Some Botanical and Ethnological Considerations of *Manihot esculenta*[1, 2]

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Introduction

Of all the plants so far discussed in this symposium, *Manihot esculenta* is the least known. Corn, beans, and cucurbits all are major elements in the diet of large segments of temperate and tropical populations. These have been intensively studied, not only from a botanical and ethnological standpoint, but also agronomically by many workers.

Manioc assumes major importance only in lowland tropical areas, among people of relatively low economic status. The only product of *Manihot esculenta* that is at all well known to temperate zone people is a minor starchy material, tapioca. This product is not of sufficient importance in our economy, nor are there any areas within the continental United States where *Manihot* is grown with sufficient intensity, to warrant the United States Department of Agriculture's taking up detailed studies of the crop. Nor have any European agricultural students actively pursued studies of *Manihot esculenta*. Therefore, it will be necessary to present a much lower level of knowledge concerning the plants and their ethnology than has been presented for the first three papers in this symposium.

Botanical Aspects

Nomenclature. There are several specific scientific epithets presently employed for manioc. Many workers refer to *Manihot utilissima*, others to *M. dulcis, M. aipi,* or *M. palmata*. These epithets were (or are) intended to reflect some differentiation within the cultivated complex between those cultivars that have a high concentration of cyanogenetic glycoside in the root (*M. utilissima*) and those with a low concentration or no cyanogenetic glycoside (*M. aipi, dulcis, palmata*). A number of workers have suggested that this separation is not valid from a taxonomic standpoint, and Ciferri (1938, 1942) formally took up Crantz's epithet, *Manihot esculenta*.

The combination of the various races into one species was given further validation by an analysis of 107 cultivars for HCN made by the Jamaican Department of Agriculture on cultivars growing under standardized conditions in Jamaica. The results of these analyses indicate that there is no break in the concentrations of the $[CN]^-$ and that there is a straight line curve from cultivars with low concentrations to those with very high percentages. It is, therefore, more meaningful to classify all of the cultivars as one highly variable species, using the name *Manihot esculenta*, the earliest valid name proposed by Crantz (1766). Further basis for this taxonomic decision is given below.

Morphological Description of Manihot esculenta. Manioc is a shrubby perennial species, with variously enlarged tuberous roots and stems either unbranched, tall and slender, to 15 feet tall, or variously branched with a whole range of intermediate branching patterns to that of a highly branched plant no more than three or four feet tall (Fig. 1). The stems of the species are woody, usually with a very large pith and therefore quite brittle. Stem segments six to eight inches long with three to eight nodes are used as vegetative propagating material. The foliage is dimorphic in most of the cultivars. The fully developed vegetative leaves are usually five- to nine-

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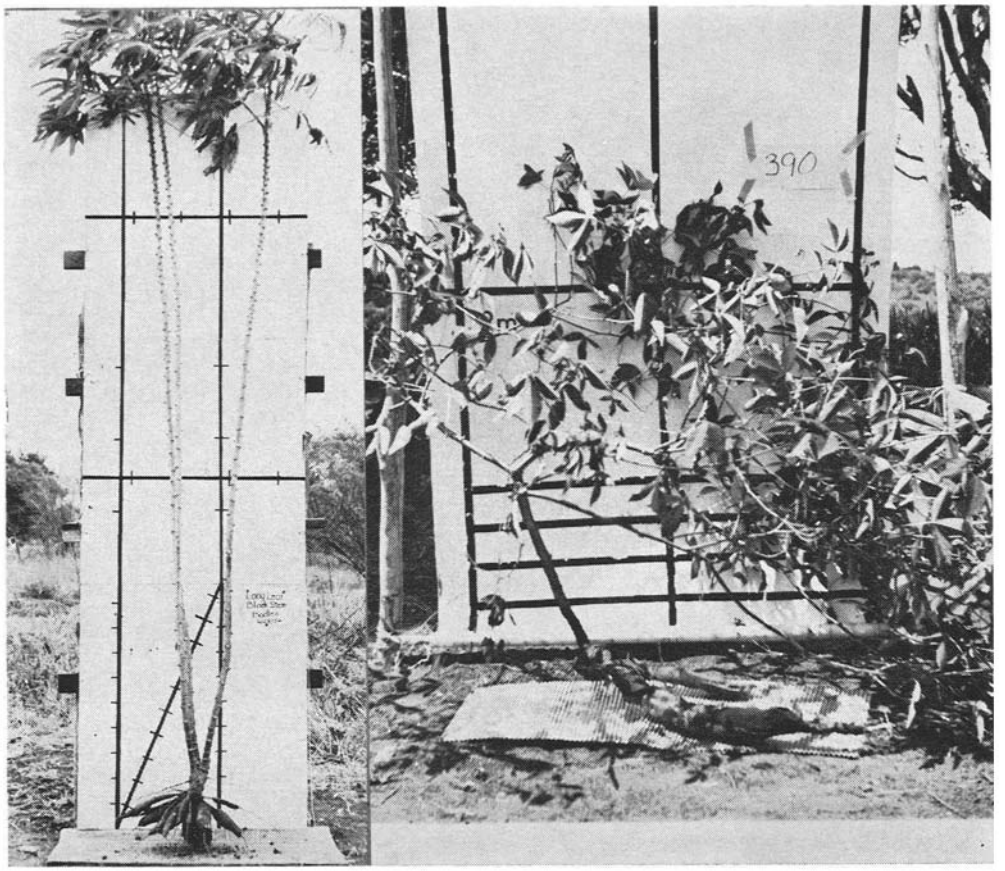

Fig. 1. Two cultivars of *Manihot esculenta* demonstrating extremes of variation in branching patterns. On the left, a cultivar from Jamaica; on the right, a cultivar from northeastern Brazil.

lobed, but the leaves found in association with the inflorescences are almost invariably reduced in numbers of lobes—most frequently three-lobed but with occasional occurrences of an undivided, simple leaf.

Manihot esculenta is monoecious, the pistillate flowers with five separate tepals lowest on the inflorescence opening first, whereas the staminate flowers have five-lobed, united tepals appearing on the upper portions of the inflorescence, opening long after the pistillate flowers. There are ten stamens, frequently arranged in two circles of five, the inner circle mostly shorter than the outer. A disc is produced at the base of both the staminate and pistillate flowers, enclosed by the tepals. In the staminate flowers there may be a rudimentary pistil-like structure. The fruit is a dehiscent capsule with three locules. Each locule contains a single carunculate seed. At maturity the schizocarp dehisces explosively ejecting the seeds some distance. Most of the cultivars bear a relatively small number of fruits per plant as contrasted with wild *Manihot* species. I have never seen a cultivar seedling growing in a farmer's field, although there seems to be no reduction in viability of the seeds. It is certain that the natives who cultivate manioc seldom use seeds as propagules.

Pigmentation of the stems provides one of the most stable characteristics for taxonomic differentiation of cultivars. One

group of cultivars has very light gray stems with a silvery aspect (due in part, no doubt, to the granular, waxy surface), whereas another group has varying amounts of anthocyanins, causing the plants to be either yellow, orange, or some shade of brown. This pigmentation seems to be associated with another characteristic useful in distinguishing among the cultivars—namely, that those cultivars with "silver" stems have a root the epidermis of which is quite smooth. The other group of cultivars most frequently have roots with a quite rough epidermal layer (Figs. 2 and 3). These two characteristics unfortunately do not correlate with the concentration of the cyanogenetic glycoside, and there are probably no other morphological features which are correlated with the presence or absence of the $[CN]^-$ glycoside.

Manihot esculenta is pollinated by insects, and cross pollination occurs more frequently than self-pollination because the pistillate flowers are usually open and receptive to pollen long before the staminate flowers of the same plant have reached anthesis. This propensity for outcrossing gives the opportunity for inter- and intraspecific hybridization, a phenomenon which has no doubt contributed to the extreme variability found in the cultivars.

Geography of the Cultivated Species

Cultivars of *Manihot esculenta* have been distributed successfully to all lowland tropical areas of the Old and New World, and in most of these areas manioc is now, or is fast becoming, one of the major contributors to the starchy diets of many tropical countries. It is quite simple to establish, however, that the original areas of the species are the Western Hemisphere tropics, inasmuch as we have adequate documentation to indicate that Portuguese and Spanish explorers first found the plants growing not only in the West Indies (Oviedo, 1851) but wherever contact was made with Indians in the tropical areas of both Americas. In the Western Hemisphere, the plants are found below 5000 to 6000 feet, in most frost-free tropical regions. The crop is raised in southern Brazil, where occasional frosts occur (Rogers, 1963).

Inasmuch as the natural distribution pattern of the cultivated species has been very largely obscured (within the boundaries given above), there is no known method by which one may differentiate the variations within the cultivated complex on the basis of present distribution. Apparently, wherever native populations migrated, they carried with them propagules of cultivars from their original location. For example, it is known that the cultivated species was carried through the islands of the West Indies and to the southern tip of Florida by the Caribs and/or Arawak Indians (Sturtevant, 1961). In post-Columbian times, hundreds of people have moved cultivars from one part of the range to another, both as private individuals and those working for various governmental agricultural agencies. Jamaica has a very large number of varieties, perhaps over 100. It is certain that most of these were not developed in Jamaica. Searching the records of the Jamaican Department of Agriculture, one finds notices of introductions of cultivars from various places in South America (Cousins, 1903). This type of endeavor has been repeated many times in most countries where manioc is a common food plant. I located one cultivar in Costa Rica the common name of which is 'Brazil'. This cultivar was collected somewhere near the east coast of Brazil, carried by the Dutch to Indonesia, returned from Indonesia to Cuba, and from Cuba taken as an ideal producer to Costa Rica. Whether the 'Brazil' I collected in Costa Rica was indeed the same as the one originally from Brazil is a moot question.

Ecology

Within the geographic limits given above, the cultivars are found on a wide variety of different soils and moisture regimes. There are those that occur in semi-arid regions of northeastern Brazil and various other localities throughout Latin America where marked dry seasons occur. Other cultivars grow on varzeas, the mud flats or sand banks along the Amazon River that are inundated for six months of the year. Cultivars are capable of growing on soils ranging from a stiff marine clay with a pH of 8 or 9 to sands and loose laterites with a pH of 5 to 5.5. More knowledge of

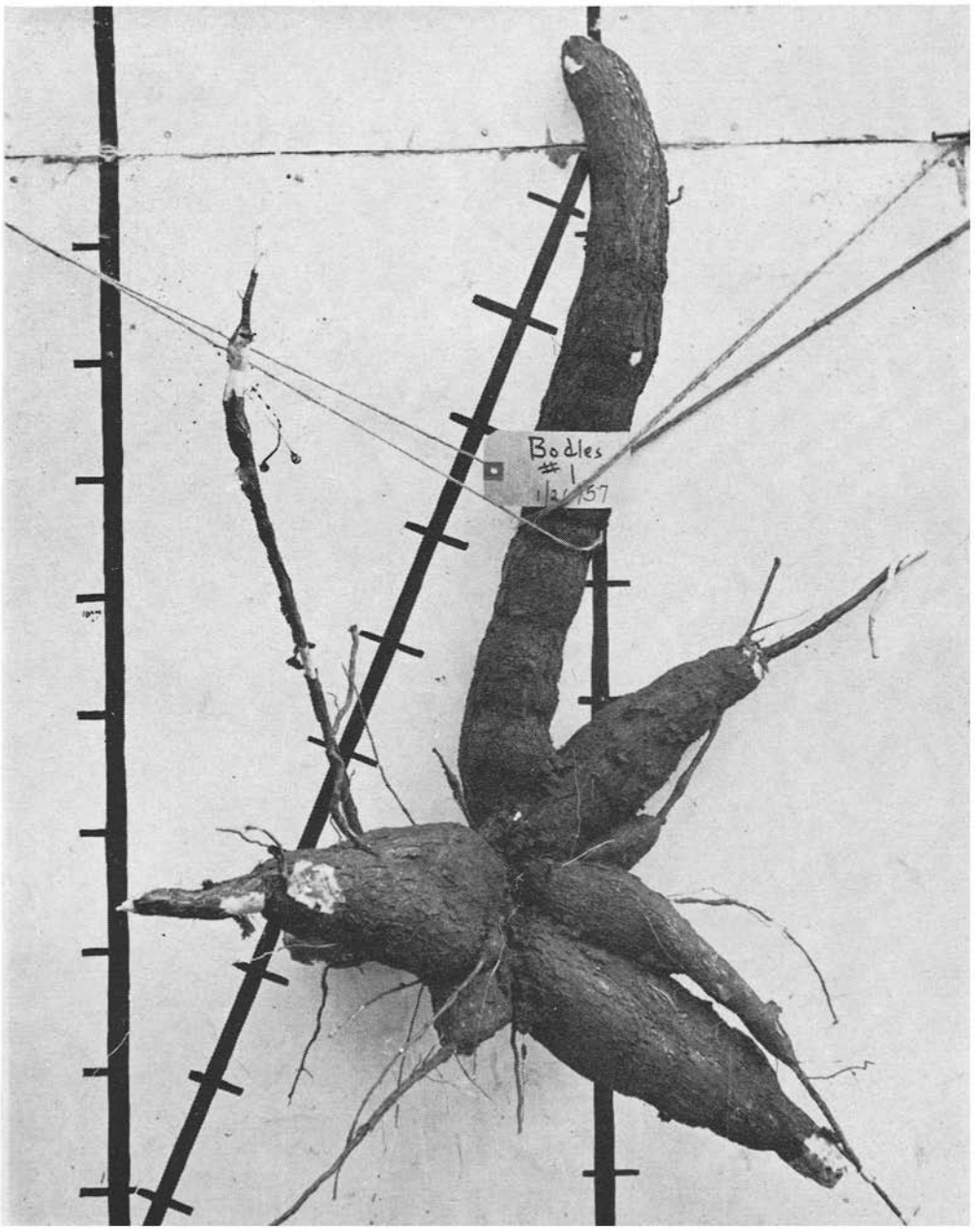

Fig. 2. Roots of a cultivar of *Manihot esculenta* with roughened epidermal layer. Jamaica.

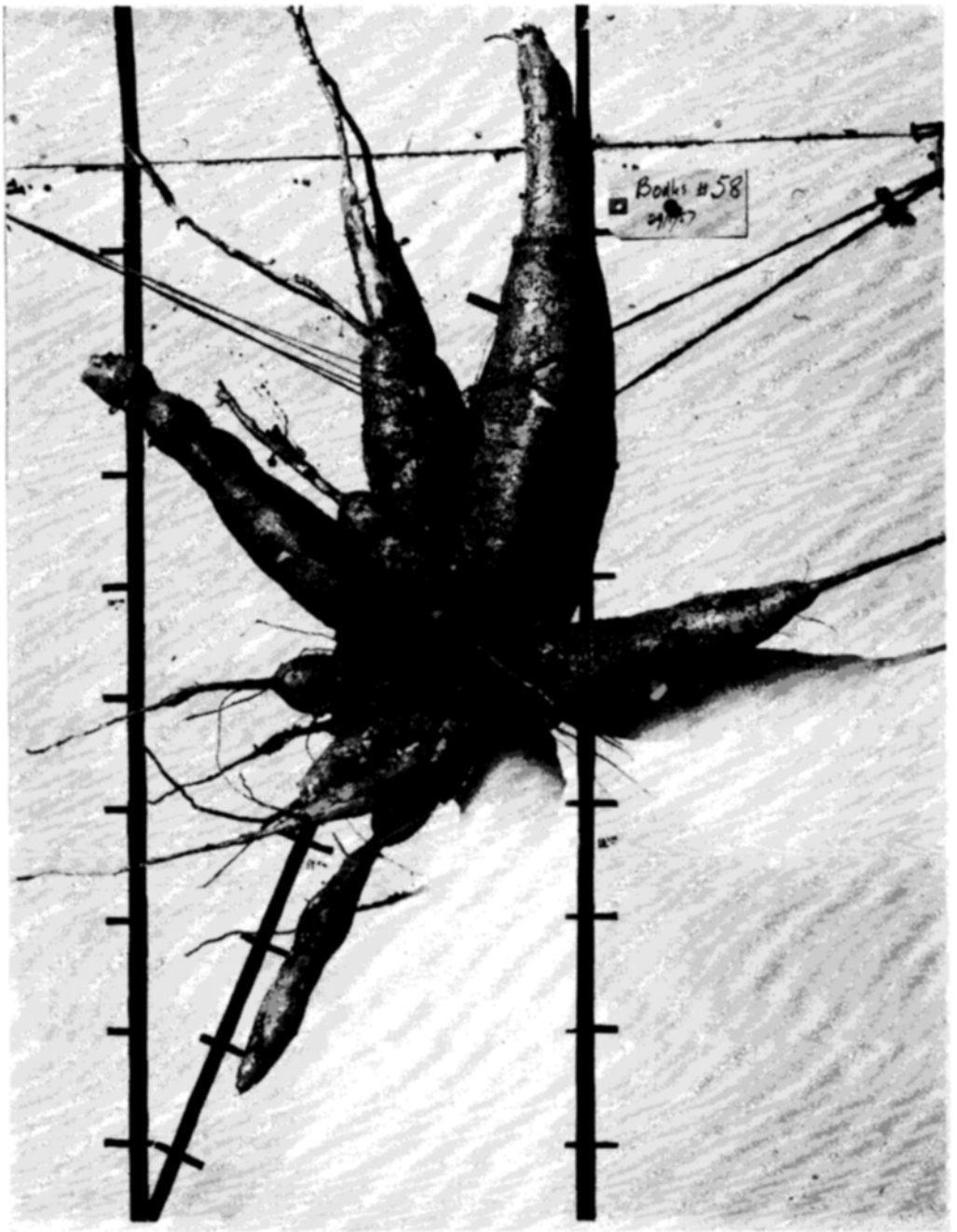

Fig. 3. Roots of a cultivar of *Manihot esculenta* with smooth epidermal layer. Jamaica.

their soil preferences and their water requirements would contribute much valuable information to the systematic study of the cultivars.

Description of the Genus

All species of the genus *Manihot* are confined, as wild plants, to the American tropics; no native species are found in the Old World. If any generalities can be made, one may say that the species of the genus are generally heliophiles, their habitats usually being those with little or no shade. The species sometimes have a tendency toward weediness, using that term to indicate the propensity of the species for growing or colonizing disturbed habitats such as roadsides, old fields, washed out stream banks, etc. Species range in size from trees 50 to 60 feet tall to low perennial herbaceous plants with a woody root stock. One group of tree species is known as a minor producer of rubber. Although the rubber is derived from several closely related species, the rubber produced is collectively known as Ceará rubber. Most of the rubber-bearing species, including *M. glaziovii, M. piauhyensis, M. dichotoma* and several others, are found in the drier regions known as the caatinga of northeastern Brazil. *M. glaziovii* has been carried far beyond its natural distribution to new areas in the American and Old World tropics, where it has been tested time and again for its rubber production. In Malaya, one may find *M. glaziovii* as an escape from cultivation, and its variability in form in this area is being clearly manifest.

Although there are certain "species groups" in the genus, the species are extremely difficult to delimit taxonomically because hybridization occurs and recombination of characteristics destroys sharp delimitations among many of the species. Successful crosses have been made in Africa between *M. glaziovii,* a tall tree, and *M. esculenta,* and the hybrids from these crosses produce viable seeds (Jennings, 1957; Nichols, 1947). *Manihot melanobasis,* a species very closely related (synonymous?) to *M. esculenta* has also been used in hybrid crosses with the cultivars (Jennings, 1959). Another wild species from Surinam, *M. saxicola,* has been successfully crossed with the cultivated species in various places in the East Indies, particularly in Java (Bolhuis, 1949).

Origin of the Cultivars

The earliest students of the origin of cultivated plants considered that Brazil was the country in which *M. esculenta* was first cultivated. One of the first to propose this area was Alphonse de Candolle in his *Origins of Cultivated Plants* (1886). Following de Candolle, Vavilov (1951) also considered Brazil, particularly northeastern Brazil, to be the most likely point of origin of the cultivars. Vavilov's consideration was based upon the fact that the largest number of cultivated variants were found in this area. Later, Carl Sauer (1952) proposed that the most likely place of origin of the cultivars was in the savannas of Venezuela. Sauer's basis for this decision was the movement of people and present-day utilization of the plant. While all of these hypotheses have some merit, and it is likely that certain portions of the cultivated complex did arise in the proposed areas, it is rather surprising to find that meso-America (present-day southern Mexico, and portions of Central America, particularly Guatemala and Honduras) has not been considered as an area of origin.

A number of species of the genus *Manihot,* some of which bear morphological traits similar to the cultivars, occur naturally in Mexico. Actual plant remains provisionally attributed to *Manihot* from archeological digs in La Perra Cave, in the State of Tamaulipas, Mexico, attributed to the Laguna cultural phase, have been uncovered by MacNeish (1958). Callen (1965) has been able to identify starch grains in coprolites which correspond well with *Manihot* from the Santa Maria culture, 900–200 B.C., in caves in the Tehuacan Valley, State of Puebla, Mexico. He feels, however, that the manioc consumed in the Tehuacan Valley was not raised in the area, but was brought in from areas nearby. The present-day agriculture of the Tehuacan Valley does not include this crop (Smith, 1963), but it is possible that contiguous lowland areas to the east do have manioc cultivation. The Mayan Indians, who were early occupants of the lowlands in parts of

Fig. 4. Interplanting of non-poisonous cultivars of *Manihot esculenta and* maize near Valladolid, Yucatan, Mexico. In the middle distance may be seen the separate plantings of poisonous varieties.

southern Mexico and Guatemala very likely cultivated yucca some time before any contact with white man (Lundell, 1939). Roys (1931) implies that the cultures, though pre-Columbian, were not native. He suggested that "it is not unreasonable, therefore, to look to early Toltec commerce as the source of its (*M. esculenta*) importation into northern Central America and Mexico at least." *Manihot esculenta* is extensively cultivated in meso-America, and a sufficient number of herbarium specimens have been collected to indicate a crop of fundamental importance to the inhabitants of this area.

With this background, it seemed profitable to revisit these areas, and, in the summer of 1963, I investigated areas in the State of Vera Cruz, portions of the Yucatan Peninsula, and some areas further south in

the Isthmus of Tehuantepec, Mexico. From these investigations, I found that the areas of intensive use of the crop almost, though not entirely, coincided with the areas of influence of the ancient Mayans. Hernandez (1963) indicated that the areas where yuca is grown coincides with the distribution of certain primitive types of maize, also found largely among the Mayans. This area is delimited, in the north, within the southern portions of the State of Vera Cruz, continues to the south and east throughout the Yucatan Peninsula, south and slightly west into eastern Chiapas, and in the south, by eastern lowland Guatemala. A wild species, *M. aesculifolia,* is commonly found in this area. This species has strong morphological similarities to the cultivars, but it is not the only one which should be considered when looking for an earlier wild progenitor. Other species, i.e., *M. Pringlei, M. isoloba,* and an unnamed species occurring in the vicinity of Tehuantepec, may all be considered for their roles as putative wild progenitors of manioc.

Mayan farmers in Yucatan cultivate yuca in a beautifully organized rotation with corn (maize), in which the cultivars with a low concentration of the $[CN]^-$ glycoside ("dulce") are interplanted with the corn, but the cultivars with high HCN are planted separately, away from the sweet varieties (Fig. 4). The interplanting, and the rotation, in which the roots of yuca mature at a time during which the corn is out of season, would seem to indicate a very well established and possibly quite ancient system of planting. I have not seen as carefully a planned interplanting system in any other area of yuca cultivation, though it may exist. The fact that high HCN varieties are grown at all in these regions, though reported in various papers (Standley, 1930), is at variance with a commonly held notion that no bitter *Manihot* is found in either Central America or in extreme western South America (Steward, 1948).

I have proposed (Rogers, 1963) that *M. esculenta* first became an important element in the diet of lowland tropical people somewhere in the meso-American complex and was distributed from there to the other portions of its present-day range.

At each point in its present-day range, however, by the biological nature of the species, it would be possible for the cultivars, once introduced, to hybridize with locally occurring native species. With each hybrid formed, new genetic materials were incorporated which made it possible to spread the cultivars through many different ecological habitats and made the crop adaptable to a wide range of conditions and applications.

Ethnological Considerations of the Origin of Manihot esculenta

It is fairly easy to see how *Manihot* could have been selected from the wild to be used by mankind at an early or primitive stage. The root system of many of the shrubby species is shallow, and there are few species with a large tap root. In most habitats where *Manihot* species grow, it is easy to pull up the whole root system. I have dug up several species of *Manihot* in various localities in Latin America, and it is a rare exception that these species do not have some enlarged portion of the root, with large concentrations of stored carbohydrate. A number of these species could have been progenitors of the cultivated ones, and indeed it is likely that several of the wild species have contributed useful attributes to the cultivated complex by natural hybridization. The origins of the varieties that are "sweet" as differentiated from those that are bitter is a very difficult question.

Methods of use of *Manihot* as food are well known. The methodology employed by the Indians to extract the poisonous materials from the root has been described many times (Dias, 1962; Galvão, 1959; Holleman and Aten, 1956; Schery, 1947; Smith, 1879). It is a beautiful technique whereby grating, pressure, and heat all play a role to destroy the HCN. Once the HCN has been destroyed, any number of different products may be produced. A dried, powdery meal may be derived or large cakes, "casabe," may be made. In Jamaica, a sort of a mush called "bami" is produced. In West Africa, a sticky, gelatinous mass known as "fufu" is used. Among those Indians living where maize is difficult to grow, *Manihot* has provided the major ingredient to brew chicha beer. It has been

reported that pepper pot, a sauce well known in northeast South America, is derived from the boiled down and concentrated juice from the bitter varieties. The technology involved in the production of edible products from the bitter varieties is complex and seems to indicate a very long cultural development. The fact that natives, with no inherent technology, could have developed these plants into useful food plants is a tribute to their ingenuity.

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