1

The Maize Problematic

Maize is "... a real triumph of plant breeding (or the luckiest of accidents)...."

Harlan (1995: 187)

There can be no question that maize is one of the plants that has had a major role in the development of American cultures. Ortiz (1994: 527) correctly noted that from the Andes to Mesoamerica, and from the Caribbean to the southeast of the Woodlands, maize enabled the development of high cultures as concentrations of large populations, besides allowing them to settle down.

The subject of maize is quite complex and covers several areas that concern different disciplines, from biology to history, and although it is true that a vast number of articles and books have been written on it, it can still be said that all of these areas have not been collected into one single book. I would therefore like to begin by pointing out that this book does not pretend to be complete, nor can it be so. All it intends is to present an overview of the main issues related with this plant, at the same time paying special attention to its problematic in South America, because although much has been written on this area, as yet no attempt has been made to present a synthesis.

Throughout the text the terms "gathering," "farming/cultivation," and "domestication" will often be used. These are three words commonly used but that also often conceal some confusion. Yet all three are essential to understand the way in which a plant passed from its wild state to that of a crucial tool for mankind. "Gathering" simply means collecting and harvesting the native flora just as it appears in nature, without introducing any change to it. "Cultivation" is the act through which man manipulates the natural distribution of a plant by taking it to an environment chosen and prepared by humans so that it will reproduce, thus avoiding the competition of other species. Many plants do not change when subjected to this process, so for archaeologists it is often difficult to realize when the microenvironment has been created by humans. "Domestication" is a far more complex process wherein man handles the process of growth of a plant and plays with its genetic plasticity, so that in time a series of modifications are introduced into the plant that may lead to extreme biological changes, even some that are antinatural, and that turn the plant into an artifact. In this way mankind attains the best productive conditions for those characteristics that are of interest to it. This process was taken to extremes with maize, which as we shall see has been turned into a plant that cannot reproduce itself without human intervention. The way in which man developed this phenomenon is quite complex, but it is essentially based on the genetic plasticity of plants through two essential mechanisms: selection and hybridization. This in turn leads to some alterations in their biological mechanisms. In some cases the ability to produce seeds is lost, as has happened to the oca (*Oxalis tuberosa*) and the ulluco (*Ullucus tuberosus*); in others the ability to produce viable seeds is lost, as is the case with añu (*Tropaeolum tuberosum*), achira (*Canna* sp.), and pepino (*Solanum muricatum*), or as happened to maize, which has lost its ability to disperse its seeds. This is a long process, and it is only in some cases that this is a process in which it was not mankind but nature who intervened, as when genetic mutations take place.[1]

Mangelsdorf (1974: 9) wrote the following in this regard:

> The ear of corn enclosed in its husks has no close counterpart elsewhere in the plant kingdom either in nature or among other cultivated plants. It is superbly constructed for producing grain under man's protection, but it has a low survival value in nature, for it lacks a mechanism for dispersal of its seeds. When an ear of corn drops to the ground and finds conditions favorable for germination, scores of seedlings emerge, creating such fierce competition among themselves for moisture and soil nutrients that all usually die and none reaches the reproductive stage.

Bugé (1974: 35) believes that men in preceramic times were real biologists, in that they worked not with a static material but with a veritable process. They must have considered the production and maintenance of the different races of maize as a result of the interaction of a series of mutations, of a haphazard genetic deviation, of a natural selection, and of a hybridization. In other words, as the result of a succession of biological processes that accelerated or inhibited the attainment of certain goals that culture was establishing.

Pickersgill, one of the most renowned students of these processes, says there are four questions one has to ask when studying the origin and the evolution of cultivated plants. The first question is what plant gave rise to the modern plant; second, where it was domesticated; third, when this took place; and fourth, how these plants have changed and whether they have spread since the beginning of their cultivation (Pickersgill, 1977: 591). These are the questions I try to answer, specifically in regard to maize.

The reproductive characteristic of grasses is that they freely scatter the seeds. When man intervenes, selecting and planting, the plant depends on him, and

[1] For more information see, e.g., Harlan (1992), Helbaek (1953), Sanoja (1981: 73–74), and C. Smith (1967: 223).

the visible characteristics – the phenotypes – that man has decided to select compromise its autonomous survival. One of these characteristics is the production of more seeds through the female inflorescence. The increase in the number of seeds in the corn cob is obtained through greater condensation, that is, the number of kernels per row and the number of rows. In the case of this plant, domestication essentially consists in the elimination of the characteristic of seed dispersal through the natural separation of the rachilla in which they are inserted, and an expansion of their inclusion in the rachis in order to offer a more secure harvest for man. These characteristics are found in modern maize, and this is one of the characteristics, as we shall see, that radically distinguish it from its closest congener, teosinte, whose seeds are dispersed on reaching maturity by the fragmentation of the rachis (see Grobman, 2004: 428).

In maize, the crucial environmental phenomena are variations in temperature, moisture, the photoperiod, and the length of the day (Purseglove, 1972: 310–311). The advantage we have is that the ecological transformations that took place in the Holocene, particularly as regards temperatures and patterns of precipitation, are well documented. They may have had a role in the development of maize agriculture, and students should keep them in mind (Benz and Long, 2000: 462).

Mangelsdorf, who clearly is one of the most important and renowned students of maize, was convinced that what he called "the invention of maize culture …" had two mothers. On the one hand, there was necessity, and it is probable that maize was originally never abundant in nature, so that it could go extinct if it was taken out of its natural habitat. And on the other hand, there were the shrewd observations made by the Indians, who noticed first that this plant had a different behavior in the fields cleared close to their encampment, and then that its planting led to a selection that enabled the preservation of the mutants chosen by man (Mangelsdorf, 1974: 167, 207–208).

The closest relative of maize is teosinte, and it will be discussed at length further on. But we should realize that the main problem when comparing these two plants is the differences in the structure of the inflorescence, that is, the ear. The major problem is that in teosinte the kernels are tightly encased inside the structures called cupulate fruitcases, whereas the kernels of maize are born uncovered on the surface of the ear. The domestication of maize brought a change in the development of the ear, for the cupules and the glumes formed the internal axis of its ear instead of casing the kernels. This is why H. Wang and colleagues (2005: 714) pointed out that "in a sense, maize domestication involved turning the teosinte ear inside out." In fact the maize cob, be it either a pod corn or a normal corn, can hardly be a functional design for seed dispersal that appeared as a result of natural selection. Its new shape does not fit in an evolutive sequence and instead represents a terminal descendant of one of the sequences. Its proliferation and the concentration of grain-bearing spikelets can be ascribed to an unconscious selection – albeit a deliberate one too – by man in his concern for finding ever more and better food (see Galinat, 1975a: 318).

Not all scholars agree on the way in which the domestication of maize took place. Some are inclined to accept the mechanisms of evolution and ecology as decisive, whereas others believe that the cause was essentially human intention that knew how to use the climatic variability. But it must be pointed out that it is likely that a chance genetic drift may have been a major factor that brought about the changes that can be seen in the development of this plant. It is very possible that the interaction of these factors combined in the process of change of the ear (Benz and Long, 2000: 460–464; Flannery, 1986a; Rindos, 1984; Tarragó, 1980: 182; Watson, 1995). Johannessen (1982: 97) accepts that there may have been in principle an unconscious selection, but it cannot have taken place in the case of the development of the large-seeded maize with the long, colored, strong ears and the many varieties that have appeared. He believes that this was only possible through a continuous and conscious selection. Iltis (1987: 208) and Grobman (2004: 428) concur, but Wilcox (2004: 145) believes that "… domestication is just one factor that could affect grain size; others include environmental conditions, genetic variability, crop processing and, for archaeological material, conditions of charring."

R.-L. Wang and colleagues (1999: 236) drew attention to the fact that domestication can strongly reduce the sequence of diversity in the genes controlling the traits that are of human interest, in that when the selection is strong, domestication has the potential to drastically reduce the genetic diversity of a plant. Doebley (1994: 106, 112) showed that when the human selection of the ear is strong, the evolutive changes will take place very fast, whereas when it is weak, they will take place quite slowly. This is why he believes that it is inappropriate to simply assume that the races of maize with similar ear morphology are phylogenetically united. This assumption is probably wrong when comparing maize from different geographical regions, different altitudinal zones, and different moments in time. Doebley points out that one must not forget that similar morphological forms may appear independently in different geographic regions.

Iltis analyzed the factors of human selection in domestication and concluded that, in maize, the major traits that appeared in domestication were the following:

1. An increase in the number of rows and kernels and in the size of the ear.
2. A hardening of the cupules and the glumes.
3. The development of tough cobs that do not disarticulate.
4. Naked, free-threshing kernels.
5. A decrease in the primary branches, that is, in the number of ears.
6. A condensation of the primary branches and the internodes of the ear.
7. An increase in leaf sheath size and number.

8. The total deletion of the peduncles of the tassels and of the space between the branches.
9. The suppression of all branches in the lateral tassels.
10. The suppression of all the lower orders of the lateral branches, including the inflorescences.
11. The synchronization of the maturing of the grains in an ear, a plant, and a field.
12. The evolution of ecogeographic and genetic-isolating mechanisms that prevent backcrossing to the ancestral teosinte[2] and thus lead to race formation. (Iltis, 1983b: 892)

Following Rindos (1984: 164–166), Benz and Long (2000: 460) suggest that the highest proportion of evolutive changes in maize took place before 5000 years BP, and they posit that the morphological modifications reflect an agriculture under domestication. In this they agree with Jaenicke-Deprés and colleagues (2003: 1208), who reached the conclusion that 4,400 years ago, early farmers already had the potential to produce a substantially homogeneous effect on the allelic diversity in three genes associated with the morphology of maize and with the biochemical properties of the cobs.

There can be no doubt, as Doebley (2006: 1318) points out, that of the achievements of the ancient farmers, the domestication of cereals is one of the major ones, that is, the triad rice-wheat-maize, which has supplied more than 50% of the calories consumed by humans. When compared with their ancestors, one finds that cereals have more grains; that these are bigger, the stalks are thicker, and the seeds are freely threshed from the chaff; and furthermore that their favor has grown. Besides, these cereals, just like other cultivated plants, have one more factor that is essential – their grains remain attached to the plants and have to be harvested by humans, instead of the seeds being scattered, as is the case in wild plants. Although it is known that these phenomena take place through a change in a small number of genes, their nature and the internal molecular variations are still not well known.

Pääbo (1999: 195) based his work on the work of R.-L. Wang and colleagues (1999), its tentativeness notwithstanding, and believes that the domestication of maize was quite rapid and that it could have taken place in a few hundred years.

Hilton and Gaut (1998) made a genealogical study of the *Zea* genus in order to contrast an artificial speciation with a natural one. There are three reasons why this work is not valid. First, for the problem raised by the antiquity of maize, they used a bibliography based on indirect data, and they did not use original sources. Second, the samples of maize they used in their experiment were not well chosen. There is no way of knowing what races they mean (see

[2] Iltis accepts that maize was generated from teosinte, a point on which not all specialists agree.

op. cit.: table 1, 864). Finally, their bibliography comprises 55 entries, but only one of them (Goloubinoff et al., 1993) is on South America.

The Geographical Distribution of Maize

Maize was under cultivation from Canada to Chile at the time the Spaniards arrived on the American continent. At present we find maize from 58° northern latitude in Canada and Russia to 40° southern latitude in the Southern Hemisphere. It grows below sea level in the plains of the Caspian Sea depression, and at altitudes over 3,600 meters above sea level (masl) in the Andes. It lives in zones that receive less than 2.5 cm of annual rainfall in the semiarid regions of the Russian plains, as well as in others with more than 1,000 cm of annual rainfall on the Pacific coastlands of Colombia. It grows in the short summers of Canada, as well as in the perennial summers of the tropical equatorial regions of Ecuador and Colombia. No other cultivated plant grows in such a large area, and only wheat takes up a larger surface area in acres. In fact, maize is maturing in some part of the world, in all longitudes, all year long (Mangelsdorf, 1974: 1–2; W. L. Brown et al., 1988: 8).

Description of the Plant

> It is an annual plant of fasciculated roots, whose stalk also has the property of forming adventitious roots. The stalk is a massive cane with a white and sugary medulla. A sheathing leaf appears on each node that is ligulate, strip-like and linear with parallel nervations. It is a monoic plant whose male flowers are born before the females in the tip of the stalks, thus forming a spike tassel. Female flowers are born in the axil of the leaves towards the mid-point of the stalk, and are grouped in rows along a thick, cylinder-like, spongy and alveolate rachis, which in some countries is called *olote* and *zuro*. The female flowers are sessile so that this inflorescence actually is a real female ament that is vulgarly known as the ear (*mazorca*, *panoja* or *choclo*); the latter is protected by large papyraceous bracts that are usually known as husk (*camisas*, *tusas* and *hojas de choclo*). Each female flower ends in a fluffy and very long (15 centimetres and more) filiform and hairy style; the styles of all the flowers come out through the end of the bracts and are first green and then reddish[3] on reaching maturity, and are known as silks (*barbas de maíz*, *pelo de choclo* and *cabello de elote*); the last name [*cabello de elote*] is because in some countries the green ears of maize are called *elote* [Mexico], and *jojoto* [Venezuela] in others,[4] which are taken as food when cooked. (Cendrero, 1943: 202)[5]

3 This depends on dominant or recessive color genes for anthocyanin.
4 *Choclo* is used in the central-southern Andean area.
5 For a more detailed description, see Mangelsdorf (1974: 5–9) and Johnson (1977).

There are two positions as regards the origins of the ears of maize. One of them holds that these originated due to modifications of the pistillate inflorescence of teosinte, through a small number of key morphological changes controlled by an equally small number of major genes (Beadle, 1980; Galinat, 1983, 1985a, 1988a; Langham, 1940). The second position holds that the primary lateral inflorescence of the central spike of teosinte was transformed into the ear of maize through sexual transmutation (Iltis, 1983b).[6]

Origin of the Name

In the seventeenth century Father Bernabé Cobo, that "scientific precursor," as Porras (1986: 510) called him, wrote:

> The name of *maíz* [maize] is from the language of the Indians from the island of Hispaniola. Mexicans call it *tlaolli*, and [the Indians of] Peru *zara* in the Quechua language, and *tonco* in Aymara. The Indians of New Spain call the ears of maize *elote*, the Peruvians *choclo*, and the kernel-less heart of the ear *coronte*, which is used as fuel. The husks of the ears are very useful for the muleteers, because they fill the packsaddles with them and they remain very light. (Cobo, 1964a: 162)

Specialists agree that the word "maize" comes from Taino or Carib, where the plant was know as *mahiz*. Taino was the language spoken by an elite group of the Arawak (Beadle, 1972: 3; Ortiz, 1994: 528). Some, however, claim that the term is Arawak – *marise* – and that it became *mahiz* in the Antilles (Horkheimer, 1958: 37).

The Maya terms for maize were *Ixim*, which is a general name; *Zac ixim*, which means white maize; *Peeu ixim*, small or early maize; and *Xacin*, which are the black and white kernels (Marcus, 1982: table 1, 241). *Ixim* was also the name for the Maize god. The kernels were called *nel*, a term that means "place" in the Maya texts. The rest of the ear with the kernels removed, that is, the cob, is called *b'akal*, just like the ancient name of Palenque (Antonio Aimi, personal communication 11 October 2006). We must bear in mind that all the languages in southeastern Mesoamerica, that is, in Guatemala, Belize, and Mexico to the east of the Isthmus of Tehuantepec, including the region occupied by Mixe speakers, are all members of the Maya and Mize-Zoquean language families. During a period of 400 years, the Maya family included 29 different languages spoken in numerous communities in Mexico. It is estimated that one more became extinct since the Conquest. There are 12 Mize-Zoquean languages, one of which also disappeared after the Conquest. They are mostly found in western

[6] Readers interested in details regarding the structure, growth, and reproduction of this plant should read Kiesselbach (1949), Sass (1955), and Weatherwax (1955).

Chiapas, southwestern Oaxaca, and southeastern Veracruz. All of them have a rich terminology related with maize and its uses (Stross, 2006: 578, 581).

In Nahuatl, maize is known as *cintli* or *centli* and *teocentli*. It was the food of the gods.[7]

For the Quechua vocabulary we have the *Lexicón* Friar Domingo de Santo Tomás published 47 years before the vocabulary of Diego González Holguín (Porras, 1951: XV, XVII). Here we read, "çara, 'maize, the wheat of the Indians'" (Santo Tomás, 1951: 163, 249). González Holguín (1989: 79, 579) in turn wrote, "*çara*. Maize. *çara çara*. Maize in piles. *Viñak çaraçara*, Maize fields in canes or standing." "*Mayz*. *Çara*, kernel corn, *muchhascca çara*, *o ttiuçara*." Interestingly enough, the words used to define maize in the Lake Titicaca basin have remained separate in Quechua and Aymara, the coexistence of these languages there since at least Inca times notwithstanding. In Aymara the term used is *tunqu*, and in Quechua *sara*. Yet the Aymara term is unknown in Cuzco, whereas in Copacabana the Quechua term is not known (Chávez, 2006: 624).[8]

Curiously enough, in the United States *Zea mays* is known as "corn," whereas in the rest of the world the terms "maize" or "Indian corn" are preferred, because in many countries the term "corn" is a synonym of "grain" (Mangelsdorf and Reeves, 1945: note 2, 235).

Taxonomy

The studies of the most distant relatives of maize are too general, and some genera have only rarely been studied scientifically (see Goodman, 1988: 203, and his bibliography). There are also some disagreements as regards the nomenclature, as Goodman (op. cit.: 204, 205, and table 1) pointed out.

In 1753 Linnaeus classified *Zea mays* in his *Species Plantarum* (Towle, 1961: 20). Maize and teosinte were long classified in two different genera, *Zea* and *Euchlaena*. It was in 1942 that Reeves and Mangelsdorf included teosinte in *Zea* (Iltis and Doebley, 1984: 591).

Zea mays L. belongs to the Maydeae tribe in the Poaceae family (Gramineae). The genus *Zea* comprises four species: *Z. diploperennis* Iltis, Doebley, and Guzmán, the perennial teosinte diploid; *Z. perennis* (Hitchcock) Reeves and Mangelsdorf, the perennial teosinte tetraploid, now extinct in nature; *Z. luxurians* (Durieu and Ascherson) Bird, the teosinte of Guatemala; and *Z. mays* or maize. This last species has been subdivided by Iltis and Doebley into *Z. mays* L. ssp. *huehuetenangensis* (Iltis and Doebley) Doebley, the teosinte from Huehuetenango; *Z. mays* L. ssp. *mexicana* (Schröder) Iltis, which corresponds

[7] For the linguistic terminology in Mesoamerica and North America, see Hill (2006).
[8] For the names of the varieties of maize in Quechua, Aymara, and A'karo, see Mejía Xesspe (1931: 13).

to the Nobogame race of the annual teosinte; *Z. mays* L. ssp. p*arviglumis* (Iltis and Doebley), that is, the Balsas race of the annual teosinte; and *Z. mays* L. ssp. *mays*, common maize (Grobman, 2004: 429–430).

Wilkes (1967) proposed another classification: *Zea mays* L., maize; *Z. mexicana* (Schröder) Kuntze, that is, the annual teosinte; *Z. perennis* Reeves and Mangelsdorf, the perennial teosinte tetraploid; *Z. diploperennis* Iltis, Doebley, Guzmán, and Pazy, the perennial teosinte diploid, which he believes is the most primitive form of teosinte (Grobman, 2004: 430).

The Maydeae tribe comprises seven genera, of which only two – *Zea* and *Tripsacum* – are American. The rest are Oriental: *Coix*, *Chionachne*, *Schlerachne*, *Trilobachne*, and *Polytoca* (Galinat, 1977: 1).

One important concept that is used in this book has to be explained: race. This term, which is not much used in botany, is widely employed in the case of maize, and it often causes confusion, because it is mistakenly believed that this term is only used for humans and some other animal species.

In the case of maize, several authors have presented definitions of race. For Anderson and Cutler (1942: 71) it is "... a group of related individuals with enough characteristics in common to permit their recognition as a group.... From the standpoint of genetics, a race is a group of individuals with a significant number of genes in common, major races having a smaller number in common than do sub-races." Grobman and colleagues (1961: 51), following Mayr (1942), define it as "... an actually or potentially interbreeding population, one of the several which may form a species distinguished by having in common certain morphological and physiological traits, and, therefore, also having in common the genes which determine these traits."

This concept arose due to the many problems taxonomists had in subdividing a single species with such a vast and complex interfertilization. In 1899 Stutervant attempted a classification, and he separated pod maize from popcorn, dent corn (the ordinary maize used as fodder), flint corn, flour corn, and sweet corn. This terminology is still used in trading or by individuals who do not know botany. In 1942 Edgard Anderson and Hugh C. Cutler noted that Stutervant's classification was artificial, as it only considered the characteristics of the endosperm, whereas the full genotype had to be considered. The first complete classification of Mexican maize was made in 1943, an endeavor that reached its climax with the publication, in 1951, of Wellhausen and colleagues, *Razas de maíz en México*, which was sponsored by the Mexican Secretariat of Agriculture. This was widely applied in America, and 11 volumes were published in which 305 races of maize were defined and named (Mangelsdorf, 1974: 101–105; Sánchez Gonzales, 1994: 139). This major project was carried out by the Committee of Preservation of Indigenous Strains of Maize within the Agricultural Board of the Division of Biology and Agriculture of the National Academy of Sciences, National Research Council. The committee was headed by Ralph E. Cleland, with J. Allen Clark as executive secretary. Its members were Edgar Anderson, William L. Brown, C. O. Erlanson, Claud L. Horu, Merle T. Jenkins, Paul C. Mangelsdorf, G. H. Stringfield, and George F. Sprague. They also had the support of the Rockefeller Foundation.

Four racial groups have been separated in Mexico and Central America. One is in western Mexico and includes the Chapalote Reventador and the Harinoso de Ocho. A second one belongs to the highlands of central and northern Mexico with the Grupo Cónico and the Sierra de Chihuahua. A third one is found in middle to low altitudes, from southern Mexico to Guatemala, and has three subgroups: (1) tropical dent corn (*dentados tropicales*), (2) a late-maturing group, and (3) short-maturity races adapted to low elevations and distributed above all on the coastal plains of the Pacific Ocean. The fourth group of mid- to high-altitude races extends from southern Mexico to Guatemala and is represented by the Serrano-Olotón type. There are more than 60 racial types in Mexico and Central America (Sánchez González, 1994: 154–155).

There are 32 races in Mexico that correspond to four major groups: Ancient Indigenous, Pre-Columbian Exotic, Prehistoric Mestizos, and Modern Incipient (Wellhausen et al., 1952: 146), whereas in Central America 25 races have been identified (Wellhausen et al., 1952). Hernández and Alanís (1970) added 5 more races for northeastern Mexico, and Benz (1986) described 5 new races (4 are the ones not defined by Wellhausen et al., 1951) and 3 new types (Sánchez González, 1994: 139, 141).

Eleven races were distinguished in southwestern North America (Adams, 1994).

The racial differentiation in the Andean region is remarkable. Goodman and Brown (1988) have pointed out that of the 252 races of maize known (here they disagree with Mangelsdorf, 1974: 103, who claims there are 305), 132 belong to the Andean region. These races have been extensively described (Grobman et al., 1961, Peru; Roberts et al., 1957, Colombia; Rodríguez et al., 1968, Bolivia; Timothy et al., 1963, Ecuador. For Brazil and other countries in eastern South America, see Brieger et al., 1958; for Venezuela, Grant et al., 1963; for Chile, Timothy et al., 1961). (See also Sevilla, 1994: 233.)[9]

Wittmack (1880–1887, 1888) was the first to present a classificatory outline of Andean maize developed from archaeological samples found at Ancón. He based his findings on morphological characteristics, on the shape of the ear, and on the characteristics of the kernels. He distinguished three groups:

1. A common maize he called *Zea Mays vulgata*, with kernels that are neither dented nor pointed and are of a somewhat irregular shape.

[9] To avoid misunderstandings, readers must bear in mind that when citing an author, the bibliography the latter used (the first set of parentheses) is often given before the actual reference for what I am citing (the second set of parentheses). For instance, if we read "(Soares de Sousa, n.d.: 1). (Goodman, 1988: 198)," it means that I am citing Goodman (1988), who in turn cites Soares de Sousa (n.d.).