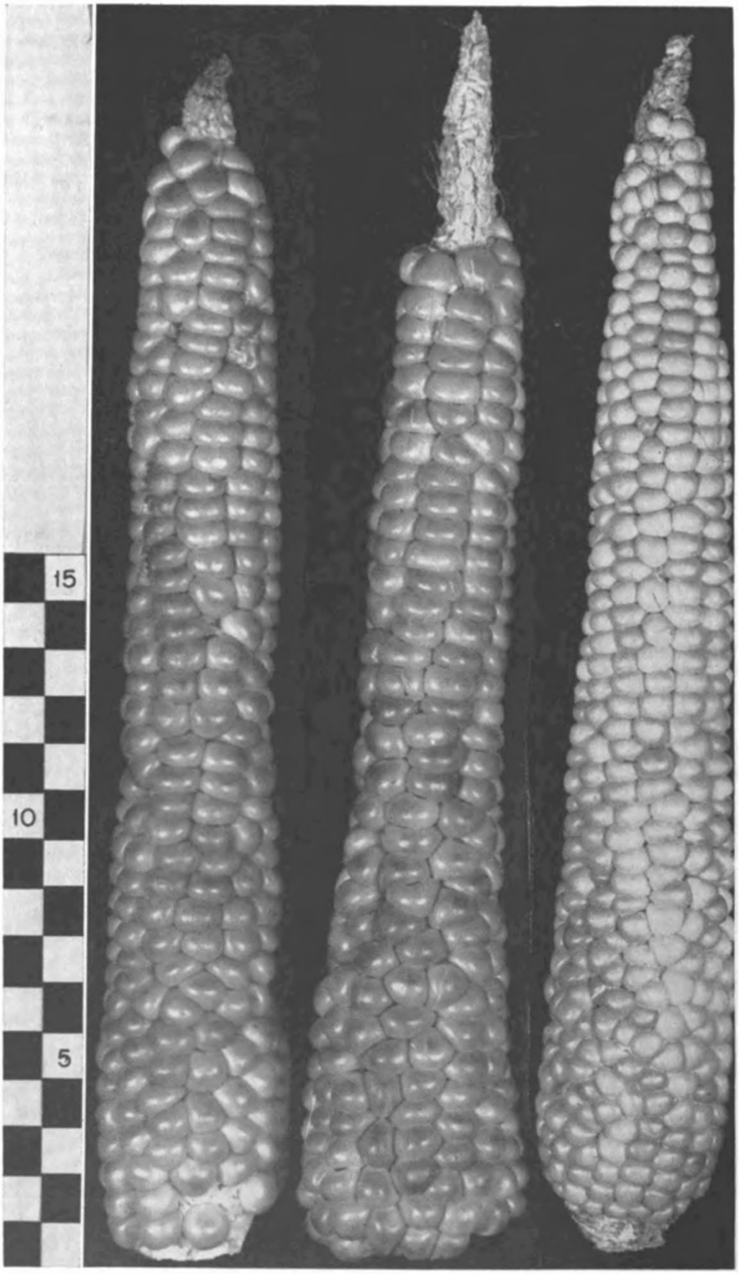

FIG. 109. A race of the Interlocked Soft Corn group from eastern Bolivia near Reyes, collected in 1953.

the diameter at kernel base is, on the average, 1.8, rachilla length is only about 2 to 3 mm. Cob diameter is 2.4 cm. and that of the whole ear 3.2 cm.; glume length about 4 mm.; cob/rachis index rather high, on the average 1.95.

It should be mentioned that the relative thinness of the rachis and the almost complete absence of sclerenchyma makes the cob extremely soft. Before drying out completely, the cob is very flexible and may even almost be doubled when the kernels have been shelled off.

Kernel: More or less round and fairly large; length 0.9 cm., width about 0.9 cm., and thickness 0.4 cm.; glume cover nearly 39 per cent of the kernel.

It may be interesting to make some calculations to show the real significance of these diameter values for the Interlocked Corn. If there were no interlocking, we would require space to accommodate side by side, not 12 rows of kernels on the average, but twice as many or 25. In order to double the surface (in the diagram, the circumference of a circle) we would require also a doubling of the diameter. Thus rachis would become 2.5 cm. thick, cob 4.8 cm., and the whole ear 6.4 cm., values not even reached in the races with the thickest cobs described, such as *Lenha* or *Northern Cateto.* In the former the cob diameter reached 4.4 cm. and the ear diameter 5.9 cm. (Table 32), while for the *Northern Cateto* the respective values were 3.5 cm. and 5.9 cm. (Table 41).

On the other hand, if we start from an ear of *Northern Cateto* and want to accommodate the same number of kernels with interlocking, and thus with half the diameter of the cob, we would require a doubling of the length of the cob as a compensation.

The volume of a cob is another matter since it changes proportionally either with the square of its radius or with its length. Thus an interlocked ear with twice the length and half of the diameter (radius) would in fact require only one half of the material necessary for a short and thick cob of a non-interlocked ear. The Indians who produced the interlocked ear type succeeded in reducing very considerably an organ, the cob, which generally is a rather useless object.

Tassel: Index of sheath covering 1.34 on the average and, with

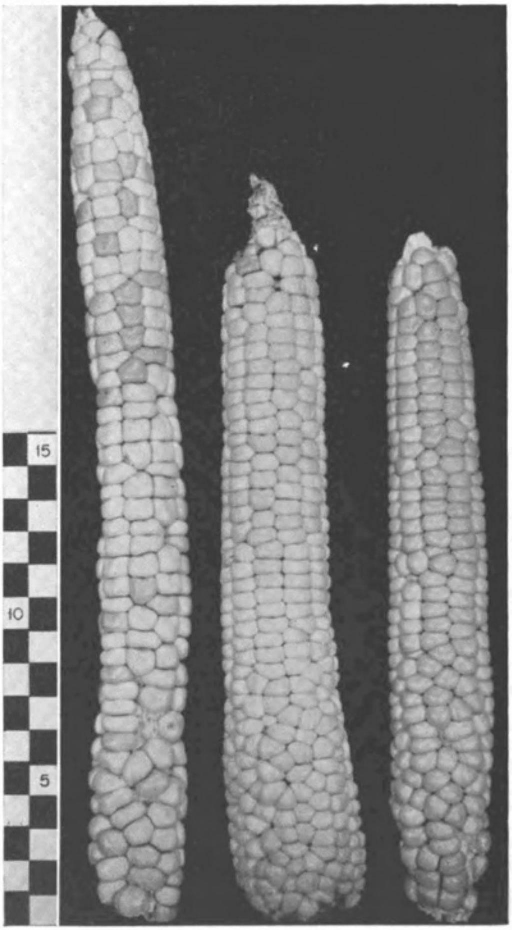

FIG. 110. A race of the Interlocked Soft Corn group grown by the Bororó Indians in Matto Grosso, Brazil.

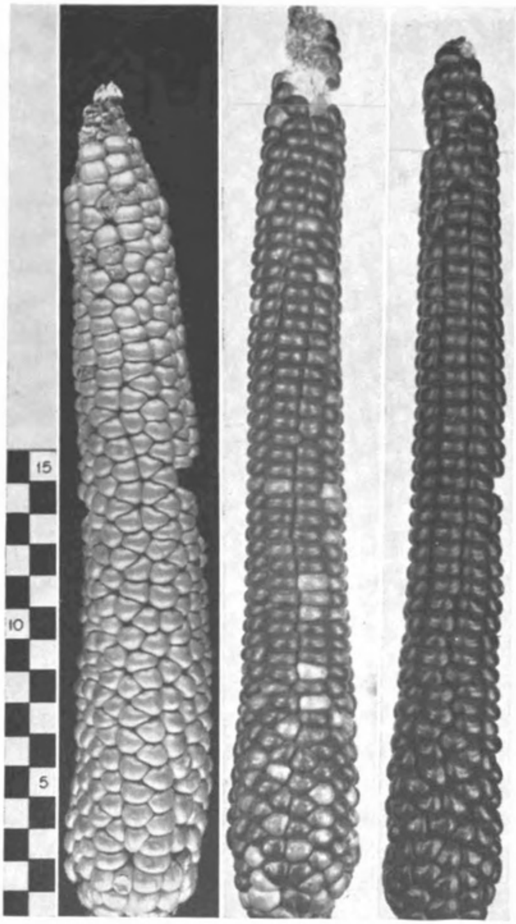

FIG. 111. A race of the Interlocked Soft Corn group grown by the Tapirapé Indians in the Brazilian States of Matto Grosso and Goiáz.

a coefficient of variation of 18.6 per cent, the variation may reach ±43 per cent. Thus there may be plants in any sample with an index as low as 0.91. There will be a fair number of plants with part of the tassel covered or inclosed by the last leaf sheath. The branched part of the tassel amounts to slightly more than 40 per cent of its total length and the number of branches is fairly high.

Plant: The plants, even when growing at Piracicaba and probably not reaching full height, are 2.5 meters high without the tassel, and the ear stands on the average slightly above the middle of the plant.

Internode pattern: We have again the bimodal type, with one maximum of internode length several nodes below the ear-bearing node, and the other maximum just below the tassel.

Origin and relationships: We must admit that the origin of this very peculiar type is a mystery. We must ask first whether the interlocking should be considered as a primitive character or as a highly developed one for which the Indians might have worked very hard in the breeding program. The latter would be in fact unique. There are many possible breeding tendencies in maize and, on the whole, each one has been tried evidently more than once, as for instance the extreme increase of ear and cob diameter, which we found in more than one race or region. But nowhere else but in the Amazon area has interlocking been observed and thus, if it should be the result of a special breeding tendency, it would really be unique. It is of course quite conceivable that some Indians selected for very long ears, perhaps in connection with some of their peculiar ceremonial customs which possibly may have been priapistic. But breeding for long ears need not be combined with breeding for (a) exceedingly high row number and (b) apparent reduction of this row number by interlocking. If interlocking were in fact the result of special breeding work, then there remain two possibilities for the breeding procedure: (a) first to obtain a considerable increase in row number and then to reduce it bv interlocking or (b) a still more difficult task, to increase row number and interlocking at the same time. However, interlocking is not always correlated with long ears. In fact, interlocking occurs in other Amazonian races which have rather short and small ears.

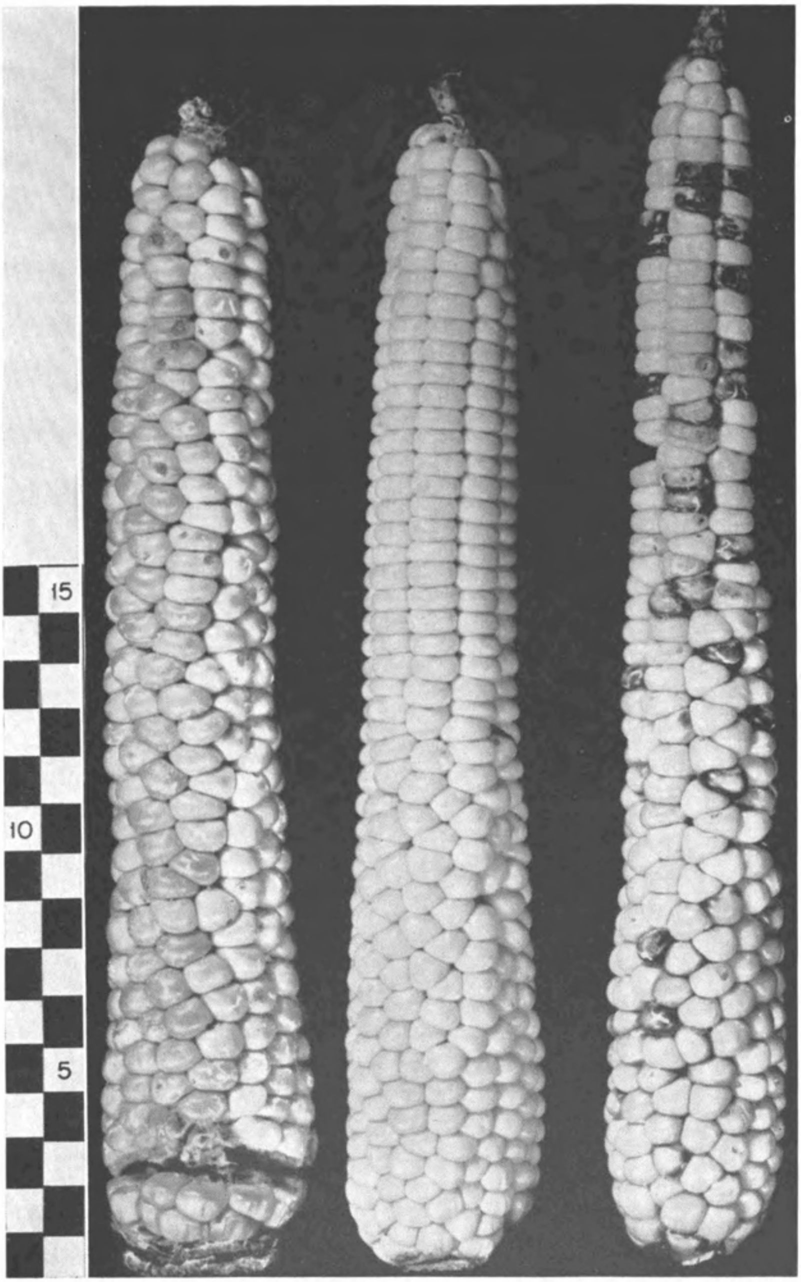

FIG. 112. A race of the Interlocked Soft Corn group grown by the Chavantes Indians, in the area of the Ilha do Bananal in Central Brazil. The photograph shows the main field corn.

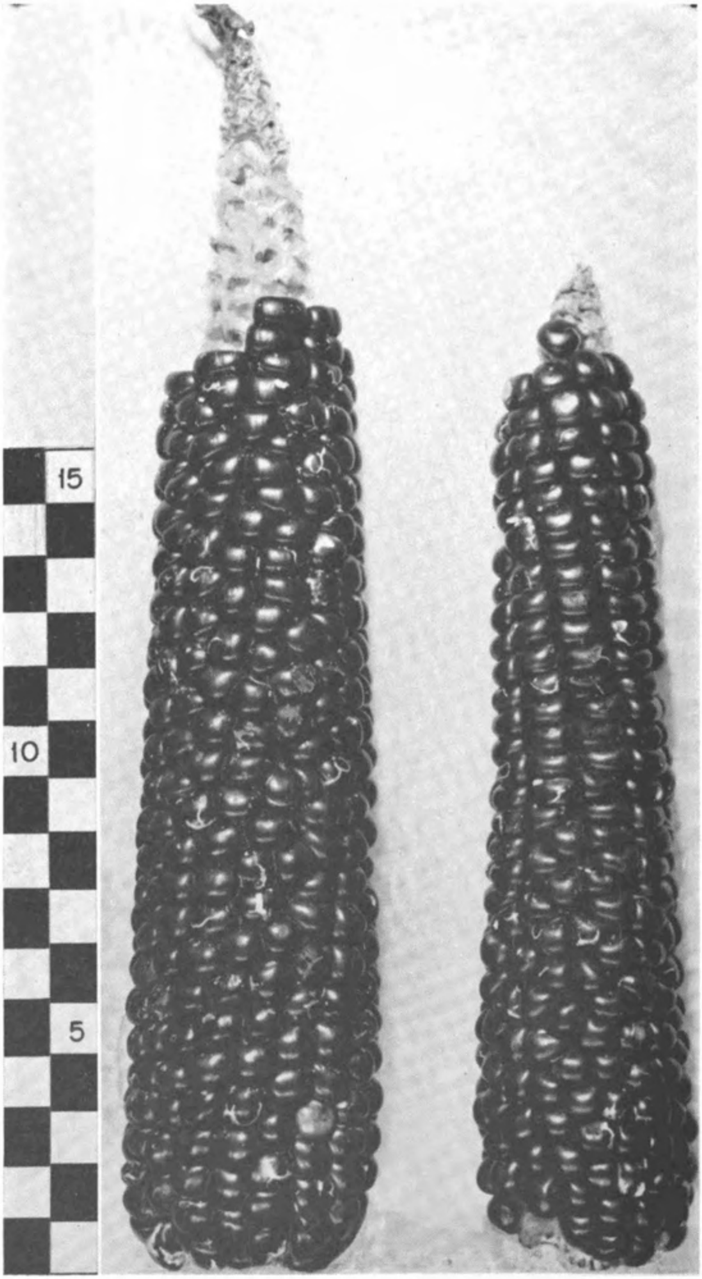

FIG. 113. This shows a *Chavantes Interlocked Soft* corn with black aleurone color.

Thus we feel rather inclined to consider interlocking, not as the result of special breeding, but as a primitive character, dating from the very early days of breeding and domestication. Normally the tendency to increase kernel number per ear must have been accomplished by the combined action of two factors: increase of row number and increase of rachis surface, the latter necessary in order to accommodate the added rows. If at this stage the breeder had tried to (a) increase row numbers and (b) increase ear length, maintaining at the same time the relative position of kernels in adjoining rows of neighboring ranks which we discussed in the beginning of this paper, then interlocking would result automatically. In fact, an increase of row numbers without a proportional increase of the surface, by increasing either the diameter of the rachis or the length of the rachilla, must lead to interlocking, and the "spiral oblique" arrangement of kernels may even be considered as the beginning of interlocking. In any case, by continuing the procedure, it would be possible to increase actual row number (counted disregarding interlocking) much beyond the normal limit, without getting ears with an extremely wasteful cob but obtaining exceedingly long ears. We now believe, therefore, that interlocking is the incidental result of a breeding tendency in the early phases of domestication, when increase of row number beyond the initial four (2 ranks) just started but when an increase in surface "at kernel base" was not achieved.

Next we must try to explain why interlocking is limited geographically. The Amazon region required special adaptations, and this may represent a certain barrier to excessive introgressive hybridization. If the genes for interlocking and for climatic adaptation were correlated after a first period of domestication in the Amazon Basin, this would explain that genes neither spread outside the region nor became lost within the region. On the other hand, a certain amount of hybridization and expansion occurred, since the *Interlocked Soft Corn* at least has the same endosperm texture, general shape of kernels, and especially the same type and range of aleurone color as the bulk of *South American Soft Corn* races. Thus the latter character complex, with its necessary genes and wherever it originated, did spread into the interlocked race, while its interlocking and tropical adaptation did not.

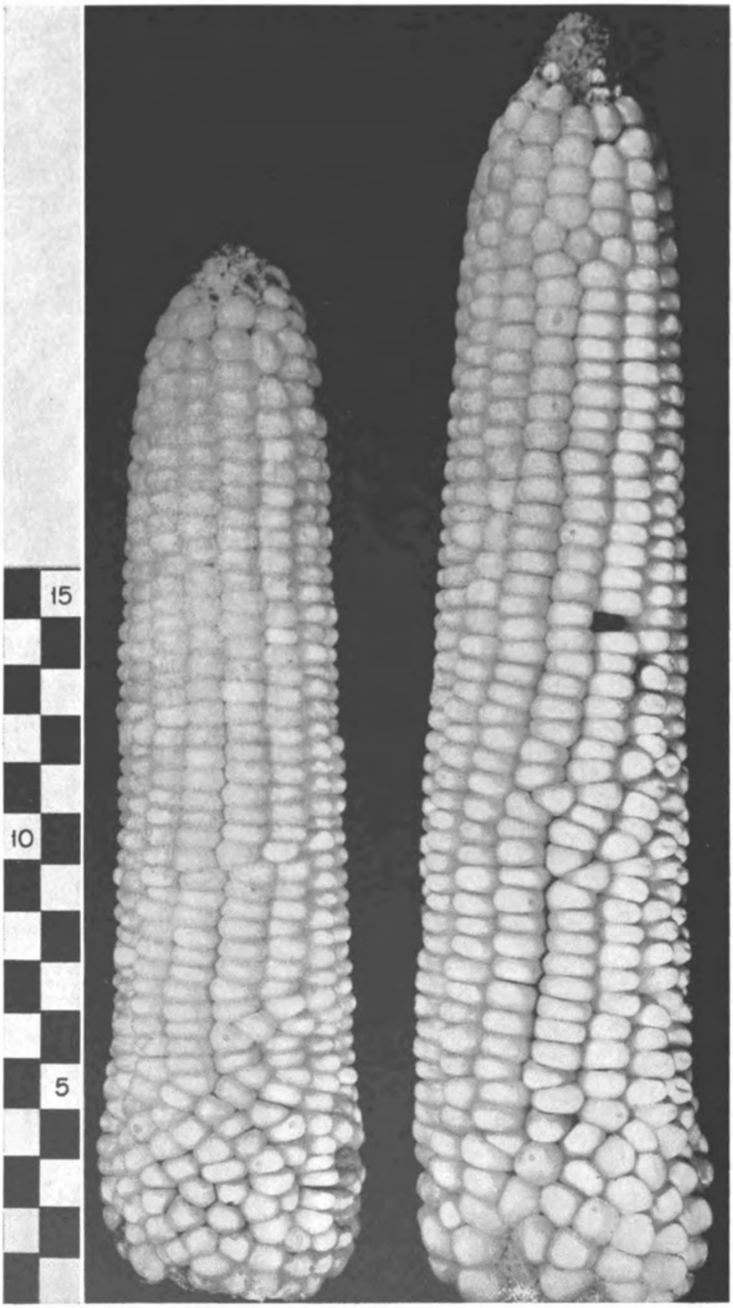

Fig. 114. The Chavantes Indians were extremely hostile until very recently, but now they have been pacified and even accept modern dent corn. The ears above show the results of the infiltration of dent corn into the old Interlocked Soft Corn.

It should also be remembered that this *Interlocked Soft Corn* has other characters in common with, for instance, *Guaraní Soft Corn,* namely the "tunicatoid" characters (high cob/rachis index and high glume cover percentage) and also the tendency for enclosing, at least partially, the tassel base within the last leaf sheath.

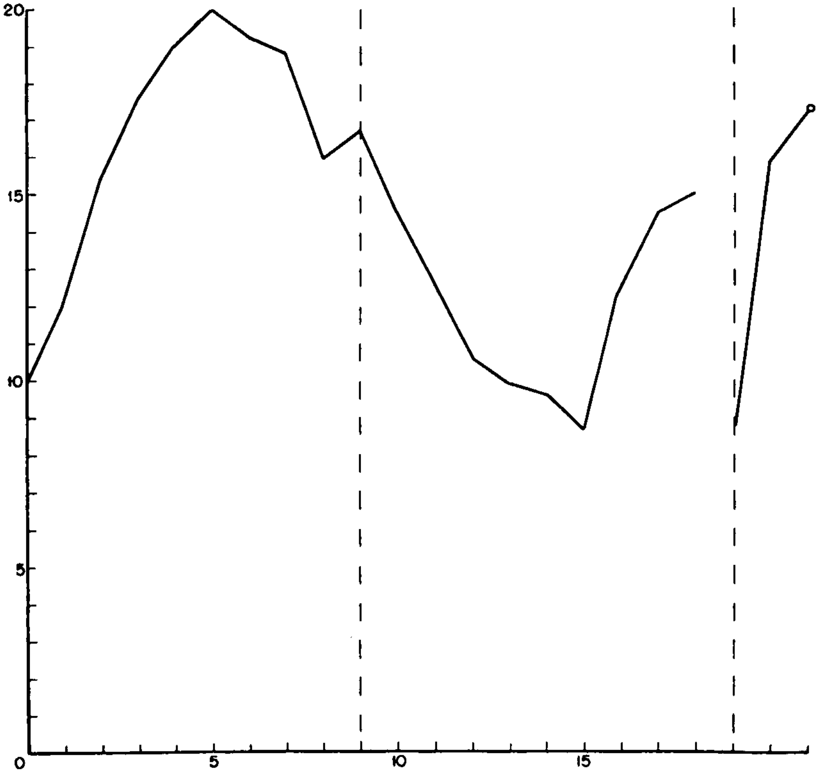

FIG. 115. Internode pattern of Interlocked Soft Corn races.

We must mention another important point. While on the whole the group of *Interlocked Soft Corn* races corresponds to other racial groups, such as the *Calchaqui White Flint,* the *Guaraní Soft Corn,* or the *Caingang White Dent,* it differs in one important point: the three races mentioned are strictly limited, each to one tribe or group of Indians, while the *Interlocked Soft Corn* races are grown, not by one tribe or language group, but by tribes of many language groups (Guaraní, Aruak, etc.). We may, in analogy, suppose that one tribe at some time must have produced this remarkable type of maize, but we have no grounds whatsoever for deciding which Indian tribe, at what locality or time, may have accomplished this breeding work which seems to us as outstanding as the production of a good dent corn by the Caingang Indians, or an excellent flour corn by the Guaraní.

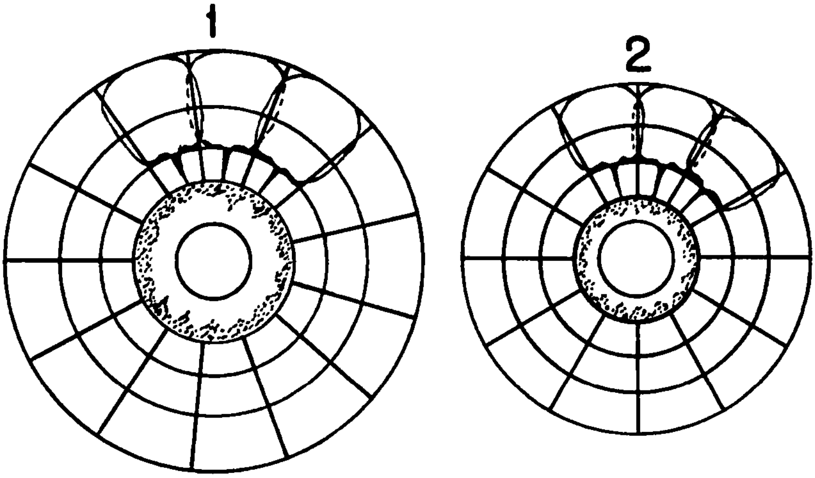

FIG. 116. Ear diagram of Interlocked Soft Corn races.

Races from the Amazon-Rio Negro Region

44. IAUARETÉ

Ear photograph, Figure 123

This is a soft corn with fairly large round kernels, with colorless pericarp, aleurone, and endosperm. The ears are large and decidedly conical. Rows are quite regular, except in the basal butt. The race resembles somewhat and seems related to *Andaqui,* described from Colombia and which also penetrates into Venezuela, *i.e.*, the areas west and north of the occurrence of the *Iauareté* race. We know too little about the races of Ecuador, but it seems quite possible that *Andaqui-Iauareté* may extend into this country also. But if the area of distribution were so extensive, a more detailed study would certainly be justified.

Races of the Eastern Amazon

45–50 RACES OF THE CARAJA-DO-SUL

Ear photographs, Figures 117–122

The photographs in Figures 117 to 122 show that we are now entering into a completely new range of maize races, different from anything we discussed before. In all races through the subtropical area which we called "under the Capricorn," in the *Interlocked Soft Corn* and the *Iauareté Soft Corn,* the two sister kernels in each alveolus tended generally to remain more or less side by side, in a way which we called in the beginning a "horizontal" arrangement. In fact, we cited the *Interlocked* type as a good example of a "horizontal-whorled" arrangement. Now we meet almost exclusively with "spiral" arrangements, and an "oblique" position of sister kernels of the same alveolus. This is especially evident in the two ears of *Maisirará* (to the right in Fig. 117), those of *Guararé* (Fig. 118), of *Itudoné* (Fig. 119), while in the remaining races this situation is less clear.

The shape of the *ear* in almost all races is conical, and at the same time the ears are quite slender. Row arrangement may be regular, and interlocking is not uncommon.

The *kernels* are in general round and quite small, in shape and size being still very close to the popcorn stage, even though endosperm is more frequently soft than hard and horny. One fairly large-seeded popcorn (Fig. 120) shows some tendency for a point to be formed at the tip of the kernels, and this characteristic becomes even more pronounced in the race shown in Figure 122, which sometimes gives ears with rather soft kernels and where, besides the beak at the tip, a small indentation appears, forming kernels of a pointed dent corn.

The colors are mostly white endosperm and colorless pericarp and aleurone; sometimes black aleurone appears. In some races, as in the race *Itudoné* (Fig. 119) yellow-brown aleurone is present.

We may characterize the different samples as follows:

Maisirará. Ears and kernels fairly large. The ears generally conical and slender, with a certain tendency to show interlocking. Kernels round, with soft endosperm.

Guararé. Ears mostly slender and conical, with interlocking,

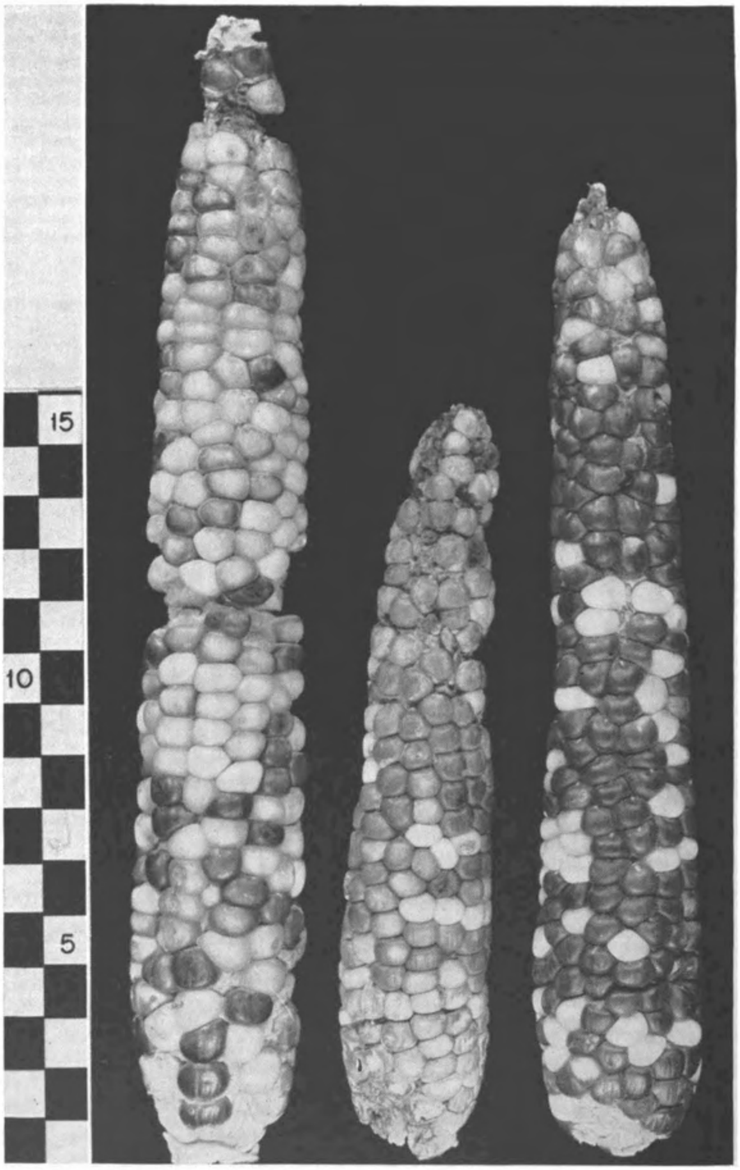

FIG. 117. The *Carajá do Sul* Indians live south of the lower Amazon River and cultivate a number of races which show relations to small round-seeded popcorn. Interlocking is found in some races such as the race Maisirará shown above.

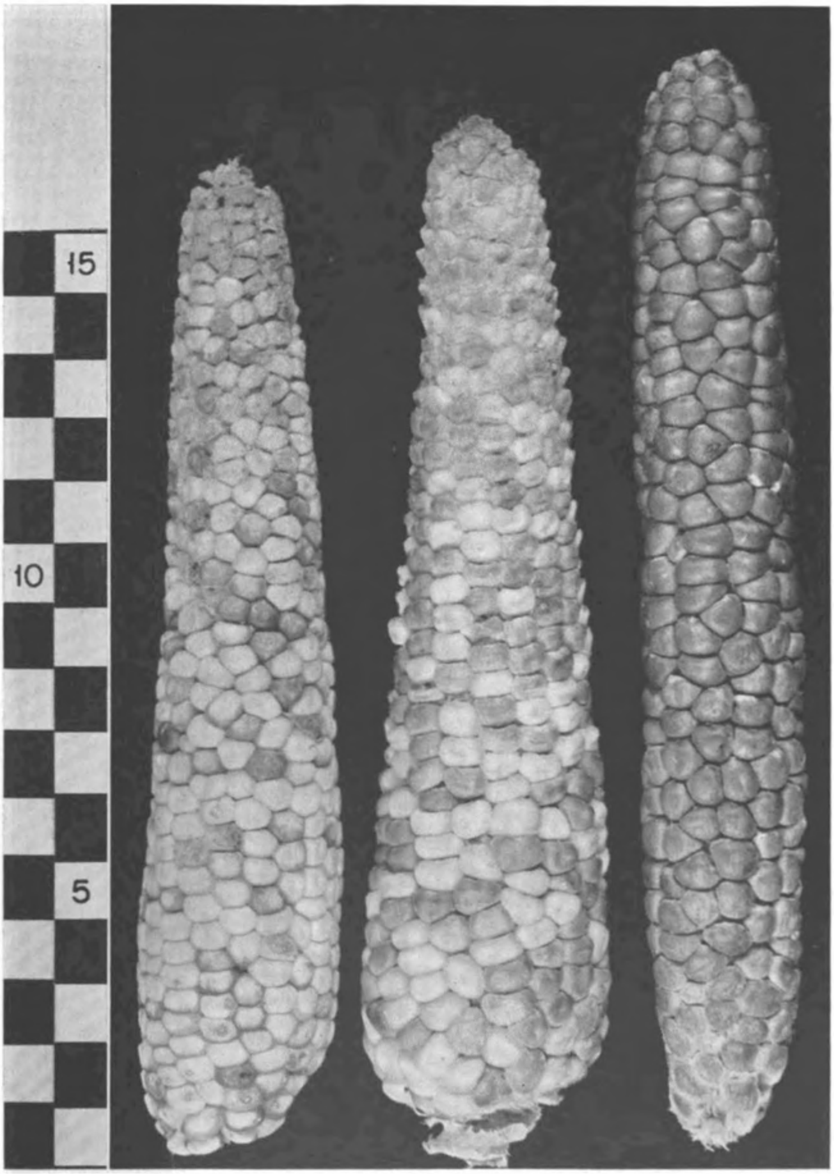

FIG. 118. Guararé, another race of the Carajá do Sul with some interlocking in the ears.

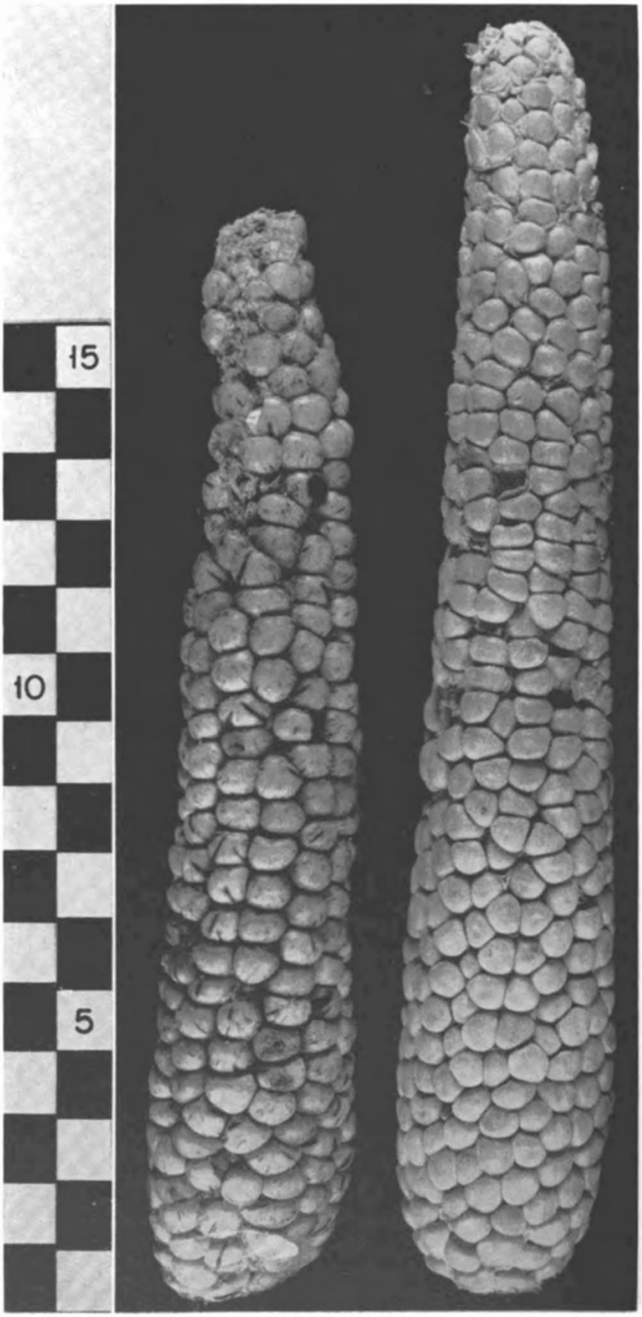

FIG. 119. Itudoné is another rather small-eared race which belongs to the group of Interlocked Soft Corn.

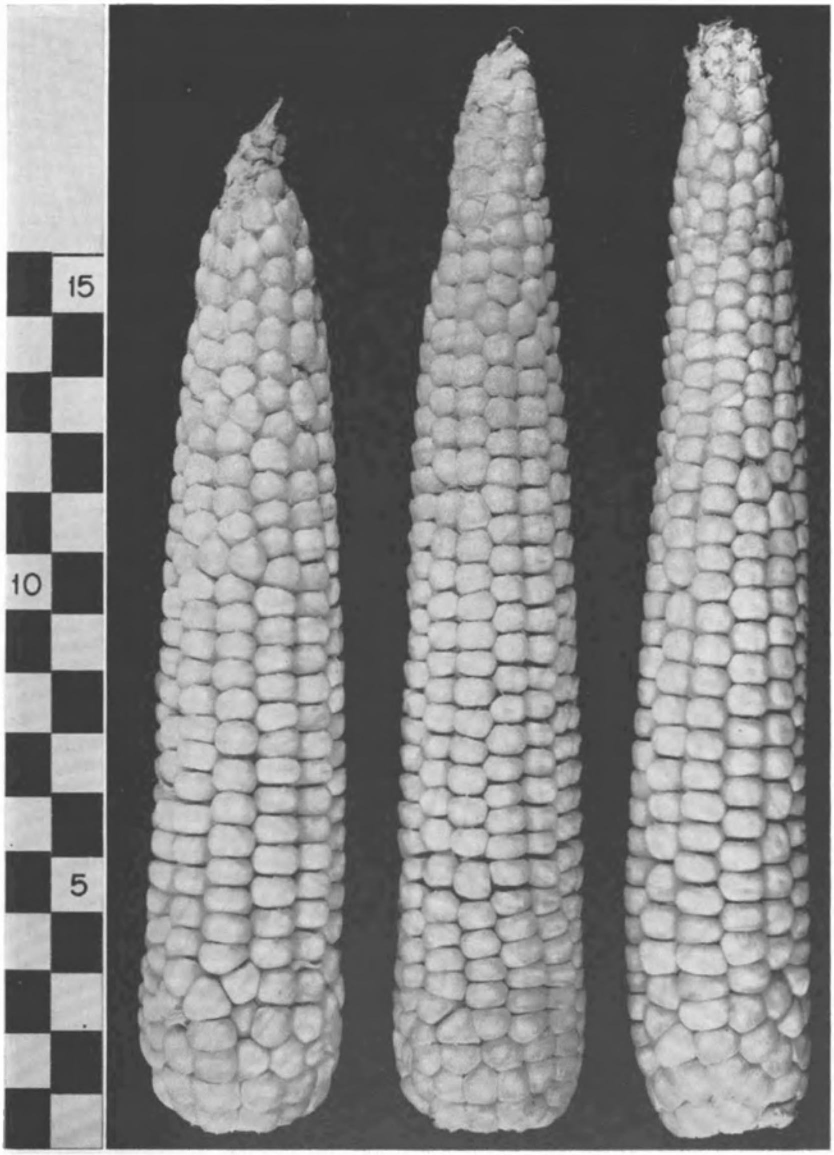

FIG. 120. A large-seeded popcorn of flint corn from the Carajá do Sul Indians, received without name.

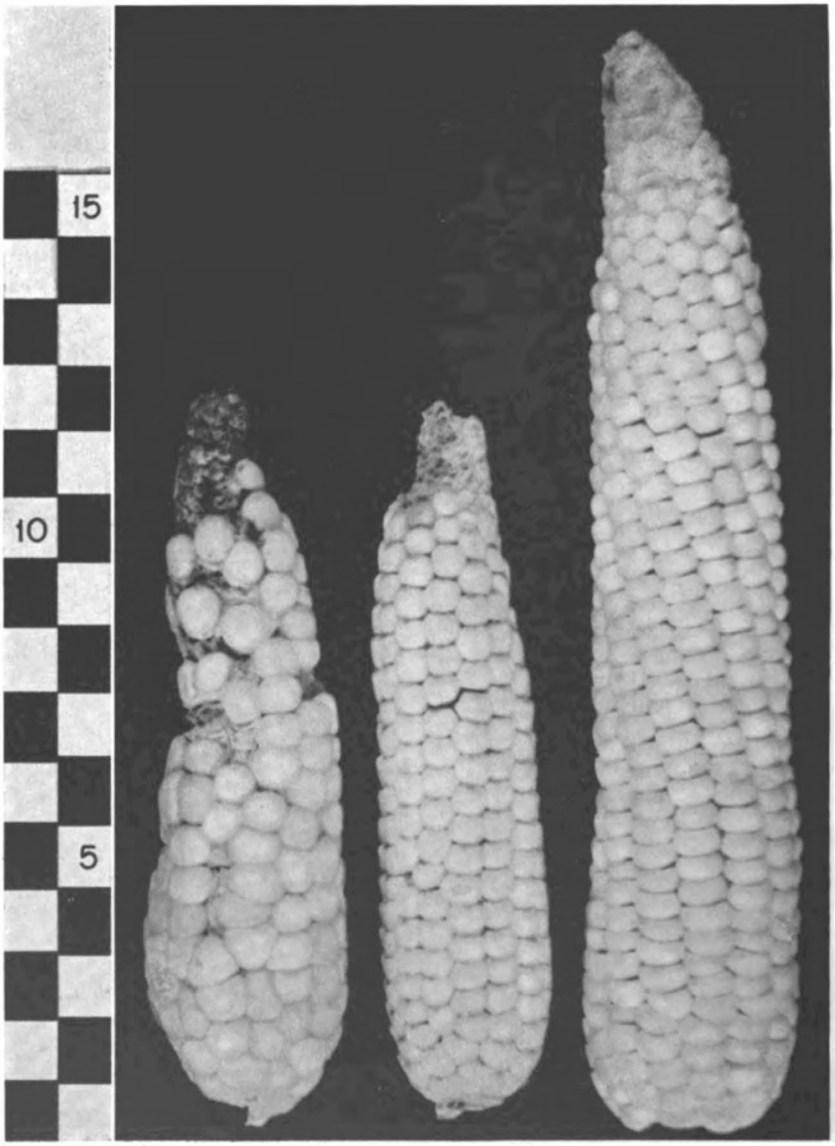

Fig. 121. Another soft corn race with small seeds, called Mai by the Carajá do Sul.

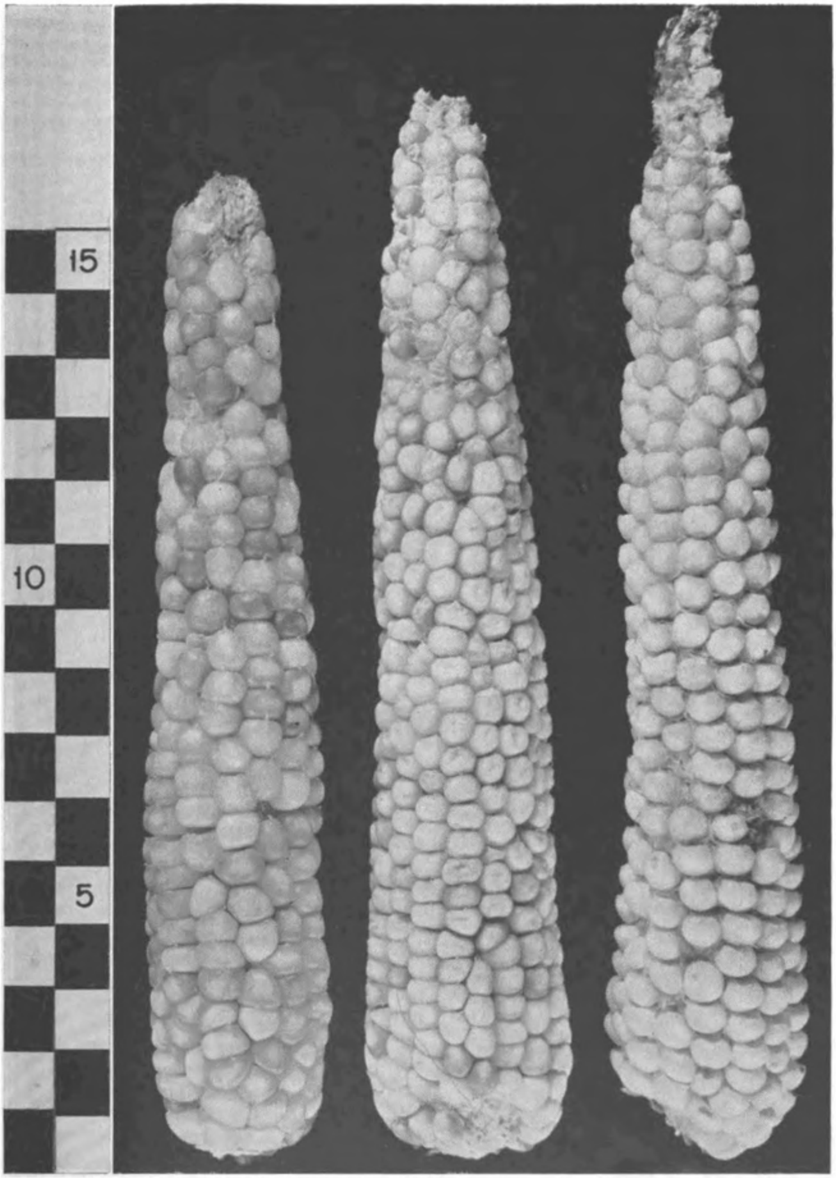

FIG. 122. A small-seeded popcorn, sometimes with pointed kernels and not very hard endosperm. The kernels are even sometimes slightly dented. This race was received without name from the Carajá do Sul Indians.

smaller than the foregoing race. Kernels small, with soft endosperm.

Itudoné. Quite similar to the preceding race, but ears hardly conical. Endosperm soft.

An unnamed race, which is a fairly large-seeded popcorn, or small-seeded flint corn (Fig. 120) with white kernels, quite regular row arrangement, and no interlocking.

Mai. Again a soft corn with rather small seeds of white color, on ears which show no interlocking but regular row arrangement.

The last race, also without indigenous name, consisted mostly of ears of a small-seeded popcorn, sometimes with pointed kernels, slightly conical ears without interlocking. Sometimes, however, the kernels contained soft endosperm, or even belonged to the type called "pointed dent."

51. RACES OF THE EMERILHÓN

This material was received some 15 years ago, and no records were taken at that time which would now be suitable. The ears show that we are dealing with a very primitive type, with slender ears and a closely packed "spiral-oblique" kernel arrangement. The kernels themselves are of the size of popcorn, though endosperm is often soft.

These ears give on the whole the same aspect as many of the Carajá ears. They are rather small, either slightly conical or tapering at both ends. The longitudinal rows are often not too clearly defined, and the whole arrangement becomes "oblique-spiral," with very tightly packed kernels. The latter may be round or they may be pointed. In the latter case, and in combination with the "oblique-spiral" arrangement, the kernels cover each other like the shingles on a roof. The color is generally orange, owing to the presence of pericarp coloration. The endosperm is either hard like popcorn or soft.

The Coastal Area

52. THE NORTHERN CATETO FLINTS

A complete analysis of Caribbean or Cuban Flint lies outside the scope of the present paper, and we shall limit ourselves to presenting here the results of the study of material collected by Dr. Kerr in the Guianas and by Dr. Froes in the Amazon area. In each case, there were two samples available.

Ear: The statistical analysis showed that the samples are far from uniform and that in some characters the variation within origins is of the same order or even greater than that between the two origins. The ears are on the whole rather long, though not in proportion to their thickness, with an average length per sample from 16 to 21 cm. Row number lies between 14 and 15 rows for the Amazon sample, and between 16 and 17 for the Guiana sample. In the ear diagram, the extreme thickness of the medulla is rather striking, with mean diameters between 0.9 and 1.5 cm. All other diameters are proportionally big and the total mid-ear diameter varies, with sample means from 4.7 to 5.8. Rachilla length comes out as 3 to 4 cm., which is not large in comparison with the other diameters of the ear diagram. Mean glume length varies between approximately 5 and 6 mm. The cob/rachis index is of the order of 1.58 to 1.68 for three of the samples and 1.85 for the fourth.

Kernel: The kernels are of about the normal size in the *Amazonas* type, and very large in the *Guiana* type. Glume cover varies from 30 to 47 per cent with a mean of 37 per cent. The kernels are not so hard as those of Southern *Cateto,* and they contain a certain amount of softer starch in the endosperm. Endosperm color is an intense yellow but not a deep orange.

Tassel: Perhaps the most striking characteristic is the low index of internode coverage, which is 1.13 for the *Amazonas* type and 1.30 for the *Guiana type.* This means that in both types, but especially in the first, quite a number of plants will have even part of their tassel enclosed in the last leaf sheath. The branched part of the tassel is relatively long and forms from 40 to 50 per cent of the whole tassel. The number of primary tassel branches is also quite high, about 43 in the *Amazonas type* and 24 in the *Guiana type.*

Plant: In plant characters there is more variability between samples than between the two types. The plants are always quite tall, with means from 251 to 280, not including the tassel, which measures from 40 to 50 cm. The ear always stands rather high, about at the end of the second third of the plant (mean for all samples 66 per cent of plant height). The leaves are consequently quite numerous and also large.

Internode pattern: This agrees completely with the pattern of the *Southern Cateto,* with one maximum of internode length several nodes below the ear, and the other maximum in the internode immediately below the tassel.

Origin and relationships: There is no doubt that, according to the texture and color of the kernels, we are dealing with representatives of the "*tropical*" or "Caribbean" Flint, names for which we substituted "*Cateto.*" The origin of the differences between these *Northern Catetos* and the *Southern Catetos,* especially in the diameter of the ears, the partial enclosure of the tassel within the last leaf sheath, and some other points, cannot yet be explained. This would require a study of a much larger series of samples of *Northern Catetos* and a more complete knowledge of the other races from which genes may have infiltrated, or which may have been grown by the coastal Indians in the north before the *Southern Catetos* expanded their areas sufficiently. We may, for instance, recall the maize which we described briefly as *Iauretê* or *Andaqui* (Fig. 123), which could have introduced many of the characters in question such as the increase in ear diameter and the tassel covering. We do not know, either, what races may have been brought in by the Aruak tribes when they migrated to the Guianas. Thus we must leave the question of the origin of the *Northern Cateto* so far open.

CONCLUDING DISCUSSION

In order to facilitate the description of the races and their coordination we submitted a number of questions to a critical discussion at the beginning of this paper. Now, after this description has been given, it seems appropriate to turn back to some of the general problems, in order to see if new conclusions may be drawn or if statements made before should be altered.

THE GEOGRAPHIC SUBDIVISION OF MAIZE DISTRIBUTION

We stated above that the whole of the South American area can be divided into several very large regions, in accordance with general climatic factors which control not only the distribution of a crop plant such as maize, but also of wild species such as orchids.

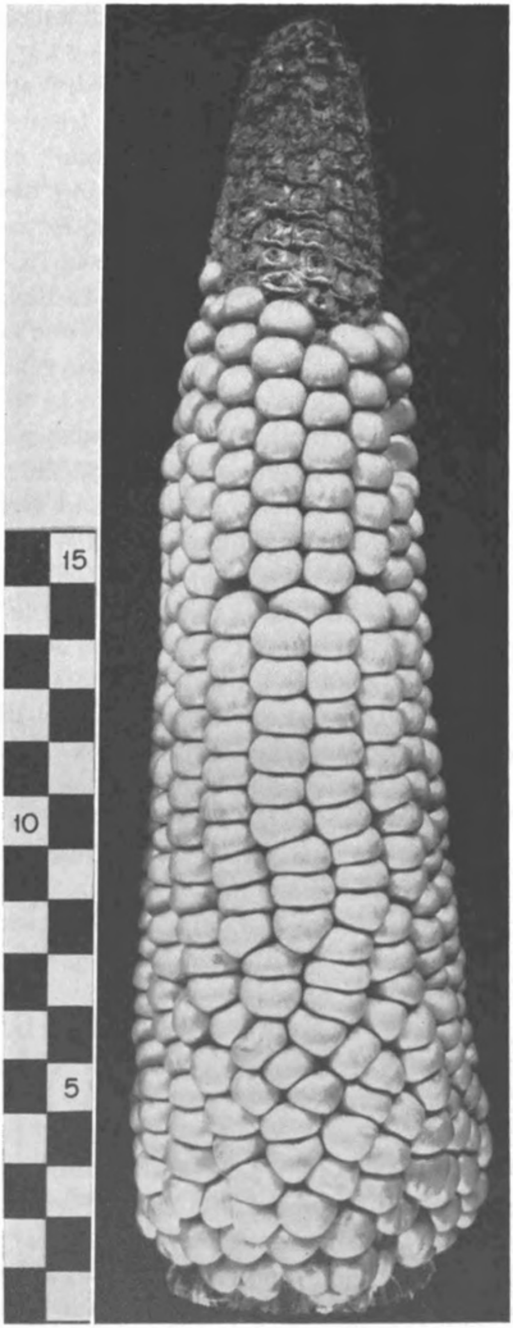

Fig. 123. This ear was received through missionaries from the Iauareté Indians, who live in the area of the Amazon-Rio Negro. It resembles somewhat the race *Andaqui* from Colombia and Venezuela.

We shall now attempt to give a general characterization of the main regions in maize distribution.

(1) *The Andean region* includes both High Valleys, roughly from 1,700 to 3,500 meters, and the Altiplano, from about 3,000 to 4,500 meters. This region forms in a way a rather narrow stretch of territory which is extremely long, reaching over nearly 40 degrees of latitude from north to south of the Equator. It must, however, be subdivided into at least two areas.

(a) From northern Argentina in the south to Ecuador or even southern Colombia in the north extends a vast zone which, at least at the time of the Conquest, had been under the general influence of the Central Government of the Incas, and

(b) in the North, in Colombia, Inca influence was just ready to start when the white conqueror appeared on the scene and interrupted a course of development which had been going on, more or less steadily, for many hundreds, if not thousands, of years.

However, the influence of an expanding people such as the Incas, and probably before them other factors such as exchange by commerce, may not have been the only factors which made the races of maize different in the southern or mainly Bolivian-Peruvian sector and the northern one of Colombia. It seems highly probable that climatic factors must have also played a role, as shown by the fact that only in the former or southern zone exists the geographic formation, generally called the Puna, where the Altiplano races of maize and the many other special crops of the Central Andes developed. In Colombia, owing to differences in the rainfall distribution, the Puna is replaced by the rather humid Páramas.

The races of maize of the northern area in Colombia give a completely different picture from those of the southern one, as can be seen easily from the complete description of the former given recently by Roberts *et al* (1957) and of races from the southern zone by Cutler (1947) and also above. The northern region is quite evidently connected with the Central American sectors with which it has even some races in common. (See Wellhausen *et al* 1952 and Wellhausen *et al* 1957.) We must distinguish two races. There are some races from the Bolivian and Peruvian Andes, such as

Sweet Corn or *Harinoso de Ocho* which reach southern Colombia from Peru and reappear in western Mexico. These races, and probably some others like them, could have reached Mexico only over the sea route, let us say roughly from the area of Guayaquil in the South. It is shown that they have not followed a land route through Central America, since no remains have ever been found in any Central American locality, *i.e.*, in the region through which a route from northern Colombia to Mexico must pass. On the other hand, such races as Sabanero (Colombia)—*Serrano* (Guatemala)—*Cacahuacintle* (Mexico), *Montaña-Capio* (Colombia)—*Salpor* (Guatemala)—*Montaña* (Colombia)—*Olotón* (Guatemala and Mexico) form another group, because here representatives are found throughout all regions on the route of migration. The authors of the papers above, Wellhausen, Roberts *et al* are inclined to believe that all these races came from Colombia and migrated north to Central America and Mexico.

Now we must ask where the races came from which characterize either the *Andean Inca Area* or the *Andean Colombian Area.* Such questions can certainly not be answered simultaneously for all races of both areas, since evidently these races differ very much in age and have been the product of a development going on for several thousands of years. However, the important point is that, except for some minor interchange between the two regions, the bulk of the races in each zone are so different as to point to a completely independent origin. The relation of a race like *Sabanero,* with its yellow orange-bronze aleurone, to the flour corn races of the lowlands to the east, containing races with the same color factors, seems to us quite evident, though it is not our intention to enter into a more detailed discussion of this group, fully described in all its aspects by Roberts *et al* (1957). As far as the southern area is concerned, the *Andean Inca Area,* we came to the conclusion that there are hardly any relations between the Andean races and types of maize in the lowlands in the east, belonging either to the *Interlocked Soft Corn* or the *Guaraní Soft Corn,* nor to the south, the *Calchaqui White Flint,* with two possible exceptions. There has been (a) some rather recent and probably even post-Columbian infiltration and (b) very little pre-Columbian infiltration. This leads us to postulate that nearly all Andean races, or rather their predecessors, migrated north to south, up through the river valleys of the Upper Amazon River system.

We have now to make one specific reservation, which refers to a peculiar situation in the 8-rowed races, which show certain remarkable features that can hardly be a coincidence. As far as our knowledge goes, there are the following races with eight rows: (1) *Northeastern Little Flint,* of the United States and Canada, which stands in fact completely isolated (Brown and Anderson 1947), (2) *Harinoso de Ocho,* of Mexico, which we consider derived from Peru, (3) Peruvian 8-rowed races, known so far mainly from pottery (according to information kindly given to us by Dr. Grobman), and (4) *Cuzco Large Grain*—(5) *Amarillo de Ocho* of Humahuaca, (6) *Avatí Morotí Mitá* of the southwestern Guaraní area and (7) *Canario de Ocho,* of northern Argentina, a member of the group of *Southern Cateto.* The last three races occupy a continuous area, and we explained *Canario de Ocho* as a probably quite recent synthetic of (*Mitá* x *Cateto*). The question thus arises whether *Amarillo de Ocho* and *Avatí Morotí Mitá* are related. If we study the characteristics of these two races (or three races if we include *Canario de Ocho*), we find that they have one character in common besides the existence of eight rows in rather straight and cylindrical ears: namely a very peculiar internode pattern, in which there is a continuous increase of internode length from the base of the plant to the last internode below the tassel, without any second maximum somewhere in the region of the ear. We feel it would be too much of a coincidence if two such independent and unrelated characters as the presence of only eight rows on cylindrical ears on the one side, and the peculiar internode pattern on the other, should always become correlated. If we study the internode patterns reported by Wellhausen *et al* for Mexico (1952) and by Roberts *et al* for Colombia (1957) we find only one more example of this same pattern: in the 8-rowed *Harinoso de Ocho* of Mexico (Wellhausen *et al,* 1952, Fig. VII) and we repeat that we consider this race as closely related to and derived from Andean 8-rowed races, *i.e.,* possibly even *Amarillo de Ocho.*

Thus we must consider it as probable that at some time and somewhere in the latitude "under the Capricorn," there has been an old eight-rowed maize type from which both the lowland and the Andean eight-rowed races may have been derived. We must admit the possibility of a double origin of the races of the *Andean Inca Area:* while we still believe that the bulk of the races moved up from the lowlands following the general direction from north to south, the eight-rowed types may have moved up in the opposite direction, from south to north or rather southeast to northwest, and *Amarillo de Ocho* would thus be an old relict type of this migration, in the southern margin of the Andean area. The pottery relicts mentioned from Peru may show that eight-rowed maize once had a much larger distribution there, and the *Cuzco Large Grain* is the most recent and most highly developed synthetic of the group.

Conclusion: (1) The whole *Andean area* must be divided into two quite separate and independent regions, with a very slight amount of racial interchange. The majority of the races came up from the lowlands somewhere in the general area of eastern Ecuador and the adjacent lowland regions northeast, east, and southeast and moved up independently, one group into the *Colombian Andes* and the other into the *Peruvian-Bolivian Andes.* But the eight-rowed races came originally from the lowlands "under the Capricorn" in the southeast and they entered only the Bolivian-Peruvian area, never the Colombian area.

(2) *The Pacific Coastal Area* must be divided into three parts.

(a) We explained that in the south, "under the Capricorn," the subtropical *Calchaqui White Flint* moved over the Andes to the coast of northern Chile, which is perfectly logical, since the same Indians lived on either side of the Andes.

(b) The *Chocoseño,* on the Pacific coast of Colombia in the north, shows, we believe, rather clear relations to other lowland races of the South American area east of the Andes, and thus it seems most likely that it had moved from east to west through the Magdalena plains of northern Colombia and along the Caribbean coast.

(c) Little has been published about the races from the coast of Peru but, after a preliminary inspection of Dr. Grobman's collection, we came to the conclusion that there is a rather close correlation between Peruvian Highland and coastal lowland races of the same latitude, indicating that there have been a number of migrations down through the many river valleys, always in a general direction from east to west.

(3) The third region is formed by a narrow belt in the *Eastern Slopes of the Andes,* from Colombia to Argentina. While this belt is not too well known, we think that it is occupied by a group of more or less *Brachytic Popcorn* races to which also belong *Pollo* from Colombia and *Confite Morocho* of Peru.

Next we come to the vast region east of the Andes which forms the main bulk of South America. It must again be divided quite evidently into three main areas. It should be remembered once more that we apply the term "lowland" here in contrast to the Andean highland above 2,000 meters and not in a strict altitude sense.

(4) The *southern subtropical lowland under the Capricorn* is the one which we have studied more intensively. In this zone, definite regions can again be distinguished, according to the main races of maize cultivated: *Calchaqui White Flint—Guaraní Yellow Soft Corn* and *Popcorn—Caingang White Dent—Southern Orange Cateto Flints.*

(5) *The middle and tropical area of the Amazonas Basin* may still yield some surprises, but it can be divided into at least four main zones: that of the *Interlocked Yellow Soft Corn* on the western and southern margin (including Orinoco region), the peculiar races of the *Eastern Amazon Basin,* and finally the *Northern Cateto Flints* in the coastal area.

(6) The *northern and also tropical area of Colombia and Venezuela,* from the Pacific and the Andes stretches to the Caribbean and includes the large region of *Cariaco Yellow Soft Corn,* of *Chocoseño* and of the races of the *Sierra de St. Martha.*

As we have stated repeatedly, these three regions (4, 5, and 6) are not in any way separated by mountain ranges or other easily visible geographic barriers, but nevertheless they represent quite pronounced and different climatic regions. The subdivisions within the three zones are perhaps more difficult to explain, and they seem to some extent to correspond to a change in ecological conditions, but also to a change in the composition of the Indian tribes. However, since we do not know what determined the fixation of these tribes in definite and separate areas, we must admit the hypothesis that the limitations of their principal field crops may have been the main responsible factor, *i.e.*, an ecological factor.

An attempt to reconstruct, from the facts of the present day distribution of the maize races in this vast area, the history of these maize races, would seem as little justified as an attempt to conclude, from today's distribution of people and of their languages in northern Europe and the Mediterranean area, the course of events which took place over the last few thousand years in this part of the world. Furthermore, in the discussion on the origin of maize races in Mexico, Guatemala, or Colombia it was still possible to speak of native races and others "come from the outside," from "somewhere else." Now this argument cannot be used any more, because there is not any "elsewhere" left.

The only conclusion which may seem justified is the statement that there are in reality several distributional patterns, one overlaid on the other.

(a) We have the general rule of the marginal distribution of the flint races, which in our case are the *Calchaqui White Flint* in the south and southwest, the *Southern Cateto Flints* in the southeast and east, and the *Northern Cateto Flints* and the *Caribbean Flints* in the northwest and the north, forming a wide arc from the Pacific coast of northern Chile to the Atlantic coast of Argentina and then up north to the islands of the Caribbean Sea. Then flints appear again at higher altitudes, in the Andes.

(b) We have the relict pattern of the popcorn races with a "spiral-oblique" arrangement, such as the *Avatí Pichingá Ihú* of the Guaraní, possibly some predecessor of *Cuarentón* among the *Southern Cateto Flints,* the indigenous races of the eastern Amazon Basin (some *Karajá* and *Emerilhon* races), some races of the *Sierra de St. Martha* in northern Colombia, and *Chocoseño* of the northern Pacific Coastal Plains.

(c) We have the area of the races with interlocking of kernels, which may represent an independent trend in the initial domestication, and which occurs mainly in the southwestern part of the Amazon Basin, stretching, however, far into the eastern part of it.

(d) Finally, we have the north-south pattern of distribution, from *Cariaco* and other Colombian races through the *Interlocked*

Soft Corn to the *Guaraní Soft Corn,* thus including all important races with soft endosperm and yellow-orange-bronze pigmentation of the aleurone layer.

Since, as already mentioned, we must assume that some races may be autochthonous, while others migrated into some region "from elsewhere," we must also assume that many originated in the regions where we find them. But an attempt to bring order into this puzzle would require that one would first be able to date the different trends in breeding and to try to explain them on a chronological basis.

This situation hardly helps us to get any more factual information about the place of origin of maize as a domesticated crop plant, which in all probability lies somewhere in this general region.

THE EXISTENCE OF "TRIPSACOID" MAIZE

In the discussion of the literature, we were forced to draw the conclusion that the distinction of two basic types of maize, the so-called *"pure maize"* and the *"Tripsacum-contaminated maize,"* cannot be substantiated, primarily because not one of the authors who make reference to this alternative includes a complete list of distinctive characters. We feel now, after more complete knowledge of the races of the subtropical area "under the Capricorn," that a distinction between these two types becomes still more obscure. This region lies definitely outside the area of distribution of any *Tripsacum* species, since the most southern point, where *Tripsacum australe* has been found, lies in the Bolivian lowlands, near the southern margin of the *Interlocked Soft Corn* races. But if we understand rightly the use made of the term *tripsacoid* then many races of this area "under the Capricorn" must be considered as *"Tripsacoid."* Roberts *et al* (1957, page 13) make special reference to *"Mais Amargo"* and claim that its "ears are highly tripsacoid and scarcely distinguishable from segregates of experimental maize-Tripsacum hybrids." All types of "Mais Amargo" which we have seen show characters which leave little doubt that they are extracts of *Calchaqui White Flint.* This race, and also the derived synthetics *Cristal* and *Cristal-Perola,* have very hard cobs which are highly sclerenchymatized, including the rachis flaps and the horny part of the glumes. Now if *Calchaqui White Flint* were not only a *"tripsacoid"* maize, but one which has acquired a very strong and resistant gene complex for these "tripsacoid" characters, it must have originated in or around Colombia, where *Tripsacum* species seem most frequent, and then have migrated from north to south nearly through the whole South American Continent, without much change even when passing through the supposed region of the so-called *"pure maize,"* before reaching finally the region where this race now occurs. The authors cited above continue in their discussion: "From this maize, as well as from slightly less tripsacoid varieties from Colombia, Venezuela, Brazil, Paraguay, Peru, and Bolivia . . ." which means that there is really no part in the whole of South America where the so-called "tripsacoid" maize does not occur both within and without the area in which *Tripsacum* itself occurs in the wild.

We think one must go back to the beginning of the whole speculation to understand all such reasoning, *i.e.,* to a time when one had still a very incomplete knowledge of Andean races as representatives of "pure maize" and wanted to explain some characteristics, believed to be limited to Mexican and Central American races and considered to be in contrast to the Andean races. At that time, the authors hardly knew anything at all about the existence of South American lowland races. Thus at that time there seemed to exist some justification for distinguishing two main types, with differences in characters and in geographical distribution. Now, however, the situation is completely changed, and there are nearly a hundred races of maize known as to their characters and their geographical distribution. If there were really two basically different groups, it must now be possible to define very clearly and even in terms of quantitative data what might be their most important and decisive differences. Since we do not see any possibility of reaching such a descriptive definition or distinction, nor can we find the competent data in literature of the authors who defended the distinction, we feel that the alternative "pure maize" versus "tripsacoid maize" should be abandoned.

We may add one more argument to the discussion. Assuming that there was a special "tripsacoid" type of maize, and even admitting that it has spread indiscriminately over the whole maize area in the Americas, we must still expect that there should be a very pronounced concentration and an increase in intensity of all "tripsacoid" characters in those areas where constant gene infiltration can and should occur, and this area would be Colombia and regions further north. On the other hand, in such regions as the subtropical zone "under the Capricorn," where *Tripsacum* does not exist and the only possibility is of retaining the *Tripsacum* infiltration which had been acquired, the *tripsacoid* characters should be at a minimum. In looking over the available data of the present and in the other papers already published, no indication of such differences in concentration or in intensity of the *"tripsacoid"* characters became evident.

Thus after acquiring much more knowledge, we feel still more convinced that there is no justification for speaking of "tripsacoid" characters whenever we meet such characters as long cylindrical ears with straight rows, hard cobs, horny glumes, etc., and that the distinction of "pure maize" and "tripsacoid maize" is no longer justified.

THE PROBLEM OF THE "TUNICATOID" CHARACTERS

Though in all publications only vague references can be found to what may be the characteristics of "pure maize," we can, however, define what may be considered as characters which came from pod corn, and these characters have sometimes been considered as part of the character complex of "pure maize."

Pod corn, carrying the dominant *Tu* factor, may be characterized by the following characters, which incidentally may be easily seen in the illustrations of pod corn in Figures 9 and 13: long glumes, long rachilla, kernels covered by the glumes, high cob/rachis index. These characteristics are not independent of each other, but are at least in part correlated in their variations. The extreme increase in glume length, necessary for covering the kernels, must lead by simple algebraic relations to an increase of the cob/rachis index even independently of an actual and observed reduction in rachis diameter. The latter requires some compensation in rachilla length, since otherwise the surface would become too small to accommodate all the kernels without a reduction in row number or without enforced interlocking. It seems that weak or half-tunicate alleles have similar effects, only in a reduced degree. Thirdly, it is not easy to distinguish the action of tunicate alleles and of modifiers of genes at the tunicate locus, and thus the possibility remains that other genes may act in a similar way, without belonging to the tunicate series.

If the “tunicatoid” characters were controlled only by alleles ferences of the *tu* alleles present, we would expect that any change in degree of “tunicatoid” effects should be correlated for all these characters, in accordance with the presence of “stronger” or “weaker” tunicate alleles. We give below a resumé of the expression of these “tunicatoid” characters in the South American races described in this paper.

Name of Race	*Cob/ Rachis Index*	*Diameter (cm.) of*		*Length (mm.) of*		*Kernel Covering %*
		Rachis	*Cob*	*Rachilla*	*Glume*	
Humahuaca:						
Valley type	1.54	1.73	2.63	2.5	3.2	13
Pisincho	1.69	1.52	2.50	2.4	3.8	27
Altiplano type	1.65	1.26	2.05	2.0	3.0	23
Soft Corn Lenha	1.57	2.80	4.40	5.5	5.2	32
Northern Cateto Flint	1.68	2.40	3.85	3.4	5.4	37
Calchaqui White Flint	1.76	1.10	2.66	4.3	5.6	43
Morotí Guapí	1.76	1.92	3.36	3.9	5.0	37
Morotí Djakaira	1.84	1.60	2.42	3.5	4.8	39
Interlocked Soft Corn (1)	1.86	1.42	2.50	2.6	4.5	39
Southern Cateto	1.86	1.53	2.82	3.0	5.0	43
Canario de Ocho	1.89	1.17	2.22	2.2	4.2	43
Caingang White Dent	1.95	1.60	2.92	3.5	4.8	39
Avatí Morotí	1.95	1.51	2.87	3.7	4.9	34
Interlocked Soft Corn (2)	2.04	1.09	2.21	2.6	4.3	39
Pichingá	2.05	1.01	2.06	2.0	4.2	49
Morotí Mitá	2.21	1.00	2.21	3.1	4.5	42
White Soft Corn	2.24	1.20	2.72	3.8	5.7	52
Cuarentón	2.25	1.15	2.58	2.6	5.8	54

From the inspection of these data, we can draw the following conclusions about existing correlations, using the cob/rachis index as the point of reference for all other characters.

With increasing cob/rachis index, there is a certain proportional decrease in the rachis diameter, which at first sight might be taken as the result of a parallel action of tunicate factors, but since an equally proportional decrease is also observed for the cob diameter, while we would really expect an increase, the situation remains ambiguous.

With increasing cob/rachis index, both rachilla length and glume length first decrease, but then start to increase again. With regard to the glume cover percentage, there may be a slight tendency to increase a little with increasing cob/rachis index.

In short, there is no strong correlation anywhere, giving an indication that special and different alleles are at work at the *tu* locus and not alleles of other loci. There is no uniform and simultaneous action regarding all these characters.

One may even raise the question again whether the cob/rachis index is really a safe indicator for the presence of alleles at the tunicate locus, as postulated by Mangelsdorf. If we compare the relatively heavy cobs of *Soft Corn Lenha* or of the *Northern Cateto Flints,* with an index of about 1.6 on the one hand, with the rather slender ears of *Chavantes Opaié* or *Cuarentón,* with an index of 2.2, on the other hand, we have rather the impression that in thick ears the cob diameter as a whole increases proportionally more than the rachis diameter, while in thin ears the opposite is the case; the cob diameter is more reduced than the rachis diameter.

In conclusion, we may say that no proof is available showing that any group of South American races described in this paper may have a higher allele at the tunicate locus, beyond the normal non-tunicate allele. Furthermore, there is again no indication that "tunicatoid" characters may serve to identify any kind of especially "pure" maize.

The arguments taken together point to the impossibility of objectively distinguishing *"pure"* and *"tripsacoid"* maize.

INCREASE IN ROW NUMBERS AT THE BEGINNING OF DOMESTICATION

Of the several important steps which must have characterized the beginning of domestication, *i.e.,* the transformation of a wild grass into the cereal maize, no new facts became known as to how the glume cover of the wild grass was lost, how the shattering of kernels at maturity was changed, etc. We may try, however, some speculative thinking about the increase in row numbers, from the wild type character of two ranks, with two rows each, to the many-ranked condition under domestication.

Since the 8-rowed races seem now to occupy a somewhat special position, it should be remembered that the change from two ranks to four ranks—a change not too rare even in wild grasses—does not involve serious morphological difficulties. Firstly, there is enough space available on two-ranked ears, since the flanks between the ranks are free. Secondly, no complications by twisting of rows or changes in the symmetrical position of the many alveoli are required, since the distichous condition can change easily into the decussate one.

If, however, the change occurred immediately from a two-ranked condition to a many-ranked condition, then the question of available space on the cob surface becomes a serious problem. There are three possibilities:

(a) If the increase in surface space is not sufficient, a "pressure" between kernels or rather at the formation of spikelet primordia must become effective, and the result will probably be an "oblique-spiral" arrangement. In fact this type of arrangement occurs in races considered as primitive, such as the races of the eastern Amazon, the Guaraní *Popcorn Pichingá Ihú,* and other races such as *Chocoseño.*

(b) If, instead of an increase in width, there is one in length, a solution which requires only half the cob material necessary, then interlocking results. This was found in several races of the Amazon Basin.

(c) Finally, if neither the row arrangement is abandoned nor interlocking occurs, then the available surface must be increased, and this may be accomplished in either of two ways: increase of rachilla length or increase of rachis diameter. It is interesting to note that in a number of South American races the first occurred in addition to the second, which is now present anyway in most races.

We have found a rachilla length beyond 3 mm. in the following races: Rachilla longer than 3 mm. on the average: *Soft Corn Lenha, Calchaqui White Flint,* all *Guaraní Soft Corn* races, *Caingang White Dent,* all *Cateto* races except *Cuarentón.*

Rachilla less than 3 mm. long: *Interlocked Soft Corn,* the *Guaraní Popcorn,* all the races from Humahuaca and *Cuarentón.* The Humahuaca races have, as we stated, a different origin from the lowland races, or rather they were derived long ago from some lowland races, and the *Interlocked* race does not require a great amount of surface increase, owing to the interlocking.

If we compare these data with those of other areas, it will be interesting to cite here the data of Roberts *et al* (1957) for Colombia, mentioning only those races which have a rachilla length of 3 or more mm.: *Cariaco* 3.7, *Montana* 4.3, *Capio* 5.1, *Cacao* 3.5. It may not be an accident that among these four races there are two at least which have yellow or bronze aleurone coloration, a character typical for lowland races.

SOME SPECIAL CHARACTERISTICS OF SOUTH AMERICAN MAIZE

Special reference seems indicated regarding two characters which to a certain extent determine the aspect of the plants of maize: the internode pattern and the partial enclosure of the tassel within the last leaf sheath.

Internode pattern. Besides the rather characteristic feature of the races with 8-rowed ears, we can register three different types of internode pattern: in all of these three there are two maxima of internode length, while in the 8-rowed races there is only one, in the internode just below the tassel. The other three types are distinguished by the position of the longest internode in the middle of the plant, a maximum which generally occurs in addition to the second one below the tassel. There are now three types:

(a) *Maximum length in the internode just below the ear:* This situation was found in all the races from *Humahuaca* except those which follow the pattern of 8-rowed races, in *White Soft Corn Lenha,* and in *Caingang White Dent Corn.*

(b) Maximum internode length above the ear: This was found in the following races: *Calchaqui White Flint,* all races of the *Guaraní Soft Corn* and *Guaraní Popcorn,* and also in the synthetic *Cristal,* derived from these races.

(c) Maximum internode length several nodes below the ear: This was found in the *Interlocked Soft Corn* and the synthetic Cristal-Perola derived from it, and in all *Cateto Flint* races studied.

If we compare results with other data contained in the literature, we find the following: Wellhausen *et al* (1952) reported for the Mexican races: Type (a) only for *Cacahuacintle, Naltel,* and *Conico,* while it seems that all the other races—of course except the 8-rowed *Harinoso de Ocho*—follow type (c) with the maximum internode length several nodes below the ear. Roberts *et al* (1957) showed for practically all races from Colombia, that the maximum lies several nodes below the ear type (c).

Type (b), which seems very frequent among the South American races, has not yet been observed elsewhere.

The *sheath covering of the tassel* seems to be now known only from South American races, though it was first reported also for some races in Asia. If we accept the calculations, carried out on several occasions above, we may distinguish two groups: Those races which have a cover index of 1.40 or more and those which have an index of between 1.0 and 1.4. In the former, no part of the tassel is ever covered by the sheath, while in the second group a fair amount will have the lower part of the tassel enclosed in the sheath in adult plants.

If the classification had been made at the beginning of pollen shedding, practically all plants of the second group would have shown an enclosed tassel. The distribution of the races into these two groups is as follows:

Tassel always free from the last leaf sheath (index 1.4 or more): *Humahuaca, Calchaqui White Flint, Soft Corn Lenha, Southern Cateto Flint.*

Tassel partly covered (index between 1.00 and 1.40): all races of *Guaraní Soft Corn* and *Guaraní Popcorn, Caingang White Dent, Interlocked Soft Corn, Northern Cateto Flint.*

CONCLUSION

When the Committee on Preservation of Indigenous Strains of Maize established their working program and organized the "Maize Centers," to carry out the work, they did not set up any special program or request that special scientific problems should be solved. The aim of the work foreseen consisted in helping to collect and to describe the indigenous races of this important cereal, which have been obtained and left to us by the American Indians in their agricultural work of many thousands of years. In trying to do our share in this project, we have touched on a number of general problems, but the description and the classification of the still existing races has been the main object throughout. Thus no general final scientific conclusions can be drawn here, or should be set apart. In concluding, we want to express our thanks to the members of the Committee not only for the financial help given, but mainly for the scientific support and for the stimulus we received in our efforts to contribute to the knowledge about one of the most important cereal crops of the world.

BIBLIOGRAPHY

ALAVA, R. O., 1952. Spikelet variation in *Zea mays* L. Ann. Mo. Bot. Gard. **39**: 65–96.

ALLEONI, M. R. B., 1957. Raças de milho da "Quebrada de Humahuaca." Républica Argentina). Tese para doutoramento. Piracicaba. 46 pg.

ANDERSON, E., 1944a. Homologies of the ear and tassel in Zea mays. Ann. Mo. Bot. Gard. **31**(4): 325–342.

ANDERSON, E., 1944b. The sources of effective germplasm in Hybrid maize. Ann. Mo. Bot. Gard. **31**(4): 355–361.

ANDERSON, E., 1945. What is Zea Mays? A report of progress. Chronica Botanica **9**(2–3): 88–92.

ANDERSON, E., 1946. Maize in Mexico. A preliminary survey. Ann. Mo. Bot. Gard. **33**: 147–247.

ANDERSON, E., 1947. Field studies of Guatemalan Maize. Ann. Mo. Bot. Gard. **34**: 433–467.

ANDERSON, E., AND BROWN, W. L., 1947. The northern flint corns. Ann. Mo. Bot. Gard. **34**: 1–28.

ANDERSON, E., AND BROWN, W. L., 1948. The southern dent corns. Ann. Mo. Bot. Gard. **35**: 255–268.

ANDERSON, E., AND BROWN, W. L., 1952a. The history of the common maize varieties of the United States corn belt. Agr. Hist. **26**: 2–8.

ANDERSON, E., AND BROWN, W. L., 1952b. Origin of corn belt maize and its genetics significance. Heterosis 124–148. J. W. GOWEN Ed. Iowa State Coll. Press. Ames.

ANDERSON, E., AND BROWN, W. L., 1953. The popcorns of Turkey. Ann. Mo. Bot. Gard. **40**: 33–48.

ANDERSON, E., AND CUTLER, H. C., 1942. Races of *Zea mays:* I. Their recognition and classification. Ann. Mo. Bot. Gard. **29**: 69–88.

ARBER, A., 1934. The Gramineae. A study of cereal, bamboo, and grass. 480 pp. Cambridge University Press. London.

ASCHERSON, P., 1880. Bemerkungen über ästige Mais kolben. Bot. Verein. Brandenburg **21**: 133–138.

BARGHOORN, E. S., WOLFE, M. K., AND CLISBY, K. H., 1954. Fossil maize from the valley of Mexico. Bot. Mus. Leaft. Harvard Univ. **16**: 229–240.

BIRD, J., 1948. Preceramic cultures in Chicama and Virú. Am. Antiquity **13**: 21–28.

BONNETT, O. T., 1940. The development of the staminate and pistillate inflorescences of sweet corn. Journ. Agr. Res. **60**: 25–38.

BONNETT, O. T., 1948. Ear and Tassel Development in maize. Ann. Mo. Bot. Gard. **35**: 269–287.

BONNETT, O. T., 1953. Developmental morphology of the vegetative and floral shoots of maize. Bul. 568, Agric, Exper. Station, 47 pp.

BRIEGER, F. G., 1943. Origem do milho, Rev. Agric. **18**: 409–418.

Brieger, F. G., 1944. Estudos experimentais sôbre a origem do milho. Anais da E. S. A. "Luiz de Queiroz" **10**: 226–263.

Brieger, F. G., 1945a. Estudos genéticos sôbre o milho tunicata. Anais da E. S. A. "Luiz de Queiroz" **17**: 210–238.

Brieger, F. G., 1945b. Estudos sôbre a inflorescência de milho com referência especial aos problemas filognéticos. Bragantia **5**: 659–716.

Brieger, F. G., 1946. Limites unilaterais e bilaterais na análise estatística. Bragantia **6**: 479–545.

Brieger, F. G., 1949a. Origem e centros de domesticaçao do milho. II. Centros de domesticaçao. Melhoramento. Ciencia e Cultura **1**: 191–201.

Brieger, F. G., 1949b. Origem e domesticaçao do milho. De Lilloa **20**: 37–44. Tucuman. Argentina.

Brieger, F. G., 1950a. Consideracoes sôbre o milho indentado. Ciência e Cultura. **2**: 60.

Brieger, F. G., 1950b. A distribuicao do milho indigena e comercial. Primeira Assembl. Latino Amer. Fitogen. 90–95. Ofic. Estud. Esp. S. A. G. Mexico.

Brieger, F. G., 1952a. The structure of the maize inflorescence. 54 pp. Boletim n° 10—Amais da E. S. A. "Luiz de Queiroz" **8**: 1–101.

Brieger, F. G., 1952b. Sôbre a caracterizacao das raças indigenas de milho. 2° Reuniao Latino-Amer. de Fitogen. e Fitoparas. (Resumo.)

Candolle, de A., 1882. Origin of cultivated plants. New York.

Clisby, K. H., 1954. Studies of Mexican profiles. 2) Pollen profiles. Bull. Am. Geol. Soc.

Collins, G. N., 1918. Tropical varieties of maize. Jour. Hered. **9**: 147–154.

Collins, G. N., 1920. Waxy maize from Upper Burma. Science **52**: 48–51.

Cutler, H. C., 1945. Espiguetas de dois graos no milho. Anais da E. S. A. "Luis de Queiroz" **2**(23): 423–430.

Cutler, H. C., 1946. Races of maize in South America. Bot. Mus. Leaft. Harv. Univ. **12**: 257–292.

Cutler, H. C., and Anderson, E., 1941. A preliminary survey of the genus Tripsacum. Ann. Mo. Bot. Gard. **28**: 249–269.

Cutler, H. C., and Cutler, M. C., 1948. Studies on the structure of the maize plant. Ann. Mo. Bot. Gard. **35**: 301–316.

Galinat, W. C., 1956. Evolution leading to the formation of the cupulate fruit case in the American maydeae. Bot. Mus. Leaft. Harvard Univ. **17**(8): 217–239.

Galinat, W. C., Mangelsdorf, P. C., and Pierson, L., 1956. Estimates of Teosinte introgression in archaeological maize. Bot. Mus. Leaft. Harvard Univ. **17**(4): 101–124.

Harshberger, J. M., 1893. Maize, a botanical and economical study. Cont. Bot. Lab. Univ. Pa. **1**: 75–202.

Harshberger, J. W., 1896. Fertile crosses of teosinte and maize. Gard. and Forest. **9**: 522–523.

Hatheway, W. H., 1957. Races of maize in Cuba. Nat. Acad. Sc. — Nat. Res. Council Publ. **453**: 75 pp.

Jones, D. F., 1924. The origin of flint and dent corn. The Journal of Heredity **15**: 416–418.

Kitajima, E., 1958. A ocorencia do gen "waxy" no milho. Brasileiro (in press).

Mangelsdorf, P. C., 1945. The origin and nature of the ear of maize. Bot. Mus. Leaft. Harvard Univ. **12**(2): 33–75.

Mangelsdorf, P. C., 1947. The origin and evolution of maize. Advances in Genetics **1**: 162–207.

Mangelsdorf, P. C., 1948. The role of pod corn in the origin and evolution of maize. Ann. Mo. Bot. Gard. **35**: 377–406.

Mangelsdorf, P. C., and Cameron, J. W., 1942. Western Guatemala, a secondary center of origin of cultivated maize varieties. Bot. Mus. Leaft. Harv. Univ. **10**: 217–252.

MANGELSDORF, P. C., AND OLIVER, L., 1951. Whence came maize to Asia? Bot. Mus. Leaft., Harvard Univ. **14**(10): 263–291.

MANGELSDORF, P. C., AND REEVES, R. G., 1939. The origin of Indian corn and its relatives. Texas Agr. Exp. Sta. Bull. **574**: 315 pp.

MANGELSDORF, P. C., AND REEVES, R. G., 1945. The origin of maize: present status of the problem. American Anthropologist **47**(2): 235–243.

MANGELSDORF, P. C., AND SMITH, C. E., JR., 1949. New archaeological evidence on evolution in maize. Bot. Mus. Leaft., Harvard Univ. **13**: 213–247.

MANGELSDORF, P. C., MAC NEISH, R. S., AND GALINAT, W. C., 1956. Archaeological evidence on the diffusions of maize in northeastern Mexico. Bot. Mus. Leaft. Harvard Univ. **18**: 125–150.

NICKERSON, N. H. 1953. Variation in Cob Morphology among Certain Archaeological and Ethnological Races of Maize. Ann. Bot. Gard. **40**: 40–111.

PARODI, L. R., 1935. Relaciones de la Agricultura Prehispanica con la Agricultura Argentina actual. Anales Acad. Nac. Agron. y Veter. de Buenos Aires **1**: 115–167.

PARODI, L. R., 1948. Los maices indigenas de La Republica Argentina. Anales Acad. Nac. de C. E. F. y N. de Buenos Aires. **12**: 9–14.

PATERNIANI, E., 1955. Estudos sôbre as raças do milho indigena "Caingang." Tese doutoramento, Piracicaba. 74 pp.

RANDOLPH, L. F., 1952. New evidence on the origin of maize. The American Naturalist, LXXXVI (829): 193–202.

RANDOLPH, L. F., 1955. Cytogenetic aspects of the origin and evolutionary history of corn. pp. 16–17. In: G. F. Sprague, Corn and Corn Improvement, New York, 16–57.

ROBERTS, L. M., GRANT, U. J., RAMIREZ, R., HATHEWAY, W. H., SMITH, D. L., AND MANGELSDORF, P. C., 1957. Races of Maize in Colombia. Nat. Acad. Sc. — Nat. Res. Council Publ. **510**: 153 pp.

SAINT-HILAIRE, A. DE, 1829. Letter une varieté semarquable de mains du Bresil. Ann. Sc. Nat. **16**: 143–145.

STONOR, C. R., AND ANDERSON, E., 1949. Maize among the hill peoples of Assam. Ann. Mo. Bot. Gard. **36**: 355–404.

SUTO, TIHARA, AND YOSHIO YOSHIDA, 1952–53. Characteristics of the Oriental Maize. Land and Crops of Nepal Himalaya. Fauna and Flora Research Society, Kyoto University, Kyoto, Japan, v. II, 375–530.

TABORDA, R. F., 1956. Análise genética da aleurona incolor em racas mexicanas de milho. Tese para doutoramento apresentada à E. S. A. "Luiz de Queiroz," 78 pp. Piracicaba.

VAVILOV, N. F., 1926. Studies on the origin of cultivated plants. Bul. Appl. Bot. Gen. and Plant Breeding **16**: 139–248.

VENCOWSKI, R., 1958. Correlacao entre altura da planta' da espiga em milho (in press.).

WEATHERWAX, P., 1935. The phylogeny of *Zea Mays*. Amer. Midland Nat. **16**: 1–71.

WEATHERWAX, P., 1942. The indian as a corn breeder. Proc. Indiana Acad. Sci., **51**: 13–21.

WEATHERWAX, P., 1955. Early history of corn and theories as to its origin. In: G. F. Sprague, Corn and Corn Improvement, New York, pp. 1–15.

WELLHAUSEN, E. J., ROBERTS, L. M., HERNANDEZ, E. X., AND MANGELSDORF, P. C., 1952. Races of Maize in Mexico. The Bussey Inst. Harvard Univ. 223 pp. and also 1951, Ofic. Estud. Espec., S. A. G., Fol. Tecn., n° 5–237 pp.

WELLHAUSEN, E. J., FUENTES, A., CORZO, A. H., MANGELSDORF, P. C., 1957. Races of Maize in Central America. Nat. Acad. Sc. — Nat. Res. Council Publ. 511, 128 pp.

APPENDIX

TABLE 1. Ivaí Amarello, a synthetic between Avatí Morotí and Caingang White Dent.

SYNTHETIC—*Ivai Amarello*		*Avati*	*Ivai Obs.*		*Amarello Esp.*	*Caingang Ivai*	*Error Estimate*
Ear characters	*N*	*16*		*49*		*209*	
Length of ear		15.0	19.2	d	17.4	19.8	2.29
N° of rows		10.2	11.0	=	11.0	12.8	2.14
Width of:							
Medula		0.48	0.56	=	0.61	0.74	0.14
Rachis		1.00	1.20	=	1.22	1.44	0.26
Kernel base		1.62	1.84	=	1.88	2.13	0.35
Cob		2.21	2.48	=	2.50	2.80	0.27
Ear		3.08	3.62	=	3.66	4.25	0.32
Cob/rachis index		2.21	2.14	=	2.10	2.00	0.26
Kernel		*10*				*222*	
Length		0.85	0.96	=	0.99	0.99	0.09
Width		0.85	0.95	=	0.86	1.13	0.09
Depth		0.47	0.48	=	0.46	0.44	0.05
Kernel covering		0.42	0.41	=	0.39	0.36	0.09
Plant characters:	*N*	*40*		*140*		*222*	
Plant height		113	194	i	168	222	20.5
Ear height		35	159	(h)	76	117	17.3
Ear/plant height		0.36	0.58	d	0.48	0.61	0.06
N° leaves below ear		4.3	7.1	=	6.2	8.0	1.02
N° leaves above ear		4.4	5.6	=	5.3	6.2	0.81
Tassel characters:	*N*	*20*		*53*		*168*	
Tassel base:							
Length, leaf sheath		17.5	14.2	=	16.4	15.3	1.61
Length, internode		12.9	17.9	=	16.8	20.7	2.89
Internode, cover		1.36	1.22	(—h)	1.34	1.32	0.15
Tassel:							
Length, branched part		12.6	23.4	h	15.6	18.7	2.96
Length, terminal spike		24.9	21.1	(—h)	25.2	25.4	5.57
Branched part/tassel length		0.33	0.53	h	0.37	0.41	7.05
Branches N° of:							
1° order		15.2	24.3	h	18.9	22.6	4.37
2° order		4.6	15.8	h	10.4	8.9	3.94

TABLE 2. Different types of the synthetic group *Cristal:* Cristal Paraguay and Paulista derived from Avatí Morotí × Calchaqui White Flint, and Cristal Perola "Reys" nº 1113, 1108 and Santa Cruz—Ear characters.

Cristal (White Flint) Ear Characters	*N*	*Ear Length (cm.)*	*Nº of Rows*	*Diameter (cm.)*					*Cob-Rachis Index*	*Kernels (cm.)*			*Kernel Covering*
				Medulla	*Rachis*	*Kernel Base*	*Cob*	*Ear*		*Length*	*Width*	*Depth*	
Means:													
Cristal Paraguay	119	17.4	13.2	0.75	*1.75*	2.29	*3.05*	*4.13*	1.76	0.97	0.89	0.46	0.43
Cristal Paulista	35	17.3	13.1	0.68	1.56	2.09	2.95	4.04	1.90	0.99	0.86	0.45	0.43
General mean		17.4	13.2	0.73	1.74	2.24	3.03	4.11	1.79	0.97	0.88	0.46	0.43
Cristal Santa Cruz	5	*18.4*	*15.6*	*1.20*	*1.96*	*2.58*	*3.56*	*4.76*	*1.87*	*1.02*	*0.88*	*0.48*	*0.45*
Cristal Reys 1113	5	20.7	14.0	0.66	1.14	1.70	2.44	3.38	2.16	0.86	0.79	0.56	0.15
Cristal Reys 1108	5	21.0	15.0	0.76	1.38	2.20	2.84	4.12	2.10	0.95	0.80	0.53	0.33
General Mean		20.8	14.8	0.70	1.26	1.95	2.67	3.75	2.13	0.90	0.80	0.54	0.24
Error ratios:													
Between 3 types	2	2.82	2.06	3.35	3.82	3.68	4.48	3.68	8.57	2.20	2.79	3.54	5.01
(Probability)		1%	1%	1%	1‰	1‰	1‰	1‰	1‰	5%	1%	1‰	1‰
Between Paraguay/SP.	1	1.92	0.27	1.63	2.91	2.91	1.49	3.51	2.61	0.70	2.21	0.93	—
(Probability)		5%	5%	5%	1‰	1%	5%	1‰	1%	5%	1%	5%	—
Between 2 types Reys	1	1.77	1.33	0.73	1.12	2.32	1.80	1.27	1.36	1.70	0.30	0.93	3.50
(Probability)		5%	5%	5%	5%	1%	5%	5%	5%	5%	5%	5%	1‰
Residual error:	164	2.71	1.90	0.22	0.34	0.34	0.35	0.37	0.28	0.08	0.07	0.07	0.08
Coeff. of var.		15.4%	14.3%	29.3%	19.5%	15.2%	11.7%	18.1%	13.3%	8.4%	7.7%	5.9%	19.0%

TABLE 3. Same as Table 2—Tassel Characters

Tassel Characters Cristal (White Flint)	N	Base			Tassel			Branches	
		Sheath Length (cm.)	Internode Length (cm.)	Internode Covering	Branched Part (cm.)	Terminal Spike (cm.)	Proportion Branch/Term	N° 1° Order	N° 2° Order
Means:									
Cristal Paraguay	125	13.3	14.0	1.06	17.1	24.8	0.41	25.3	10.4
Cristal Paulista	45	13.6	14.9	1.09	16.6	23.2	0.40	23.9	8.5
		13.4	14.2	1.07	17.0	24.4	0.41	24.9	9.9
Cristal Santa Cruz	5	10.4	13.0	1.26	14.4	23.2	0.38	2.18	11.6
Cristal Reys 1108	5	13.8	18.4	1.35	15.0	19.2	0.44	22.6	10.2
Cristal Reys 1113	5	11.8	17.4	1.41	24.0	20.8	0.54	30.4	17.2
		12.8	17.9	1.43	19.5	20.0	0.49	26.5	13.7
Error ratios:									
Between 3 types	2	1.31	2.76	3.72	2.24	2.44	3.11	1.18	2.02
(Probability)		5%	1%	1‰	1%	1%	1‰	5%	5%
Between Paraguay/S.P.	1	0.83	1.65	0.81	1.06	2.20	0.55	1.65	2.68
(Probability)		5%	5%	5%	5%	5%	5%	5%	5%
Within Paraguay/S.P.	32	1.32	1.46	1.31	1.47	1.38	1.45	1.42	1.78
(Probability)		5%	1%	5%	1%	5%	1%	1%	1‰
Between Reys (2 origins)	1	1.64	0.69	0.86	7.91	1.57	5.33	2.31	2.32
(Probability)		5%	5%	5%	5‰	5%	1‰	5%	5%
Residual error:	148	1.73	3.02	0.22	3.09	3.96	0.06	5.16	4.24
Coeff. of var.		13.0%	19.8%	20.1%	18.2%	16.4%	14.8%	20.7%	4.2%

TABLE 4. Same as Table 2—Plant Characters

		Height			*Leaf*					
Cristal (White Flint) Plant Characters	*N*	*Plant (cm.)*	*Ear (cm.)*	*Ratio Ear/Plant Height*	*N° Below Ear*	*N° Above Ear*	*Length (cm.)*	*Width (cm.)*	*N° of Veins*	*Venation Index*
Means:										
Cristal Paraguay	242	*185*	*110*	0.59	9.1	5.9	96.5	10.7	27.1	2.55
Cristal São Paulo	86	222	133	0.60	9.8	6.1	98.7	10.9	28.5	2.64
General Mean		195	116	0.59	9.3	6.0	97.1	10.8	27.5	2.57
Cristal Sta. Cruz	10	242	141	0.59	7.7	8.2	—	—	—	—
Cristal Reys 1108	10	244	141	0.58	7.2	8.2	—	—	—	—
Cristal Reys 1113	10	210	122	0.58	5.3	8.2	—	—	—	—
General Mean		226	131	0.58	6.2	8.2	—	—	—	—
Error ratios:										
Between 3 types	2	6.22	3.96	0.60	8.92	11.88	—	—	—	—
(Probability)		1‰	1‰	5%	1‰	1‰	—	—	—	—
Between Paraguay/S.P.	1	12.88	10.62	5.25	5.01	1.98	9.17	1.59	4.40	2.44
(Probability)		1‰	1%	1‰	1‰	5%	1‰	5%	1‰	5%
Within Paraguay/S.P.	32	2.56	1.67	6.10	2.10	1.92	—	—	—	—
(Probability)		1‰	1‰	1‰	1‰	1‰	1‰	1‰	1%	1‰
Between Reys (2 Types)	1	3.06	2.58	—	5.25	—	—	—	—	—
(Probability)		1%	5%	—	1‰	—	—	—	—	—
Residual error:	321	22.63	18.00	0.06	1.02	0.77	8.74	1.10	2.59	0.27
Coeff. of var.		11.7%	15.3%	10.0%	11.2%	11.7%	9.0%	10.2%	9.4%	10.5%

TABLE 5. Different types of synthetics between *Capia Blanco* and *Amarillo de Ocho*

Ear Characters	*Capia Blanco*	*Capia Yellow*	*Capia Amar. de Ocho*	*Amar. de Ocho*	*Error Estimate*
Numbers of ears	23	9	18	3	
Length of ear	12.3	11.9	12.8	15.8	1.61
N° of rows	14.1	12.7	9.7	8.0	2.40
Diagram:					
Medulla	0.79	0.76	0.51	0.50	0.18
Rachis	1.81	1.68	1.27	1.23	0.29
Kernel base	2.30	2.25	1.65	1.63	0.26
Cob	2.72	2.54	2.04	2.03	0.26
Ear	4.94	4.56	3.83	3.65	0.33
Cob-rachis Index	1.53	1.53	1.63	1.64	0.18
Kernel:					
Length	1.37	1.35	1.16	1.20	0.27
Width	0.90	0.91	0.95	0.97	0.18
Depth	0.43	0.43	0.40	0.40	0.04
Kernel covering	0.14	0.12	0.17	0.17	0.04
Tassel Characters					
Number of tassels	60	25	20	10	
Tassel Base:					
Length of Sheath	14.5	14.4	15.1	14.0	1.57
Length of internode	23.8	24.8	26.7	24.7	4.07
Internode covering	1.66	1.69	1.61	1.74	0.09
Tassel:					
Length, branched part	15.0	15.7	14.3	14.8	3.66
Length, terminal spike	25.4	23.7	25.6	27.7	5.89
Branched/term. spike	0.37	0.38	0.38	0.36	0.10
N° of branches:					
1° order	18.9	15.3	15.9	12.4	4.39
2° order	7.00	5.8	4.8	6.2	3.36

TABLE 5a. Different types of synthetics between *Capia Blanco* and *Amarillo de Ocho*

Plant Characters	*Capia Blanco*	*Capia Amar. de Ocho Type 1*	*Capia Amar. de Ocho Type 2*	*Capia Amarillo*	*Capia Amar. de Ocho Type 3*	*Amarillo de Ocho*	*Estimate Error*
Number of plants	120	10	10	50	10	10	—
Height:							
Plant Height	175	158	153	146	142	136	21.00
Ear Height	85	75	74	60	56	43	20.60
Ear/Plant	0.48	0.47	0.46	0.40	0.40	0.32	0.08
Number of leaves:							
Below ear	5.8	5.6	5.5	4.8	4.7	3.5	1.04
Above ear	5.1	4.7	4.6	4.8	4.3	5.0	0.96
Leaf:							
Length	83.7	77.4	—	76.0	73.5	—	6.74
Width	9.7	9.3	—	8.3	8.1	—	1.52
Veins	21.8	20.5	—	19.0	18.1	—	3.34
Venation index	2.25	2.27	—	2.21	2.17	—	0.62

TABLE 6. *Humahuaca: Capia* and its two groups of subraces: *Capia Blanco* and *Capia Amarillo*—Ear Characters

Capia Humahuaca Ear Characters	*N*	*Ear Length* (cm.)	*N° of Rows*	Diameter (cm.)					*Cob-Rachis Index*	Kernels (cm.)			*Kernel Covering*
				Medulla	*Rachis*	*Kernel Base*	*Cob*	*Ear*		*Length*	*Width*	*Depth*	
Means:													
White Endosperm Types	23	12.3	14.1	0.79	1.81	2.30	2.72	4.94	1.53	1.37	0.90	0.43	0.14
Yellow Endosperm Types	9	11.9	12.7	0.76	1.68	1.97	2.54	4.56	1.53	1.35	0.91	0.43	0.17
Error ratios:	d.f.												
Between types	1	1.37	1.90	1.45	2.02	3.24	1.10	3.45	—	1.15	0.45	2.33	1.77
(Probability)		>5%	>5%	>5%	>5%	1%	>5%	1%	—	>5%	>5%	5%	>5%
Between subraces	5	0.77	12.45 [*]	1.40	1.00	2.20	1.03	1.42	0.59	0.62	1.63	1.00	2.50 [†]
(Probability)		>5%	1‰	>5%	>5%	1%	>5%	5>%	>5%	>5%	>5%	>5%	1°/ooo
Residual error:	25	1.82	1.87	0.20	0.35	0.29	0.29	0.40	0.17	0.13	0.08	0.03	0.03
Coeff. of var.		14.4%	13.3%	19.8%	12.7%	10.9%	8.3%	8.2%	11.0%	9.6%	8.9%	7.0%	25.0%

[*] Mean of Capia Amarillo 10.50 fileiras, mean of the other subraces 14.2 fileiras.

[†] Mean of Capia Amarillo 0.22, mean of all other subraces 0.13.

TABLE 7. Same as Table 6—Tassel Characters

		Base			*Tassel*			*Branches*	
Capia Humahuaca Tassel Characters	*N*	*Sheath Length (cm.)*	*Internode Length (cm.)*	*Internode Covering*	*Branched Part (cm.)*	*Terminal Spike (cm.)*	*Proportion Branch/ Term.*	*N° 1°* Order	*N° 2° Order*
Means:									
White Endosperm Types	60	14.5	23.8	1.66	*15.0*	25.4	0.37	18.9	7.0
Yellow Endosperm Types	25	14.4	24.8	1.70	14.7	23.7	0.38	15.3	5.8
Error ratios:	d.f.								
Between types	1	0.60	1.00	0.52	0.74	1.80	0.41	3.88	1.39
(Probability)		>5%	>5%	>5%	5%	>5%	>5%	1‰	>5%
Between plantings	2	3.80	0.89	1.42	2.58	0.95	1.64	1.29	1.17
(Probability)		1‰	>5%	5%	1%	>5%	>5%	>5%	>5%
Within subraces and plantings	13	2.41	4.56	0.02	1.59	1.55	1.51	2.03	1.56
(Probability)		1‰	1‰	>5%	1%	5%	5%	1‰	5%
Residual error:	68	1.91	4.11	0.33	3.31	4.38	0.03	4.12	3.78
Coeff. of var.		13.3%	17.1%	19.8%	21.7%	13.7%	8.2%	23.2%	56.9%

TABLE 8. Same as Table 6—Plant Characters.

		Height			*Leaf*					
Capia Humahuaca Plant Characters	*N*	*Plant (cm.)*	*Ear (cm.)*	*Ratio Ear/ Plant Height*	*Nº Below Ear*	*Nº Above Ear*	*Length (cm.)*	*Width (cm.)*	*Nº of Veins*	*Venation Index*
Means:										
White Endosperm Types	120	175.7	84.8	0.48	5.8	5.1	83.7	9.7	21.8	2.25
Yellow Endosperm Types	50	146.3	60.2	0.40	4.8	4.8	76.0	8.3	19.0	2.21
Error ratios:	d.f.									
Between types	1	8.57	7.73	5.72	6.24	2.61	5.92	3.73	3.88	0.37
(Probability)		1‰	1‰	1‰	1‰	1%	1‰	1‰	1‰	>5%
Between years	2	2.59	2.03	1.28	1.27	0.90	4.08	0.75	0.11	0.10
(Probability)		1%	5%	>5%	>5%	>5%	1‰	>5%	>5%	>5%
Within subraces and plantings	13	1.44	0.80	0.92	1.82	1.33	1.46	2.11	1.14	0.97
(Probability)		5%	>5%	>5%	1‰	>5%	5%	1‰	>5%	>5%
Residual error:	153	21.7	20.2	0.90	0.98	0.79	6.74	1.52	3.34	0.62
Coeff. of var.		13.0%	26.0%	18.9%	17.8%	15.8%	8.3%	16.4%	15.9%	27.7%

TABLE 9. *Humahuaca: Pisincho* and its different types—Ear Characters

				Diameter (cm.)						*Kernels (cm.)*			
Pisincho Humahuaca *Ear Characters*	*N*	*Ear Length (cm.)*	*Nº of Rows*	*Medulla*	*Rachis*	*Kernel Base*	*Cob*	*Ear*	*Cob-Rachis Index*	*Length*	*Width*	*Depth*	*Kernel Covering*
Means:													
All types	10	11.1	18.0	0.70	1.52	2.00	2.50	3.65	1.69	0.93	0.54	0.37	0.27
Residual error:	9	2.15		0.15	0.28	0.30	0.28	0.35	0.13	0.06	0.04	0.02	0.05
Coeff. of var.		19.4%		21.4%	18.4%	15.0%	11.6%	9.6%	7.7%	6.4%	7.4%	5.4%	18.5%

TABLE 10. Same as Table 8—Tassel Characters.

Pisincho Humahuaca *Tassel Characters*	*N*	*Base*			*Tassel*			*N° of Branches*	
		Sheath Length (cm.)	*Internode Length (cm.)*	*Internode Covering*	*Branched Part (cm.)*	*Terminal Spike (cm.)*	*Proportion Branch/ Term.*	*1° Order*	*2° Order*
Means:									
Type 1	5	*18.4*	27.4	1.49	11.2	33.6	0.25	8.8	—
Type 2	20	*15.6*	25.7	1.60	7.8	29.8	0.21	*8.2*	—
Type 3	5	12.6	20.3	1.53	9.4	22.0	0.31	15.6	—
Error ratios:	d.f.								
Between types	2	3.08	1.57	0.52	1.95	1.63	1.89	2.47	—
(Probability)		1‰	>5%	>5%	5%	>5%	5%	1‰	—
Residual error:	27	2.14	5.47	0.36	5.06	6.72	0.07	0.04	—
Coeff. of var.		13.8%	21.8%	19.0%	30.1%	23.0%	31.1%	45.0%	—

TABLE 11. Same as Table 8—Plant Characters.

Pisincho Humabuaca Plant Characters	*N*	*Height*			*Leaf*	
		Plant (cm.)	*Ear (cm.)*	*Ratio Ear/ Plant Height*	*N° Below Ear*	*N° Above Ear*
Means:						
Type 1	10	154.6	85.0	0.53	6.5	3.8
Type 2	40	130.2	55.8	0.41	5.2	3.7
Type 3	10	118.3	52.2	0.43	4.1	4.2
Error ratio:	d.f.					
Between types	2	1.43	2.99	2.38	3.67	0.71
(Probability)		>5%	1‰	1%	1‰	>5%
Residual error:	57	21.0	20.6	0.17	1.04	0.96
Coeff. of var.		15.8%	34.3%	39.1%	19.9%	25.2%

TABLE 12. *Humahuaca Valley Type—Ear Characters.*

Valley Type Humahuaca Ear Characters	*N*	*Ear Length (cm.)*	*N° of Rows*	*Diameter (cm.)*					*Cob Rachis Index*	*Kernels (cm.)*			*Kernel Covering*
				Medulla	*Rachis*	*Kernel Base*	*Cob*	*Ear*		*Length*	*Width*	*Depth*	
Means:													
Capia Blanco	23	12.3	14.1	0.79	1.81	2.30	2.72	4.94	1.53	1.37	0.90	0.43	0.14
Capia Amarillo	9	11.9	12.7	0.76	1.68	2.25	2.54	4.56	1.53	1.35	0.91	0.43	0.12
Chulpi	5	10.4	15.5	0.66	1.64	*2.20*	2.66	4.54	1.65	1.24	*0.74*	0.39	0.16
Achilli	5	15.5	10.0	0.74	1.60	*2.04*	2.40	4.48	1.50	1.40	*1.03*	0.41	0.13
Marron	2	13.2	12.0	0.72	1.63	2.17	2.53	4.50	1.57	1.29	0.84	0.42	0.14
General Means:	44	12.4	13.4	0.76	1.73	2.24	2.63	4.74	1.54	1.35	0.90	0.42	0.13
Morocho	4	13.4	14.5	0.93	2.03	2.35	2.68	4.45	1.34	1.01	0.82	0.42	0.16
Error ratios:													
Between 5 races	4	2.11	2.67	0.69	0.80	2.22	1.27	1.45	0.79	1.15	3.92	1.48	1.25
(Probability)		1%	1‰	>5%	>5%	1%	>5%	>5%	>5%	>5%	1‰	>5%	>5%
Residual error:	39	1.82	1.87	0.20	0.35	0.29	0.29	0.40	0.17	0.13	0.08	0.03	0.03
Coeff. of var.		14.7%	55.0%	26.3%	20.2%	12.9%	11.0%	8.4%	11.0%	9.6%	8.9%	7.1%	23.1%

TABLE 13. Same as Table 12—Tassel Characters.

Valley Type Humahuaca Tassel Characters	*N*	*Base*			*Tassel*			*Branches*	
		Sheath Length (cm.)	*Internode Length (cm.)*	*Internode Covering*	*Branched Part (cm.)*	*Terminal Spike (cm.)*	*Proportion Branch/ Term.*	*N° 1° Order*	*N° 2° Order*
Means:									
Capia Blanco	60	14.5	23.8	1.66	15.0	25.4	0.34	18.9	7.0
Chulpi	10	14.0	24.2	1.72	15.6	24.0	0.40	17.8	7.1
Oke	10	14.7	23.6	1.60	17.3	25.5	0.42	18.6	7.2
Achilli	10	14.6	22.8	1.54	18.0	27.0	0.38	16.8	8.7
Marron	5	14.2	23.5	0.70	12.6	23.2	0.35	15.7	5.4
Culli	10	13.6	21.2	1.54	14.4	24.8	0.37	14.9	4.5
Amarillo de Ocho	5	14.0	24.7	1.74	14.8	27.7	0.36	12.4	6.2
Morocho	10	14.6	22.8	1.64	12.7	23.9	0.35	14.8	6.8
General Means:	120	14.9	23.5	1.64	15.0	25.4	0.38	17.0	6.7
Error ratios:									
Between races	7	1.02	0.90	0.24	1.02	0.85	1.90	1.88	1.30
(Probability)		>5%	>5%	>5%	>5%	>5%	>5%	1%	>5%
Residual error:	112	1.57	4.07	0.09	3.66	5.89	0.10	4.39	3.36
Coeff. of var.	112	10.5%	17.3%	19.5%	23.9%	23.2%	26.3%	25.8%	50.1%

TABLE 14. Same as Table 12—Plant Characters.

Valley Type Humahuaca Plant Characters	*N*	*Plant*			*Leaf*					
		Plant (cm.)	*Ear (cm.)*	*Ratio Ear/Plant Height*	*N° Below Ear*	*N° Above Ear*	*Length (cm.)*	*Width (cm.)*	*N° of Veins*	*Venation Index*
Means:										
Capia Blanco	60	157.7	84.8	0.48	5.8	5.1	83.7	9.7	21.8	2.25
Chulpi	20	164.2	73.8	0.48	5.3	4.2	80.7	8.0	18.7	2.33
Oke	20	162.0	82.0	0.50	6.5	4.4	87.1	9.6	21.0	2.20
Achilli	20	158.8	77.2	0.46	5.8	5.0	87.8	9.7	20.6	2.12
Morocho	20	150.8	80.2	0.50	6.0	4.6	83.2	9.8	22.4	2.27
General means:	140	158.2	81.1	0.48	5.9	4.8	84.3	9.5	21.2	2.01
Error ratios:										
Between races	4	1.10	1.14	0.95	1.88	2.17	1.96	2.32	2.02	0.58
(Probability)		>5%	>5%	>5%	1%	1%	1%	1‰	1%	>5%
Residual error:	135	21.0	20.6	0.08	1.04	0.96	6.74	1.52	3.34	0.62
Coeff. of variation:	135	11.8%	25.4%	16.7%	17.6%	20.0%	8.0%	16.0%	15.8%	27.8%

TABLE 15. *Humahuaca: Altiplano* Type—Ear Characters.

Altiplano Type Humahuaca Ear Characters	*N*	*Ear Length (cm.)*	*Nº of Rows*	*Diameter (cm.)*					*Cob-Rachis Index*	*Kernels (cm.)*			*Kernel Covering*
				Medulla	*Rachis*	*Kernel Base*	*Cob*	*Ear*		*Length*	*Width*	*Depth*	
Means:													
Altiplano	13	6.1	12.2	0.49	1.25	1.61	2.03	3.59	1.65	1.01	0.80	0.49	0.27
Bola Blanca	5	8.1	15.2	0.48	1.26	1.64	2.08	3.48	1.66	0.84	0.63	0.49	0.27
Oke	4	8.2	10.7	0.55	1.23	1.60	2.10	3.37	1.70	0.89	0.79	0.43	0.28
Culli	4	11.9	10.5	0.43	1.33	1.80	2.08	4.05	1.61	1.20	0.91	0.44	0.12
Amarillo de Ocho	6	13.8	8.0	0.50	1.23	1.63	2.03	3.65	1.64	1.20	0.97	0.40	0.17
General Means:	32	8.9	11.5	0.49	1.26	1.64	2.05	3.62	1.65	1.03	0.82	0.46	0.23
Error ratios:													
Between races	4	6.85	2.05	0.56	0.53	0.81	0.62	2.50	0.32	0.95	1.22	2.00	2.66
(Probability)		1‰	1%	>5%	>5%	>5%	>5%	1%	>5%	>5%	>5%	5%	1%
Residual error:	26	1.23	3.03	0.16	0.19	0.21	0.21	0.20	0.19	0.08	0.05	0.05	0.06
Coeff. of variation:	26	13.8%	26.3%	32.6%	15.1%	12.8%	10.2%	5.5%	11.5%	7.6%	6.6%	10.8%	26.1%

TABLE 16. Same as Table 15—Tassel Characters.

Altiplano Type Humahuaca Tassel Characters	*N*	*Base*			*Tassel*			*Branches*	
		Sheath Length (cm.)	*Internode Length (cm.)*	*Internode Covering (cm.)*	*Branched Part*	*Terminal Spike (cm.)*	*Proportion Branch/ Term.*	*Nº 1º Order*	*Nº 2º Order*
Mean:									
Altiplano	5	12.8	21.4	1.61	12.0	20.7	0.36	14.8	9.4
Bola Blanca	10	13.4	22.2	1.72	12.3	23.2	0.33	14.9	3.4
General Mean:	15	13.1	21.8	1.68	12.2	22.0	0.34	14.8	6.4
Error ratios:									
Between races	1	0.58	0.28	0.61	0.17	0.78	1.80	0.04	1.93
(Probability)		>5%	>5%	>5%	>5%	>5%	>5%	>5%	>5%
Residual errors:	13	1.64	5.58	0.33	2.83	5.09	0.10	4.64	4.92
Coeff. of var.		44.3%	25.6%	19.6%	23.2%	23.1%	25.6%	31.4%	76.9%

TABLE 17. Same as Table 15—Plant Characters.

Altiplano Type Humahuaca Plant Characters	*N*	*Height*			*Leaf*	
		Plant (cm.)	*Ear (cm.)*	*Ratio Ear/ Plant Height*	*N• Below Ear*	*N• Above Ear*
Means:						
Altiplano	10	141.0	55.0	0.38	4.3	5.0
Marron	10	137.5	42.5	0.31	3.6	4.4
Amarillo de Ocho	10	136.5	43.0	0.32	3.5	5.0
Culli	20	134.2	63.5	0.47	5.0	4.4
Bola Blanca	20	119.2	48.0	0.40	4.2	3.9
General Mean:	70	131.7	51.9	0.39	4.3	4.4
Error ratio:						
Between races	4	1.63	1.68	6.12	4.42	3.64
(Probability)		5%	5%	1‰	1‰	1‰
Residual error:	66	21.0	20.6	0.08	1.04	0.96
Coeff. of variation:	66	17.0%	39.7%	20.5%	24.2%	21.8%

TABLE 18. Humahuaca: Resumé of the Three Main Types: *Valley* Type *Altiplano* Type and *Pisincho*—Ear Characters.

Humahuaca Ear Characters	*N*	*Ear Length (cm.)*	*N° of Rows*	*Diameter (cm.)*					*Cob Rachis Index*	*Kernels (cm.)*			*Kernel Covering*
				Medulla	*Rachis*	*Kernel Base*	*Cob*	*Ear*		*Length*	*Width*	*Depth*	
Means:													
Valley type	44	(12.4)	(13.4)	0.76	1.73	2.24	2.63	4.74	1.54	1.35	0.90	0.42	0.13
Pisincho	10	11.1	18.0	0.70	1.52	2.00	2.50	3.65	1.69	0.93	0.54	0.37	0.27
Altiplano type	32	8.9	11.5	0.49	1.26	1.64	2.05	3.62	1.65	1.03	0.82	0.46	0.23

TABLE 19. Same as Table 18—Tassel Characters.

Humahuaca Tassel Characters	*N*	*Base*			*Tassel*			*Branches*	
		Sheath Length (cm.)	*Internode Length*	*Internode Covering*	*Branched Part (cm.)*	*Terminal Spike (cm.)*	*Proportion Branch/ Term.*	*N° 1° Order*	*N° 2° Order*
Means:									
Valley type	120	14.9	23.5	*1.64*	15.0	25.4	0.38	17.0	6.7
		12.6			7.8			8.2	
					9.4				
Pisincho	30	15.6	25.1	*1.57*	11.2	29.1	0.23	8.8	—
		18.4						15.6	
Altiplano type	15	13.1	21.8	*1.68*	12.2	22.0	0.34	14.8	6.4

TABLE 20. Same as Table 18—Plant Characters.

		Height			Leaf					
Humahuaca Plant Characters	*N*	*Plant (cm.)*	*Ear (cm.)*	*Ratio Ear/ Plant Height*	*N° Below Ear*	*N° Above Ear*	*Length (cm.)*	*Width (cm.)*	*N° of Veins*	*Venation Index*
Means:										
Valley type	140	158.2	81.1	0.48	5.9	4.8	84.3	9.5	21.2	2.01
		118.3	52.2	0.41	4.1	3.7	—	—	—	—
Pisincho	60	130.2	55.8	0.43	5.2	3.8	—	—	—	—
		154.6	85.0	0.53	6.5	4.2	—	—	—	—
Altiplano type	70	131.7	51.9	0.39	4.3	4.4	—	—	—	—

TABLE 21. *Pisankalla* from Argentina, Lady Finger Type—Ear Characters.

				Diameter (cm.)						Kernels (cm.)			
Pisankalla Argentina Ear Character	*N*	*Ear Length (cm.)*	*N° of Rows*	*Medulla*	*Rachis*	*Kernel Base*	*Cob*	*Ear*	*Cob Rachis Index*	*Length*	*Width*	*Depth*	*Kernel Cover-ing*
Means:	5	7.8	12.8	0.22	0.57	0.88	1.34	1.74	2.1	0.52	0.42	0.27	0.38
Error:	5	0.46	1.09	0.04	0.14	0.10	0.07	0.13	0.71	0.04	0.03	0.08	0.06
Coeff. of var.:	80.00	5.89	8.52	18.18	24.56	11.36	5.22	7.47	33.80	6.9%	6.2%	2.8%	26.4%

TABLE 22. *Calchaqui White Flint*—Ear Characters.

Calchaqui White Flint Ear Characters	*N*	*Ear Length (cm.)*	*N° of Rows*	*Diameter (cm.)*					*Cob-Rachis Index*	*Kernels (cm.)*			*Kernel Covering*
				Medulla	*Rachis*	*Kernel Base*	*Cob*	*Ear*		*Length*	*Width*	*Depth*	
Means:	59	17.3	13.0	0.64	1.10	1.97	2.66	3.57	1.76	0.89	0.81	0.44	0.43
Error:	58	2.57	2.32	0.16	0.30	0.33	0.35	0.43	0.25	0.13	0.10	0.07	0.12
Coeff. of var.:	58	14.9%	17.8%	25.0%	27.3%	16.8%	13.2%	12.0%	14.2%	14.6%	12.3%	15.9%	27.9%

TABLE 23. Same as Table 22—Tassel Characters.

Calchaqui White Flint Tassel Characters	*N*	*Base*			*Tassel*			*Branches*	
		Sheath Length (cm.)	*Internode Length (cm.)*	*Internode Covering*	*Branched Part (cm.)*	*Terminal Spike (cm.)*	*Proportion Branch/Term.*	*N° 1° Order*	*N° 2° Order*
Means:	70	14.3	20.9	1.47	16.3	24.9	0.38	20.2	6.3
Error ratio:									
Between origin	13	1.03	0.70	1.48	1.47	1.11	1.29	1.84	2.28
(Probability)		>5%	>5%	5%	5%	>5%	>5%	>5%	1‰
Residual error:	56	2.41	4.39	0.25	3.60	4.07	0.07	5.06	2.65
Coeff. of variation:	56	16.9%	21.0%	36.7%	22.1%	16.3%	18.4%	25.0%	41.0%

TABLE 24. Same as Table 22—Plant Characters.

Calchaqui White Flint Plant Characters	*N*	*Height*			*Leaf*					
		Plant (cm.)	*Ear (cm.)*	*Ratio Ear/ Plant Height*	*N° Below Ear*	*N° Above Ear*	*Length (cm.)*	*Width (cm.)*	*N° of Vens*	*Venation Index*
Means:										
Type 1	50	150.7	71.6	0.46	6.6	4.7	76.4	8.6	24.4	2.70
Type 2	40	180.0	86.8	0.48	7.1		82.1	8.8		
Type 3	50	210.0	125.4	0.60	8.5		88.0	9.8		
Error ratios:										
Between groups	1	8.92	8.60	3.00	5.94	↓	4.25	3.79	↓	↓
(Probability)		1‰	1‰	1%	1‰		1‰	1‰		
Within groups	11	1.10	2.23	2.10	2.09	2.03	1.42	1.86	1.51	2.19
(Probability)		>5%	1‰	1‰	1‰	1‰	5%	1%	5%	1‰
Residual errors:	126	23.54	20.64	0.09	1.17	0.77	9.03	1.07	2.78	0.27
Coeff. of variation:	126	13.1%	21.7%	17.3%	15.8%	16.5%	10.9%	11.7%	11.4%	10.0%

TABLE 25. *Guarani Soft Corn*—Different Races of Avatí Morotí—Ear Characters.

Guarani Soft Corn Ear Characters	*N*	*Ear Length (cm.)*	*N° of Rows*	*Diameter (cm.)*					*Cob-Rachis Index*	*Kernels (cm.)*			*Kernel Covering*
				Medulla	*Rachis*	*Kernel Base*	*Cob*	*Ear*		*Length*	*Width*	*Depth*	
Means:													
Avatí Morotí Mitá	16	*15.0*	*10.2*	*0.48*	*1.00*	*1.62*	*2.21*	*3.08*	*2.21*	0.85	0.85	0.47	0.42
Avatí Morotí	125	17.8	12.7	0.70	1.49	2.23	2.84	4.04	1.95	0.99	0.87	0.48	0.34
Avatí Morotí Tí	23	19.2	15.0	0.80	1.55	2.35	2.94	4.09	1.95	0.94	0.82	0.51	0.34
Avatí Djakaira	39	*18.7*	14.0	*0.68*	*1.60*	*2.29*	2.92	*3.94*	*1.84*	0.85	0.85	0.48	0.39
Avatí Morotí Guapí	19	13.0	14.8	1.00	1.92	2.70	3.36	4.56	1.76	0.95	0.87	0.47	0.37
Error ratios:													
Between 3 groups of races	2	6.23	4.22	5.74	6.41	7.20	5.09	8.14	3.46	4.81	—	—	3.22
(Probability)		1‰	1‰	1‰	1‰	1‰	1‰	1‰	1‰	1‰	—	—	1‰
Within groups of races	2	1.93	2.37	3.11	1.41	1.26	1.26	1.02	1.69	—	1.61	2.73	1.67
(Probability)		5%	5%	1‰	5%	5%	5%	5%	5%	—	5%	5%	5%
Residual error:	252	2.68	3.15	0.19	0.34	0.35	0.34	0.43	0.26	0.12	0.10	0.06	0.09
Coeff. of variation:	252	15.3%	24.2%	27.3%	22.5%	15.5%	11.9%	10.8%	13.4%	12.4%	11.4%	20.4%	25.0%

TABLE 26. Same as Table 25—Tassel Characters.

Guarani Soft Corn Tassel Characters	*N*	*Base*			*Tassel*			*Branches*	
		Sheath Length (cm.)	*Internode Length (cm.)*	*Internode Covering*	*Branched Part (cm.)*	*Terminal Spike (cm.)*	*Proportion Branch/Term.*	*Nº 1º Order*	*Nº 2º Order*
Means:									
Avatí Morotí Mitá	20	12.9	17.5	1.36	*12.6*	24.9	*0.33*	*15.2*	4.6
Avatí Morotí	180	12.8	15.9	1.24	17.0	24.4	0.41	21.9	8.9
Avatí Morotí Tí	25	13.4	16.4	1.23	17.0	25.3	0.40	24.4	8.4
Avatí Djakaira	55	12.9	14.0	1.09	*1.68*	23.4	0.42	27.6	8.8
Avatí Morotí Guapí	30	11.4	13.0	1.15	14.2	23.6	0.38	20.7	8.7
Error ratios:	d.f.								
Between Avatí Mitá and the other 4 races	1	↓	↓	↓	24.85	↓	6.85	12.10	6.77
(Probability)		↓	↓	↓	1%	↓	1‰	1‰	1%
Between the other races	3	↓	↓	↓	↓	↓	↓	↓	↓
(Probability)		↓	↓	↓	↓	↓	↓	↓	↓
Between different origins within races	6	↓	2.82	↓	2.74	↓	↓	↓	↓
(Probability)		↓	1‰	↓	1‰	↓	↓	↓	↓
Within origins	51	1.48	1.45	1.68	1.33	1.65	1.60	3.22	3.00
(Probability)		1‰	1‰	1‰	1‰	1‰	1‰	1‰	1‰
Residual error:	247	1.70	2.84	0.19	3.14	3.58	0.06	5.00	4.17
Coeff. of variation:	247	13.4%	19.6%	16.5%	18.7%	15.1%	15.5%	19.4%	47.0%

TABLE 27. Same as Table 25—Plant Characters.

		Height			*Leaf*					
Guarani Soft Corn Plant Characters	*N*	*Plant (cm.)*	*Ear (cm.)*	*Ratio Ear/ Plant Height*	*N° Below Ear*	*N° Above Ear*	Length *(cm.)*	Width *(cm.)*	*N° of Veins*	*Venation Index*
Means:										
Avatí Morotí Mitá	32	*112.7*	*35.4*	*0.36*	*4.3*	*4.4*	*61.4*	*7.1*	*19.1*	*3.25*
Avatí Morotí	275	179.2	103.6	0.55	8.8	5.9	92.6	9.9	27.3	2.61
Avatí Morotí Tí	37	196.1	123.0	0.59	8.9	5.7	96.9	10.1	26.3	2.46
Avatí Djakaira	82	*196.4*	*113.3*	0.57	8.9	6.4	*94.1*	10.2	27.4	2.70
Avatí Morotí Guapí	47	159.0	90.4	0.51	8.5	5.6	87.4	9.3	26.2	2.72
Error ratios:	d.f.									
Between Avatí Mitá and the other 4 races	1	20.46	23.43	27.33	24.37	12.73	21.21	21.00	17.37	11.34
(Probability)		1‰	1‰	1‰	1‰	1‰	1‰	1‰	1‰	1‰
Between other 4 races and origins	9	6.15	6.02	5.50	5.50	6.09	6.98	4.69	↓	↓
(Probability)		1‰	1‰	1‰	1‰	1‰	1‰	1‰		
Within origins	51	2.88	2.82	2.00	3.23	1.47	1.59	2.03	1.56	2.18
(Probability)		1‰	1‰	1‰	1‰	1‰	1‰	1‰	1‰	1‰
Residual error:	473	20.4	18.1	0.06	1.11	0.75	8.56	2.22	2.67	0.32
Coeff. of variation:	473	11.5%	17.4%	10.5%	13.0%	14.0%	9.4%	10.4%	10.0%	12.0%

TABLE 28. *Guarani Pop Corn*—Avatí Pichingá (Pointed Pop Corn or Pipoca Pontudo, Avatí Pichingá Ihú (Round Pop Corn or Pipoca Redondo) and a Mixed Group—Ear Characters.

Avatí Pichingá (Pipoca) Ear Characters	*N*	*Ear Length (cm.)*	*Nº of Rows*	*Diameter (cm.)*					*Cob-Rachis Index*	*Kernels (cm.)*			*Kernel Covering*
				Medulla	*Rachis*	*Kernel Base*	*Cob*	*Ear*		*Length*	*Width*	*Depth*	
Mean:													
Pipoca pontudo	113	12.3	—	—	—	—	—	—	—	—	—	0.33	0.48
Pipoca mixto	24	15.2	13.8	0.42	1.01	1.41	2.06	2.72	2.05	0.77	0.54	0.36	0.52
Pipoca redondo	31	15.1	—	—	—	—	—	—	—	—	—	0.39	0.59
Error ratio:	d.f.												
Between races or subraces	2	6.85	1.01	1.01	0.42	0.50	2.15	0.40	1.66	1.41	1.93	3.95	2.67
(Probability)		1‰	5%	5%	5%	5%	5%	5%	—	5%	5%	1%	1%
Residual error:	165	2.17	2.13	0.14	0.19	0.21	0.26	0.30	0.29	0.44	0.32	0.26	0.15
Coefficient of variation:	165	16.4%	14.9%	32.4%	18.7%	14.9%	12.5%	11.1%	14.1%	11.5%	11.9%	15.0%	25.4%

TABLE 29. Same as Table 28—Tassel Characters

Avati Pichingá (Pipoca) Tassel Characters	*N*	*Base*			*Tassel*			*Branches*		
		Sheath Length (cm.)	*Internode Length (cm.)*	*Internode Covering*	*Branched Part (cm.)*	*Terminal Spike (cm.)*	*Proportion Branch/ Term.*	*N• 1• Order*	*N• 2• Order*	
General means:	200	12.3	13.5	1.10	12.3	23.7	0.35	20.0	5.1	(1)
								24.6	7.8	(2)
								18.2	4.1	(3)
Error ratio:	d.f.									
Between races and origins	39	2.21	2.26	1.86	2.67	2.28	2.28	2.20	2.22	
Residual error:	160	1.46	2.80	0.21	2.56	3.60	0.06	4.72	2.22	
Coefficient of variation:	160	11.9%	20.8%	19.3%	20.8%	15.2%	16.3%	22.6%	39.1%	

TABLE 30. Same as Table 28—Plant Characters

Avati Pichingá (Pipoca) Plant Characters	*N*	*Height*			*Leaf*					
		Plant (cm.)	*Ear (cm.)*	*Ratio Ear/ Plant Height*	*N° Below Ear*	*N° Above Ear*	*Length (cm.)*	*Width (cm.)*	*N• of Veins*	*Venation Index*
General means:	338	152.4	88.6	0.58	9.2	5.4	83.1	9.1	25.3	2.82
Error ratio:	d.f.									
Between races and region	39	4.74	3.54	1.91	2.31	2.78	3.18	2.19	2.69	1.58
(Probability)		1‰	1‰	5%	1‰	1‰	1‰	1‰	1‰	>5%
Residual error:	298	20.1	15.5	0.07	1.09	0.68	8.17	1.13	2.41	0.36
Coefficients of variation:	298	13.2%	17.4%	11.8%	11.8%	12.6%	9.8%	12.4%	9.5%	12.8%

TABLE 31. *Chavantes Opaié White Soft Corn*—Ear Characters.

Chavantes Ear Character	*N*	*Ear Length (cm.)*	*Nº of Rows*	*Diameter (cm.)*					*Cob Rachis Index*	*Kernels (cm.)*			*Kernel Covering*
				Medulla	*Rachis*	*Kernel Base*	*Cob*	*Ear*		*Length*	*Width*	*Depth*	
Means:	12	24.7	14.8	0.57	1.20	1.95	2.72	3.73	2.4	0.96	0.92	0.63	0.52
Error ratio:													
Between origins	2	1.18	0.61	1.33	1.52	1.57	0.97	1.33	1.16	0.33	1.10	1.23	1.10
(Probability)		5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
Residual error:	9	7.78	2.05	0.26	0.23	0.28	0.30	0.21	0.56	0.06	0.06	0.05	0.13
Coeff. of var.:		31.4%	13.8%	45.6%	19.2%	14.3%	11.0%	5.6%	23.3%	6.2%	6.5%	8.2%	23.3%

TABLE 32. Lenha White Soft Corn—Ear Characters.

Lenha Ear Characters	*N*	*Ear Length (cm.)*	*Nº of Rows*	*Diameter (cm.)*					*Cob Rachis Index*	*Kernels (cm.)*			*Kernel Covering*
				Medulla	*Rachis*	*Kernel Base*	*Cob*	*Ear*		*Length*	*Width*	*Depth*	
Means:	4	18.5	22.5	1.9	2.8	3.9	4.4	5.9	1.6	1.1	0.8	0.40	0.32
Error:		1.87	3.4	0.64	0.74	0.66	0.64	0.49	0.38	0.05	0.06	0.05	0.24
Coeff. of var.:		10.1%	15.1%	33.6%	26.4%	16.9%	14.5%	8.3%	23.7%	5.5%	7.5%	12.5%	7.5%

TABLE 33. Same as Table 32—Tassel Characters.

Lenha Tassel Characters	*N*	*Base*			*Tassel*			*Nº of Branches*	
		Sheath Length (cm.)	*Internode Length (cm.)*	*Internode Covering*	*Branched Part (cm.)*	*Terminal Spike (cm.)*	*Proportion Branch/Term.*	*1º Order*	*2º Order*
Means:	10	13.5	19.3	1.42	16.9	29.1	0.37	20.8	6.0
Error ratio:									
Between origins	1	1.20	0.90	0.55	0.94	0.65	0.97	0.19	1.30
(Probability)		5%	5%	5%	5%	5%	5%	5%	5%
Residual error:	8	1.18	5.25	0.31	3.18	5.39	0.07	5.39	2.91
Coeff. of var.		8.7%	27.2%	21.8%	18.8%	18.5%	18.9%	25.9%	48.0%

TABLE 34. Same as Table 32—Plant Characters.

Lenha Plant Characters	*N*	*Height*			*Leaf*					
		Plant (cm.)	*Ear (cm.)*	*Ratio Ear/Plant Height*	*Nº Below Ear*	*Nº Above Ear*	*Length (cm.)*	*Width (cm.)*	*Nº of Veins*	*Venation Index*
Means:	20	209.0	107.2	0.5	8.5	5.7	93.4	10.2	28.4	2.8
Error ratio:										
Between origins	1	2.30	0.49	1.91	0.20	3.59	1.06	1.37	2.01	0.75
(Probability)		5%	5%	5%	5%	1%	5%	5%	5%	—
Residual error:	18	16.46	15.91	0.07	1.17	0.56	6.45	1.39	2.67	0.32
Coeff. of variation:		7.8%	14.8%	14.0%	13.7%	9.8%	6.9%	13.6%	9.4%	11.4%

TABLE 35. Caingang White Soft Dent—Ear Characters.

Caingang White Dent Ear Characters	*N*	*Ear Length (cm.)*	*N° of Rows*	*Diameter (cm.)* *Medulla*	*Rachis*	*Kernel Base*	*Cob*	*Ear*	*Cob-Rachis Index*	*Kernels (cm.)* *Length*	*Width*	*Depth*	*Kernel Covering*
Means:													
Icatú	90	19.1	11.8	0.55	1.37	1.99	2.63	4.14	1.94	1.10	1.00	0.44	0.31
Vanuirí	13	18.8	11.8	0.52	1.29	1.92	2.58	3.95	2.05	1.01	0.93	0.45	0.30
Paulista		19.0	11.8	0.55	1.36	1.98	2.62	4.11	1.94	1.09	0.99	0.44	0.31
Ivaí	209	19.8	12.8	0.74	1.44	2.13	2.80	4.25	2.00	1.13	0.96	0.44	0.36
Apucarana	229	20.1	12.3	0.74	1.54	2.27	2.95	4.39	1.92	1.09	1.03	0.49	0.34
Mangueirinha	45	20.1	13.3	0.71	1.58	2.43	3.12	4.45	2.02	1.05	0.98	0.52	0.36
Paranaense		20.0	12.6	0.74	1.50	2.22	2.90	4.33	1.96	1.10	0.99	0.47	0.35
Error ratios:	d.f.												
Between groups	1	3.88	4.70	10.12	5.82	6.26	10.83	7.56	0.40	1.85	0.95	6.07	4.11
(Probability)		1‰	1‰	1‰	1‰	1‰	1‰	1‰	>5%	>5%	>5%	1‰	1‰
Between subraces	3	1.02	2.84	6.82	3.32	4.08	5.13	3.83	2.44	4.66	6.38	9.39	1.78
(Probability)		>5%	1‰	1‰	1‰	1‰	1‰	1‰	1‰	1‰	1%	1‰	5%
Within subraces	22	2.65	1.08	2.65	1.68	1.43	2.17	1.74	2.52	3.14	1.99	2.27	1.33
(Probability)		1‰	>5%	1‰	1‰	1%	1‰	1‰	1‰	1‰	1‰	1‰	5%
Residual error:	559	2.10	1.55	0.17	0.22	0.35	0.24	0.27	0.25	0.08	0.08	0.04	0.09
Coeff. of var.:		10.6%	12.4%	24.2%	15.0%	16.1%	8.4%	6.3%	12.8%	7.3%	7.8%	8.8%	26.2%

TABLE 36. Same as Table 35—Tassel Characters.

Caingang White Dent Plant Characters	N	*Height*			*Leaf*	
		Plant (cm.)	*Ear (cm.)*	*Ratio Ear/ Plant Height*	*N° Below Ear*	*N° Above Ear*
Means:						
Paulista	240	*2.25*	*1.36*	*0.61*	9.2	*6.0*
Paranaense	820	2.22	1.17	0.52	8.0	6.2
Error ratios:	d.f.					
Between groups	1	2.20	15.40	17.84	15.87	2.19
(Probability)		1‰	1‰	1‰	1‰	1‰
Between subraces	3	4.83	3.14	6.10	3.53	2.39
(Probability)		1‰	1‰	1‰	1‰	1‰
Within subraces	14	6.10	5.36	10.94	6.97	2.63
(Probability)		1‰	1‰	1‰	1‰	1‰
Residual error:	1,040	21.0	17.3	0.06	1.0	0.8
Coeff of var.:		9.4%	14.2%	11.3%	12.1%	12.2%

TABLE 37. Same as Table 35—Plant Characters.

		Base			*Tassel*			*N° of Branches*	
Caingang White Dent Tassel Characters	*N*	*Sheath Length (cm.)*	*Internode Length (cm.)*	*Internode Covering*	*Branched Part (cm.)*	*Terminal Spike (cm.)*	*Proportion Branch/ Term.*	*1° Order*	*2° Order*
Means:									
Icatú	110	13.8	16.7	1.18	18.3	26.5	0.41	20.9	10.8
Vanuirí	10	16.0	20.5	1.29	18.2	25.1	0.41	22.2	10.6
Paulista		*14.0*	*17.6*	*7.19*	18.3	26.4	0.41	21.0	10.8
Ivaí	168	15.3	20.7	1.32	18.7	25.4	0.41	22.6	8.9
Apucarana	195	13.7	19.8	1.31	16.4	28.2	0.37	21.5	7.7
Mangueirinha	40	14.2	20.5	1.30	17.6	26.7	0.40	18.8	7.8
Paranaense		14.4	19.4	1.31	17.5	26.9	0.39	21.7	7.9
Error ratios:	d.f.								
Between groups	1	2.63	6.95	4.56	2.65	1.35	2.17	1.28	6.56
(Probability)		1‰	1‰	1‰	1%	>5%	5%	>5%	1‰
Between subraces	3	2.31	4.74	0.80	4.40	4.30	4.83	2.67	0.61
(Probability)		1‰	1‰	>5‰	1‰	1‰	>5%	1‰	5%
Within subraces	14	2.61	2.14	1.20	2.09	1.72	1.17	1.87	1.37
(Probability)		1‰	1‰	>5‰	1‰	1‰	>5%	1‰	5%
Residual error:	504	1.60	3.29	0.25	2.77	6.39	0.06	4.78	4.19
Coeff. of var.:		11.2%	17.4%	19.5%	15.7%	13.9%	15.0%	22.2%	48.8%

TABLE 38. *Cateto Orange Flint,* Southern Group—Ear Characters.

Southern Cateto Ear Characters	*N*	*Ear Length (cm.)*	*N° of Rows*	*Diameter (cm.)*					*Cob-Rachis Index*	*Kernels (cm.)*			*Kernel Covering*
				Medulla	*Rachis*	*Kernel Base*	*Cob*	*Ear*		*Length*	*Width*	*Depth*	
Means:													
Canario de Ocho	6	17.15	8.00	0.58	1.17	1.60	2.22	3.32	1.89	0.94	1.08	0.43	—
Cateto S. P. sabugo fino	4	15.28	12.50	0.65	1.15	1.68	2.58	3.33	2.25	0.96	0.76	0.37	0.54
Amarillo	3	16.17	11.33	0.60	1.47	2.10	2.63	3.93	1.81	0.97	0.88	0.42	0.45
Cateto Am. Sab. grosso	4	17.00	12.00	0.63	1.58	2.10	2.80	3.98	1.79	0.96	0.90	0.52	0.42
Colorado	4	19.75	13.50	0.75	1.53	2.05	2.83	4.05	1.85	0.99	0.83	0.37	0.40
Charrua	5	21.40	12.40	0.75	1.56	2.32	2.98	4.22	1.94	0.98	0.90	0.44	0.34
Cuarenton	4	19.00	13.00	0.70	1.48	1.95	2.78	4.33	1.87	1.10	0.92c	0.39	0.41
Error ratio:	G.L.												
Between 6 races	5	3.10	1.89	1.17	1.88	2.29	1.32	3.74	1.65	1.65	1.86	3.67	1.50
(Probability)		1‰	5%	5%	5%	1%	5%	1‰	5%	5%	5%	1‰	5%
Residual error:	18	1.55	0.75	0.12	0.17	0.17	0.22	0.19	0.20	0.06	0.07	0.03	0.12
Coeff of var.:	18	8.46%	6.00%	17.39%	10.96%	8.33%	7.91%	5.08%	10.42%	6.07%	8.14%	7.14%	28.57%

TABLE 39. Same as Table 38—Tassel Characters.

		Base			Tassel			Branches	
Southern Cateto Tassel Character	*N*	*Sheath Length (cm.)*	*Internode Length (cm.)*	*Internode Covering*	*Branched Part (cm.)*	*Terminal Spike (cm.)*	*Proportion Branch/ Term.*	*N° 1° Order*	*N° 2° Order*
Means:									
Canario de Ocho	5	16.20	21.30	1.32	13.60	24.70	36.02	14.80	4.40
Cuarenton	5	13.80	21.40	1.56	15.00	27.50	34.95	16.00	5.20
Amarillo	5	14.10	15.00	1.28	17.60	27.50	39.12	28.40	5.20
Cateto Fino	5	14.90	26.04	1.45	13.70	28.60	32.76	14.80	3.60
Colorado	5	13.10	22.60	1.74	11.80	26.40	35.27	12.20	4.80
Charrua	5	13.50	21.90	1.64	16.30	29.50	35.10	20.60	5.60
Cateto Grosso	5	15.40	25.20	1.63	16.92	28.58	37.26	17.20	3.00
Error ratio:	G.L.								
Between 7 races	6	1.44	3.44	1.70	1.44	0.98	0.70	2.74	0.96
(Probability)		5%	1‰	5%	5%	>5%	>5%	1‰	>5%
Residual error:	28	1.73	2.32	0.23	3.24	3.65	6.38	4.38	2.19
Coeff. of variation:	28	11.99%	10.58%	15.13%	21.61%	13.25%	17.83%	24.73%	48.24%

TABLE 40. Same as Table 38—Plant Characters.

		Height			*Leaf*	
Southern Cateto Plant Characters	*N*	*Plant (cm.)*	*Ear (cm.)*	*Ratio Ear/ Plant Height*	*N° Below Ear*	*N° Above Ear*
Means:						
Canario de Ocho	7	140.0	58.6	0.421	6.6	4.7
Cuarenton	10	176.20	9.60	0.55	6.4	7.0
Amarillo	10	161.0	63.5	0.40	7.9	5.4
Cateto Fino	10	229.0	143.0	0.63	6.7	7.6
Colorado	10	157.5	71.0	0.46	6.0	4.7
Charrua	10	207.0	109.0	0.53	7.0	5.6
Cateto Grosso	10	175.5	79.0	0.44	6.2	4.9
Error ratio:	G.L.					
Between 7 races	6	6.10	6.32	3.86	1.95	2.50
(Probability)	1‰	1‰	1‰	1%	1%	1‰
Residual Error:	60	15.20	14.57	0.07	1.02	1.41
Coeff. of var.:	60	8.46%	16.21%	14.26%	15.22%	24.74%

TABLE 41. Different Types of Northern Cateto Flint—Ear Characters.

Cateto, Northern Type Ear Characters	*N*	*Ear Length (cm.)*	*N° of Rows*	*Diameter (cm.)*					*Cob-Rachis Index*	*Kernels (cm.)*			*Kernel Covering*
				Medulla	*Rachis*	*Kernel Base*	*Cob*	*Ear*		*Length*	*Width*	*Depth*	
Means:													
Froes—1	4	20.25	14.0	0.90	2.30	2.93	3.63	5.53	1.85	1.35	0.99	0.39	0.30
Froes—2	4	15.8	15.5	1.23	2.18	2.83	3.43	4.70	1.58	0.99	0.86	0.42	0.36
Guiana 1	4	20.5	16.5	1.28	2.50	3.25	4.00	5.50	1.62	1.18	0.86	0.40	0.42
Guiana 2	4	21.0	17.0	1.45	2.78	3.48	4.35	5.85	1.68	1.15	0.94	0.43	0.35
Error ratios:													
Between 2 groups	1	4.66	2.90	10.66	1.80	4.48	2.90	2.83	0.19	3.09	2.69	1.47	1.07
(Probability)		1%	5%	1‰	>5%	1‰	5%	5%	>5%	1%	>5%	>5%	>5%
Within Froes	1	1.88	1.42	6.20	5.04	6.13	5.76	2.83	0.25	2.30	2.18	0.89	2.15
(Probability)		1‰	>5%	1‰	1‰	1‰	5‰	5%	>5%	5%	>5%	>5%	>5%
Within Guiana	1	0.39	1.42	5.26	7.94	1.43	3.20	7.78	0.48	0.43	1.46	1.16	2.38
(Probability)		>5%	>5%	1‰	1‰	1‰	1%	1‰	>5%	>5%	>5%	>5%	5%
Residual error:	12	1.81	1.58	0.34	0.49	0.23	0.49	0.59	0.42	0.47	0.39	0.19	0.13
Coeff. of var.:	12	9.3%	10.0%	28.1%	20.0%	7.4%	12.7%	11.0%	26.1%	8.4%	8.6%	9.3%	40.6%

TABLE 42. Same as Table 41—Tassel Characters.

Cateto, Northern Type Tassel Characters	*N*	*Base*			*Tassel*			*N° of Branches*	
		Sheath Length (cm.)	*Internode Length (cm.)*	*Internode Covering*	*Branched Part (cm.)*	*Terminal Spike (cm.)*	*Proportion Branch/ Term.*	*1° Order*	*2° Order*
Froes—1	5	14.00	15.90	1.14	18.80	26.30	42.09	42.60	8.80
Froes—2	5	14.40	16.00	1.12	18.50	26.60	41.06	43.20	9.20
Guiana—1	5	16.10	21.30	1.33	22.70	24.00	48.61	29.20	7.40
Guiana—2	5	16.60	21.10	1.28	23.80	26.20	47.59	20.00	4.60
Between 2 groups	1	3.34	4.57	2.38	5.57	2.90	3.52	6.47	0.67
(Probability)		1%	1‰	5%	1‰	5%	1%	1‰	>5%
Within froes	1	0.44	0.05	0.25	0.26	0.15	0.36	0.15	0.20
(Probability)		>5%	5%	>5%	>5%	>5%	>5%	>5%	>5%
Within Guiana	1	0.55	0.13	0.50	0.95	1.11	0.39	2.30	1.40
(Probability)		>5%	>5%	>5%	>5%	>5%	>5%	>5%	>5%
Residual error:	16	1.44	2.56	0.16	1.84	3.14	4.15	6.32	3.16
Coeff. of variation:	16	9.42%	13.78%	13.11%	8.78%	12.18%	9.26%	18.45%	42.13%

TABLE 43. Same as Table 41—Plant Characters.

		Height			*Leaf*					
Cateto, Northern Type Plant Characters	*N*	*Plant (cm.)*	*Ear (cm.)*	*Ratio Ear/ Plant Height*	*N° Below Ear*	*N° Above Ear*	*Length (cm.)*	*Width (cm.)*	*N° of Veins*	*Venation Index*
Froes—1	10	273.0	181.5	0.689	12.3	6.2	109.7	104.5	28.2	2.8
Froes—2	10	252.0	157.5	0.643	10.7	6.3	89.4	9.3	21.7	2.5
Guiana—1	10	251.0	166.0	0.660	11.2	6.8	100.1	106.5	28.4	2.7
Guiana—2	10	280.0	179.5	0.641	11.2	5.8	101.5	101.0	29.2	2.9
Error ratios:										
Between 2 groups	1	0.37	0.40	0.63	0.75	0.29	0.47	1.11	2.93	0.84
(Probability)		>5%	>5%	>5%	>5%	>5%	>5%	>5%	1%	>5%
Within Froes	1	1.82	2.95	1.25	2.82	0.49	5.44	1.81	3.49	1.28
(Probability)		>5%	1‰	>5%	1%	>5%	1‰	>5%	1%	>5%
Within Guiana	1	2.51	1.68	0.63	—	4.77	0.36	0.87	0.43	0.98
(Probability)		5%	>5%	>5%	—	1‰	>5%	>5%	>5%	>5%
Residual error:	36	25.87	25.73	0.08	1.27	0.47	8.34	1.42	4.16	0.5
Coeff. of var.:	36	9.80%	15.04%	12.16%	11.19%	7.49%	8.33%	14.02%	15.48%	18.25%

TABLE 44. Interlocked Soft Corn—Ear Characters.

Interlocked Soft Corn Ear Characters	*N*	*Ear Length (cm.)*	*N° of Rows*	*Diameter (cm.)*					*Cob-Rachis Index*	*Kernels (cm.)*			*Kernel Covering*
				Medulla	*Rachis*	*Kernel Base*	*Cob*	*Ear*		*Length*	*Width*	*Depth*	
Means:													
Group 1	16	—	12.6	0.75	1.42	1.94	2.58	3.55	1.86	—	—	—	—
Group 2	17	—	11.7	0.63	1.09	1.62	2.21	2.94	2.04	—	—	—	—
General Mean:		25.6	12.1	0.69	1.25	1.78	2.39	3.24	1.95	0.90	0.86	0.51	0.39
Error ratios:	d.f.												
Between groups	1	—	3.69	2.83	5.88	4.04	6.18	5.44	2.94	—	—	—	—
(Probability)		—	1‰	1%	1‰	1‰	1‰	1‰	1%	—	—	—	—
Within groups	4	0.98	2.54	2.00	0.94	1.87	2.65	1.63	2.17	0.78	1.57	1.60	1.11
(Probability)		>5%	1%	5%	>5%	5%	1‰	>5%	5%	>5%	>5%	>5%	>5%
Residual error:	27	4.21	1.42	0.12	0.16	0.23	0.17	0.32	0.18	0.23	0.07	0.05	0.09
Coeff. of var:.	27	16.8%	12.1%	17.4%	12.8%	12.9%	7.1%	9.9%	9.2%	25.7%	8.1%	9.9%	23.2%

TABLE 45. Same as Table 44—Tassel Characters.

Interlocked Soft Corn Tassel Characters	*N*	*Base*			*Tassel*			*Branches*	
		Sheath Length (cm.)	*Internode Length (cm.)*	*Internode Covering*	*Branched Part (cm.)*	*Terminal Spike (cm.)*	*Proportion Branch/ Term.*	*N° 1° Order*	*N° 2° Order*
Means:									
General mean of 4 origins	20	12.1	16.2	1.34	15.5	21.0	0.42	23.4	12.8
Error ratio:	d.f.								
Between origins	3	1.72	1.03	0.84	2.55	5.31	0.56	1.94	0.97
(Probability)		>5%	>5%	>5%	1%	1‰	>5%	5%	>5%
Residual error:	16	1.55	2.67	0.25	3.33	2.18	0.05	4.10	5.00
Coeff. of var.:		12.8%	16.5%	9.3%	21.5%	10.4%	11.8%	17.5%	39.1%

TABLE 46. Same as Table 44—Plant Characters.

Interlocked Soft Corn Plant Characters	*N*	*Height*			*Leaf*	
		Plant (cm.)	*Ear (cm.)*	*Ratio Ear/ Plant Height*	*N° Below Ear*	*N° Above Ear*
Means:						
General mean of 4 origins	40	256.4	140.8	0.55	6.2	8.3
Error ratio:	d.f.					
Between 4 origins	3	3.25	4.13	2.81	5.25	2.62
(Probability)		1‰	>1‰	>1‰	1‰	1‰
Residual error:	36	18.36	14.81	0.06	0.81	0.92
Coeff. of var.:		7.2%	10.5%	11.64%	13.0%	11.1%

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