# Mbocayá or Paraguay Cocopalm—*An Important Source of Oil*

*The pulp and kernel oils from the fruit of this palm, exceedingly abundant in Paraguay, have long been used locally in the manufacture of soap. Kernels were formerly exported to Europe but now are entirely crushed in Paraguay and only the oil exported, principally to Argentina which normally takes 50 to 75% of the production.*

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## Introduction

The Western Hemisphere is rich in palms, having more than 1,200 native species, nearly 500 of which are indigenous to Brazil. The neighboring country of Paraguay, although less rich in number of species, contains hundreds of millions of individual palms, most numerous of which is the caranday (*Copernicia australis* Becc.) of the Chaco. Perhaps next in abundance is the mbocayá palm (*Acrocomia totai* Mart.) which occurs in large numbers in the Central Zone of eastern Paraguay.

Of the ten species of palms reported as native in Paraguay, the caranday and mbocayá possess the greatest economic value. From pre-Columbian times to the present these two palms have supplied food, shelter and the raw materials for fabrication of various articles (hats, ropes, baskets, bags, hammocks, mats, etc.).

From the economic and utilitarian point of view, mbocayá is presently of greater importance to Paraguay than any other indigenous palm. In modern industrial technology they are both great but as yet incompletely exploited sources of industrially valuable products. Caranday has been previously discussed in considerable detail and in this same periodical (January–March, 1955) by the present author. This article is a similar treatment of mbocayá, based in part on original surveys covering the natural abundance and distribution of the species in Paraguay.

## Taxonomy and Nomenclature

The totai or mbocayá palm is one of about 25 species of spiny palms belonging to the genus *Acrocomia* which

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abounds from the West Indies and Mexico to Paraguay and Argentina, and which encompasses a climatic range from tropical to temperate. Mbocayá is not confined to Paraguay but is found also in Bolivia, Argentina and Brazil in areas contiguous to Paraguay. It is closely related to, and difficultly distinguishable from, *A. sclerocarpa* Mart. which occurs over a wide area of Brazil. It has been referred to in the literature by a variety of common names (Paraguay: mbocayá, mbocayá Cayiete; Bolivia: cayara, totai; Brazil: grou-grou, mbocayá-ubá, mocaje, mucujá, noz do Paraguay; elsewhere: Paraguay palm; totai palm). Unfortunately " mbocayá " or variants thereof have been applied to at least five and perhaps more species of palm (18). In Paraguay the palm is frequently referred to as " coco ", " cocotero-paraguayo " and occasionally as " coquito del Paraguay ". These names are inappropriate because the palm and its fruit are totally dissimilar to the true coconut palm (*Cocus nucifera*).

TABLE I

PRODUCTION AND EXPORTS OF MBOCAYÁ (*A. totai*) KERNEL AND PULP OILS [a]

| Year | Kernel oil | | Pulp oil | |
|---|---|---|---|---|
| | Production, m. tons | Export, m. tons | Production, m. tons | Export, m. tons |
| 1940 | 883 | 13 | ... | ... |
| 1941 | 1,190 | 254 | ... | ... |
| 1942 | 1,833 | 1,300 | ... | ... |
| 1943 | 2,404 | 1,417 | ... | 126 |
| 1944 | 1,602 | 871 | ... | 222 |
| 1945 | 1,949 | 967 | 170 | 109 |
| 1946 | 1,277 | 727 | 171 | 471 |
| 1947 | 2,694 | 1,587 | 501 | 386 |
| 1948 | 2,664 | 1,547 | 501 | 381 |
| 1949 | 2,499 | 2,588 | 620 | 2,074 |
| 1950 | 1,189 | 1,001 | 985 | 719 |
| 1951 | 2,849 | 1,056 | 1,125 | 416 |
| 1952 | 2,456 | 1,062 | 881 | 350 |
| 1953 | 1,924 | 14 | 852 | 158 |

[a] Source: Department of Economic Studies of the Bank of Paraguay and the Central Bank of Paraguay.

Because of the confusion in names and identity of the species of *Acrocomia*, various previously reported chemical analyses allegedly of the fruit of *A. totai* cannot be relied on as they undoubtedly refer to *A. sclerocarpa* or some other species [2]. Junelle (12) comments on this confusion as follows: " et la confusion est facilitée par le fait que les fruits de tous ces *Acrocomia* sont sphériques et que, d'autre part, tous ces *Acrocomia* portent, en Amérique du Sud, le nom indigéne de ' mocajá ' ou ' mbocayá ' ".

## Description

Various descriptions (3, 5, 7) of the mbocayá palm have been published, but, although they agree with respect to the principal characteristics, none is complete, and in some aspects they are contradictory. So far as the writer has been able to ascertain, the mbocayá palm has never been thoroughly studied and described from the area of its greatest abundance, namely, Paraguay. In 1951 the writer collected a large amount of authentic material supplemented with photographs and sent it to Miriam L. Bomhard, U. S. Forest Service, for study and comparison with the extant herbarium specimens and descriptions of the mbocayá palm. Unfortunately she did not complete this study prior to her fatal illness. The following incomplete description is given from the field notes of the writer (14).

**Trunk and Foliage.** The mbocayá palm is generally eight to 12 meters in height to the crown, but occasionally very old trees may reach 20 meters or more. The trunk is generally cylindrical, but it may be curved or bent, especially in very tall trees, and quite frequently it is slightly bulged or depressed for several feet somewhere near the middle. The circumference of the trees vary

[2] The analysis reported for Paraguay kernels (*Acrocomia* sp.) by Bray and Elliott (6) almost certainly pertains to *A. totai*.

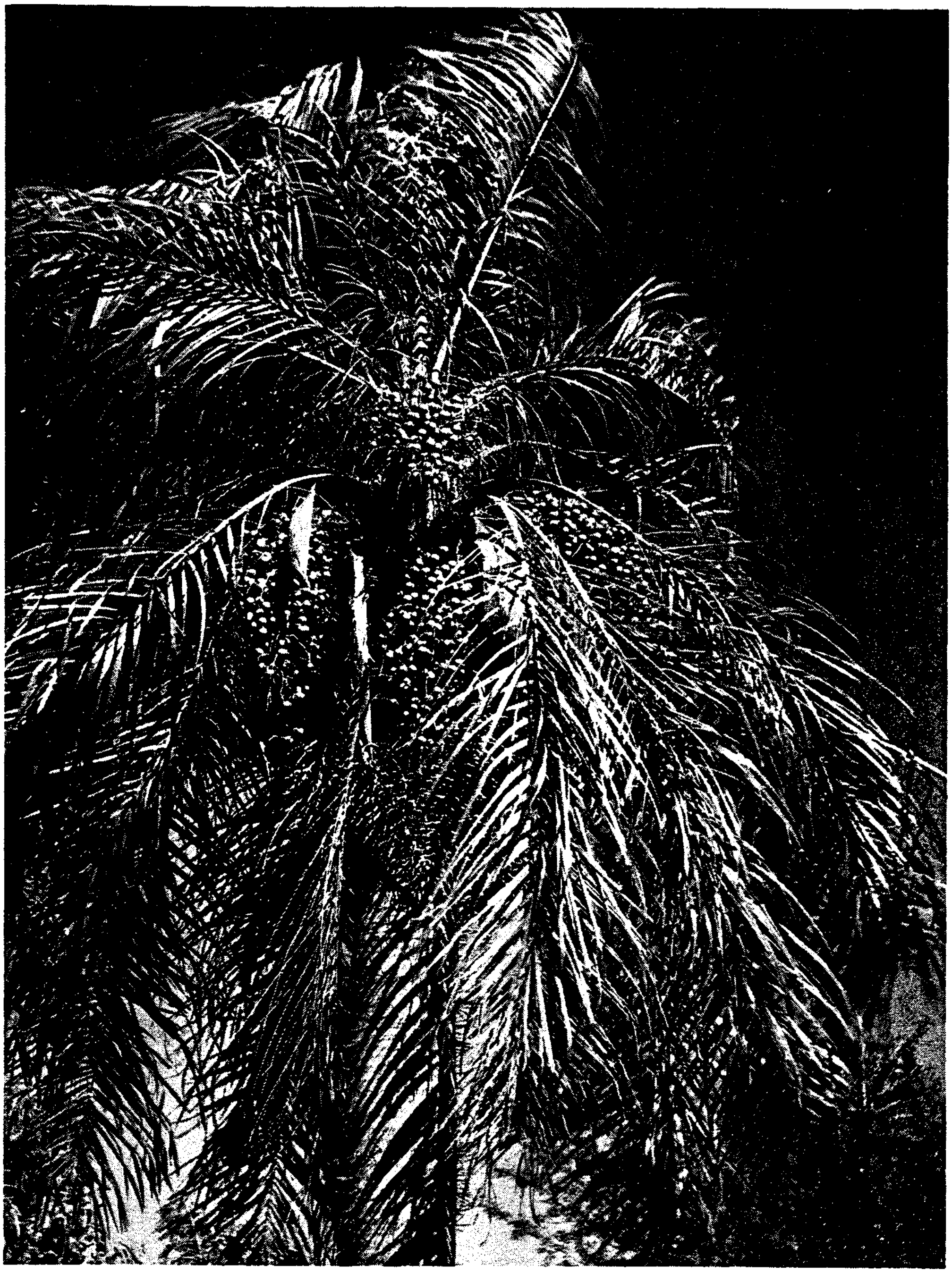

Fig. 1. Mbocayá palm (*Acrocomia totai* Mart.) of Paraguay.

from 30 to 45 cm. at the base, and from 25 to 30 cm. at 1.5 meters above the base.

The trunks vary greatly with respect to persistence of the spines which are arranged in incomplete circles in proximity to the leaf scars. Some trees are almost devoid of spines except for a short distance below the crown; others are covered with spines from the base to the crown; and all gradations between these two extremes are observed. The spines of the trunk vary in length up to 17 cm. but are usually 7.5 to 12.5 cm.

Generally the petiole bases or boots are not persistent, but occasionally young trees are observed with persistent petioles from the base to the crown—a distance of three to four meters.

Undisturbed crowns are not often observed in settled areas, owing to the practice of cutting the leaves for fodder. Normal crowns contain 20 to 25 leaves, 2.5 to 3.0 meters in length. During the dry season in settled areas where the leaves are used for fodder, the number of leaves per crown may be reduced by cutting to seven or eight and sometimes to no more than two. Mature leaves contain 100 to 114 leaflets on each side of the rachis which is covered with spines up to 8.0 cm. in length.

**Flowers and Fruit.** All species of *Acrocomia* are monoecious with the sexes separate in each spadix or flower-cluster. The ratio of staminate to pistillate flowers is very variable, resulting in marked variations in the numbers of fruits per bunch.

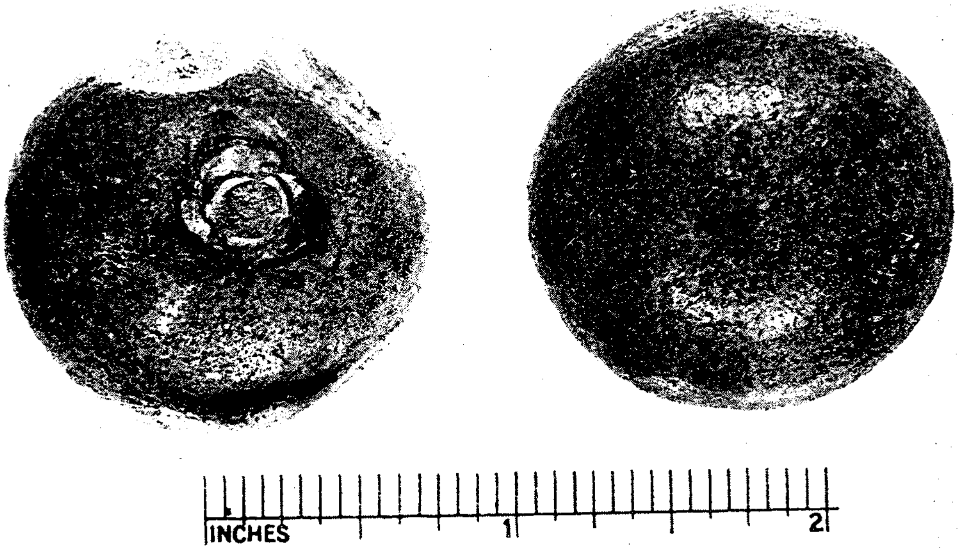


FIG. 2. Mature mbocayá fruit.

The fruit, like that of other Acrocomias, is a drupe consisting of an outer hull or rind (epicarp) and an inner fibrous pulp (mesocarp) which surround a nut or seed. The latter is composed of a hard shell (endocarp) enclosing an oily white kernel or meat, to which adheres a paper-thin reddish-brown skin or testa (Figs. 2 and 3). At maturity the oily mucilaginous pulp is dark orange in color, owing to the presence of

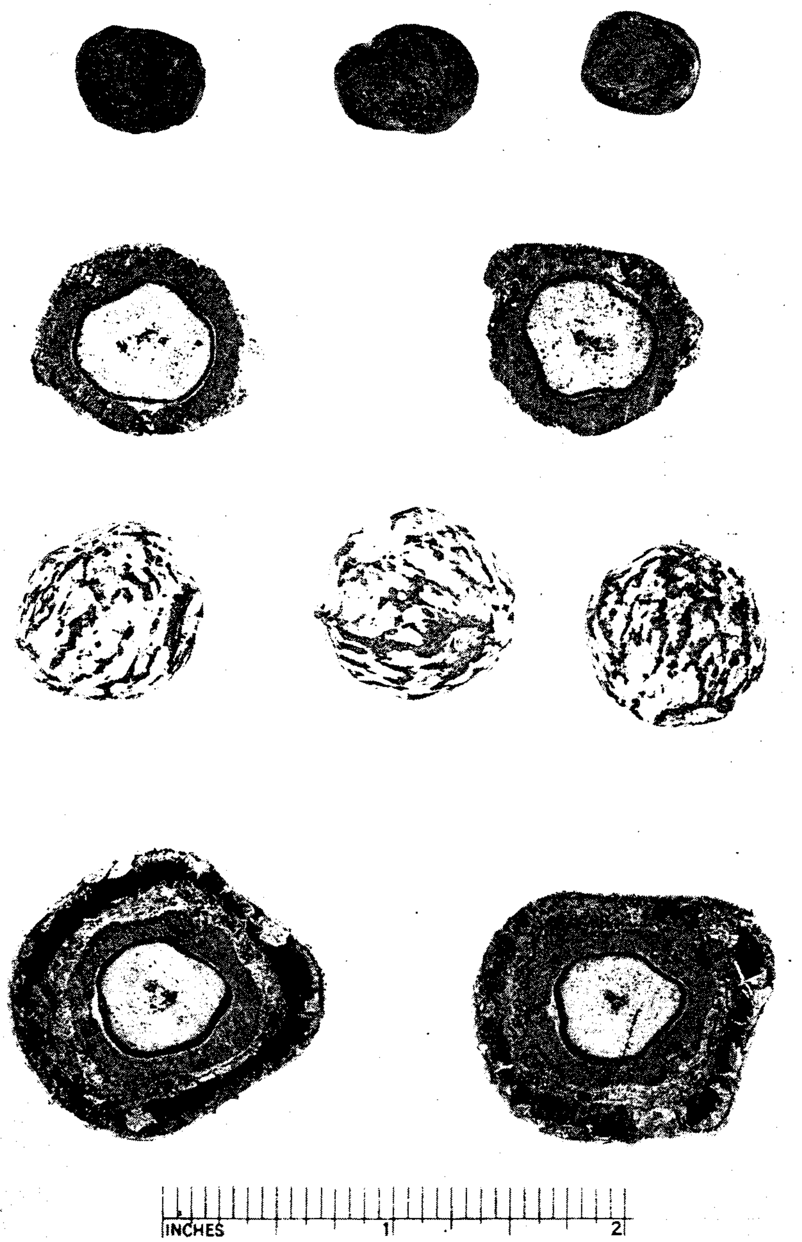


FIG. 3. Cross section of mbocayá fruit, whole nut, cross section of nut, and whole kernel.

carotene, and it possesses a sweet aromatic flavor.

The mature golden-yellow fruit is nearly spherical, varying slightly in size, depending on the age of the tree, soil, rainfall and the amount of defoliation to which the tree has been subjected. Measurements made on 75 mature fresh fruits of a tree from which no leaves had been cut for several years varied from 2.9 to 4.1 cm. (av. 3.76 cm.) in diameter and 3.0 to 4.1 cm. (av. 3.69 cm.) in height. Measurements made on 200 mature fruits sent to the U. S. Forest Service were 3.27 to 3.85 cm. (av. 3.56 cm.) in diameter and 3.04 to 4.17 cm. (av. 3.57 cm.) in height. The great majority of mature fresh fruit fall within the dimensions 3.0 to 4.0 cm. diameter and height.

The thickness of the various parts of the fruit varies with the overall size of the fruit and irregularities in the shape of the kernel and the surrounding envelopes. In a mature fruit (30 × 30 mm.) the outer hull is 0.6–0.7 mm., the pulp about 3.4 mm., the hard inner shell 2.5–3.0 mm. in thickness and the kernel 10–15 mm. in diameter.

At maturity and while the fruit is still attached to the tree, the pulp practically fills the space between the outer hull (rind) and inner shell. Since the pulp contains about 50% water, it begins to shrink as the fruit dries after it separates from the tree and possibly even before; consequently a free space develops between the pulp and the outer hull, which may be 2.3 mm. or more by the time the whole fruit attains an equilibrium moisture content of 8 to 10%. When the fruit reaches this moisture content, the hull becomes very brittle and is easily crushed and removed by hand. The pulp, however, dries to a tough fibrous mass that adheres tenaciously to the nut and is removed only with considerable difficulty. When, however, the fruit is permitted to lie on the ground, both the hull and fiber disintegrate and germination of the nut or seed soon follows.

### Distribution and Abundance

Until recently the number and distribution of mbocayá palms in Paraguay have been subjects of much conjecture and no little dispute. Most published reports generally refer to millions of these palms (21), one mentioning eight million (9), another 28 million. One widely disseminated map showing the distribution of this palm includes areas where none is found or only a few widely scattered ones.

Owing to the growing importance of the mbocayá palm to the vegetable oil industry of Paraguay and the need for expanding the number of fruit-collecting centers and hulling and cracking plants, it became important to have as reliable data as possible regarding the distribution and density of this palm. To supply this information, John L. Young of Algodones, S. A., and the writer made a ground and aerial survey of all areas in Paraguay which were reported to contain exploitable quantities of this palm (15).

Areas accessible by road were surveyed from the ground and inaccessible areas were surveyed by plane with landings at such places as were feasible. Estimates were first made of the densities of the stands by making tree counts over a series of areas of approximately one hectare (2.47 acres) in extent, and a code was developed to indicate different densities. These were found to vary from 0 to 150 or more palms per hectare. With increasing experience it was relatively easy to estimate the density of trees without making actual counts or reference to the code. In the case of the ground survey, estimates were made along both sides of the highways, kilometer by kilometer, over the visible distance between the highway and horizon. The latter distance varied from a kilometer or less up to five or more kilometers. These estimates were recorded and later, after checking them one or more times from the air, they were transferred to a large-scale map.

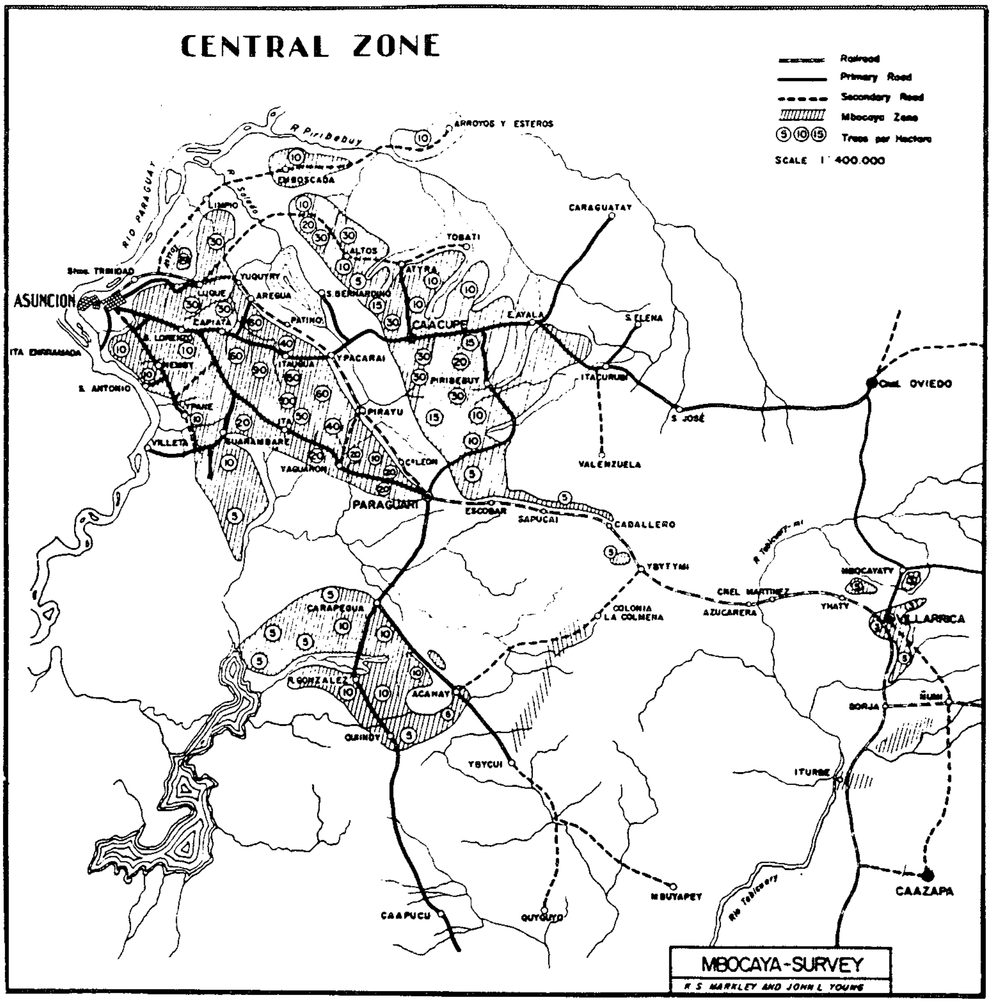


FIG. 4. Map of distribution and density of mbocayá in Central Zone of Paraguay.

In the aerial survey the densities were indicated on a map along both sides of the line of flight. A number of the areas were observed several times when they were crossed, going to or from previously unsurveyed areas. When a second or third estimate of an area was made, usually from a different direction than the previous observation, an estimate of the density was made without reference to any prior estimate.

After the survey was completed, all the results were transferred to one of two maps having scales of 1:400,000 for the Central Zone (Fig. 4) and 1:800,000 for the area designated as the North Zone (Fig. 5). The extent of the various mbocayá palm areas was then determined from the maps by means of a planimeter and the area multiplied by the weighted density factor to give the total number of palms for the zone.

The estimated numbers of palms for individual areas and the grand totals for the Central and North Zones are given in Tables II and III. The data presented in these Tables indicate that the Central Zone contains about six million mbocayá palms with somewhat more than half a million in the North Zone. Scattered palms throughout these two zones probably do not exceed ten percent of the total. The number of palms calculated on the basis of the present survey is in reasonably good agreement with the estimated eight million mentioned in a footnote of a report by Espinosa and Mendaro (9).

Comparison of the accompanying maps and tabular data for the number of mbocayá palms with previously published maps and data indicate that the area of occurrence and numbers of these palms have in the past been grossly exaggerated. Large areas included in the "mbocayá zone" of these earlier maps are devoid of mbocayá palms or contain so few as to have no significance, while other areas contain only caranday or yatay palms (*Butia yatay*).

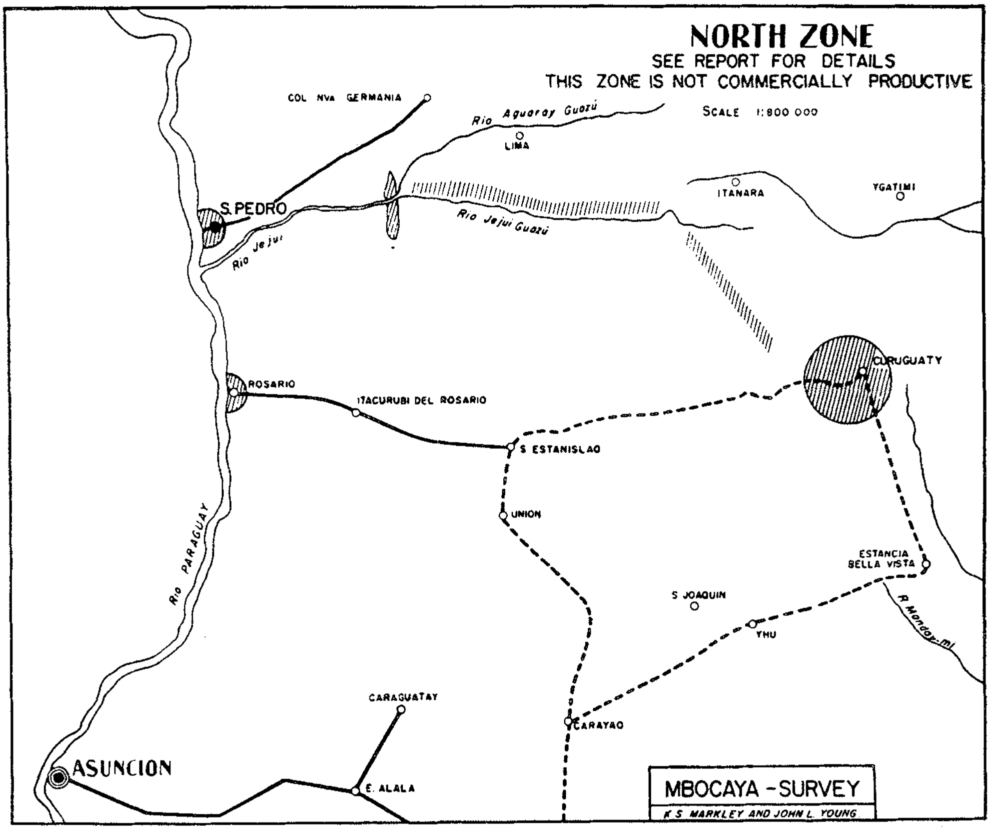


FIG. 5. Mbocayá areas in North Zone.

**Central Zone.** Reference to the accompanying maps reveals that outside the Central Zone there are no important areas of mbocayá palms. The Central

TABLE II

DISTRIBUTION OF *A. totai*—CENTRAL ZONE

| Region [a] | Area, hectares [b] | Density | | Total estimated palms |
|---|---|---|---|---|
| | | Range | Weighted mean | |
| Asunción—Paraguarí | 89,440 | 5–150 | 40 | 3,577,600 |
| Altos—Escobar | 70,240 | 5–30 | 20 | 1,404,800 |
| Carapeguá—Quiindy | 40,640 | 5–10 | 8 | 325,120 |
| Villarrica-Mbocayaty-Ayaty | 6,480 | 3–5 | 4 | 25,920 |
| Arroyos y Esteros | 5,440 | ..... | 10 | 54,400 |
| Emboscada | 4,480 | ..... | 10 | 44,800 |
| Escobar—Caballero | 1,600 | ..... | 5 | 8,000 |
| Ybytimí | 400 | ..... | 5 | 2,000 |
| La Colmena—Ybycuí | Scattered [c] | ..... | .. | ........ |
| Borja—Iturbe | Scattered [c] | ..... | .. | ........ |
| Caazapá | Scattered [c] | ..... | .. | ........ |
| Grand total | 218,720 | ..... | .. | 5,442,640 |

[a] See map.
[b] One hectare equals 2.47 acres.
[c] Few palms scattered over wide area. Total scattered palms throughout Central Zone probably less than 10 percent of total.

Zone can, moreover, be divided into two principal areas and several smaller, more or less isolated, ones with respect to the occurrence of this palm. The two main areas are separated by the long and broad Ypacaraí drainage basin which includes Lake Ypacaraí, the Rio Salado outlet to the Rio Paraguay, and Arroyo Pirayú and tributary inlet. Since the railroad from Asunción to the South follows the southern edge of this drainage basin, it may also be taken as the dividing line between the two great mbocayá areas of the Central Zone.

TABLE III

DISTRIBUTION OF *A. totai*—NORTH ZONE

| Region [a] | Area hectares [b] | Average density | Total estimated palms |
|---|---|---|---|
| Curuguaty | 46,080 | 10 [c] | 460,800 |
| San Pedro | 5,760 | 5 | 28,800 |
| Rosario | 5,120 | 5 | 25,600 |
| Jejuí—Aguaray Jct. | 3,840 | 5 | 19,200 |
| Jejuí-guazú valley | Scattered [d] | .. | ...... |
| Grand total | 60,800 | .. | 534,400 |

[a] See map of North Zone.
[b] One hectare equals 2.47 acres.
[c] Range 5 to 40.
[d] Few scattered over wide area. Total scattered palms throughout North Zone probably less than 10 percent of total.

Within these two principal areas there are marked variations in the concentrations of palms. Although not evident from the map which shows average densities for fairly large areas, there is much land, even within the relatively dense sections, where there are few or no palms. This palm-less land comprises farmlands, from which the palms have been removed, and terrain, in which the palm is not adapted.

The mbocayá palm is found only on the higher portions of hills and ridges and on elevated plateaus. As one goes down the slopes from the ridges the palms decrease in density and eventually vanish when the lower meadowland is reached. This succession of heavily palm-populated ridges and palm-less valleys and meadows is repeated over and over throughout the rolling terrain of the Central Zone.

The mbocayá palm is found principally in cultivated land or land which had once been cultivated. Only occasionally in the Central Zone is it in wooded areas, and then it is usually evident that the land had once been cultivated and had returned to bush and forest following abandonment of its use for agriculture.

In sections where the land had only recently been brought under cultivation, the average density of mbocayá was usually low and the trees were obviously young, sometimes no more than seedlings. The cross-hatched areas on the map of the Central Zone which carry no density figures generally represent the newer agricultural areas, for example, the areas around Caazapá, Iturbe and Colonia La Colmena to Ibycuí where the trees are few and scattered. A somewhat older cultivated and hence denser palm area is evident between Carapeguá and Quiindy.

The densest area in the Central Zone lies south of and parallel to the railroad, becoming less dense as the distance from the railroad increases. The long and broad southeast to northwest drainage channel which divides the Central Zone is practically devoid of mbocayá palms. This is generally true of the uncultivated low-lying meadows and pasture land, whether it is the size of Ypacaraí drainage basin or merely a very narrow drainage channel.

The distribution of the mbocayá palm within the Central Zone indicates that it is closely associated with the agricultural development of the land. The older and more intensely cultivated areas contain the greatest numbers of trees, sometimes in excess of 150 per hectare. The newest agricultural areas have the fewest palms and sometimes none at all. The meadowlands, which generally are not cultivated, are also devoid of palms.

This relation between the presence of the mbocayá palm and the intensity of agricultural development has been observed qualitatively and remarked upon by others, but here it is reduced to a quantitative basis. The interdependence of the two has given rise to such expressions as " the mbocayá palm follows the plow " and " the mbocayá follows the ox ". Perhaps earlier it might have been expressed as " the mbocayá follows the planting stick ". According to Winkelried Bertoni, there is an ancient Guaraní legend to the effect the mbocayá follows the Indian. These various legends may be summarized best by saying " the mbocayá follows the agriculturists ".

If this is true, and the evidence appears to be overwhelming that it is, the question arises, where did the mbocayá originate and how does it spread? Two possibilities suggest themselves, one that the mbocayá occurred in the past, and possibly still does, as an isolated tree or at least a tree of low density in the virgin forests, much as the pindó does in the Alto Paraná or in the montes in the lower Chaco. In the forest it continued to persist in varying but relatively small numbers, depending on its ability to compete with the surrounding vegetation. The other possibility is that somewhere in or contiguous to Paraguay the mbocayá palm occurs in pure stands comprising large or small palmars from which it spread or was carried into cultivated areas. The first assumption could be verified, whereas, despite numerous reports to the contrary, no large pure stand of mbocayá was observed by the author which could not be associated with the agricultural development of the area from which it was reported.

Irrespective of its primary source, the mbocayá palm appears to have been spread principally by the agency of man and associated domestic animals through use of the fruit and kernels as food and feed. Concomitant with the movement of man, mbocayá nuts become scattered and find their way into the soil, often at considerable distances from their point of origin. Where the fields are well cultivated the nut or seed soon becomes covered to an optimum depth for germination, and thus protected it emerges as a new plant. The better the cultivation the greater the chance that the seeds or nuts will find a favorable environment for germination. It is not surprising, therefore, that the most intensely and thoroughly cultivated farmlands of the Central Zone contain the greatest concentrations of palms (Fig. 6).

Under the competitive environment of the forest just the reverse is true. The nuts or seeds have little chance of being covered by soil, and if an occasional individual succeeds in germinating, the emergent seedling faces many hazards to survival. It may be devoured by the multitude of insects, birds or other forms of animal life which swarm in the forest;

FIG. 6. Mbocayá palms in cultivated land of Central Zone.

it is subject to attack by microorganisms; and it may suffer from insufficient moisture or at times from excessive exposure to the sun. If the new plant does survive these and other hazards, it then has to fight for existence in competition with the surrounding plant life, much of which is better adapted for this struggle. It is easy, therefore, to understand why the mbocayá palm is found in large numbers in cultivated fields and only as a comparatively rare plant in its normal environment, the mixed forest.

**North Zone.** Although the foregoing theory of the occurrence and distribution of the mbocayá palm seemed to hold throughout the Central Zone, it was persistently reported that large stands of this palm occurred in the less densely populated and agriculturally underdeveloped North Zone, particularly in the vicinity of Curuguaty, San Pedro, Rosario and Concepción.

One report (20) states that one of the largest zones of coco (mbocayá) lies within a 15-kilometer radius of Curuguaty, in the Department of San Pedro. This area is literally covered with millions of tons of mbocayá nuts that have fallen from millions of trees during past years. The zone is said to cover 90,000 hectares, and it yields 50 to 100 times as many nuts as are now utilized each year.

Because of the number and persistence of these reports, a separate survey was made of this zone, with particular attention to the area in the vicinity of Curuguaty. The areas in the North Zone where the mbocayá palm was observed are shown on the accompanying map. The area observed from the air in the vicinity of Curuguaty comprised about 500 square kilometers of dense forest and bush in which many palms could be seen.

The densest stands were estimated to be about 40 per hectare and the average for the area about ten per hectare. All but a few were in heavy forest or dense undergrowth. From the air the palms did not appear to resemble the mbocayá. The crowns were small, and the trunks, which projected above the other forest trees, presented a grayish-white or bleached appearance.

This was the first time that the author had seen the mbocayá palm in appreciable numbers in dense forest and appeared to contradict the theory that the mbocayá palm follows the plow which had been repeatedly confirmed everywhere else.

A landing was made on a grass airstrip on the edge of the village of Curuguaty, and the forest was explored at several places where the mbocayá palms were seen from the air. The appearance of the palm from the ground was as unusual as from the air. It occurred as an individual specimen and in small groups in a relatively dense growth of bush and forest trees. Except along well defined trails, movement through the forest was impossible without first cutting away the bush undergrowth with a machete.

All palms seen were very tall (50 to 60 feet or more), and no seedlings or young trees were evident. The trunks were straight, and the bulges or bottle effect, seen so frequently in the mbocayá of the Central Zone, was absent. The crowns were small despite the fact that they had not been cut for fodder as in the Central Zone. The trunks presented the same bleached appearance as from the air. Few spines were observed on the trunks except near the crown. Most of the trees were devoid of fruit or had a few bunches with relatively few fruit. Few of the palms were flowering, although the survey was made at the season in which they should have been blooming heavily. There were also many obviously dead palms (straight trunks without crowns) which probably would have fallen except for the forest growth surrounding and supporting them.

A search of the ground revealed only

a few scattered fruit. When the sandy soil was dug into with a machete, nuts from previous years were found down to a depth of several inches. Specimens of the fruit and nuts on the surface and of nuts below the surface were collected. Examination of these revealed that the fruit on the surface was normal, while the nuts from below the surface often (70%) contained no kernels. Generally these nuts had been parasitized by organisms which had eaten or otherwise destroyed the kernels.

The observations made in the vicinity of Curuguaty were so much at variance with those made elsewhere in Paraguay that it was difficult at first to believe that the same species of palm was being dealt with.

A subsequent study of the history of Curuguaty revealed that the area had been a center of agriculture off and on from pre-Columbian times until after the war of the Triple Alliance (1865–70). Subsequently the area declined in population and in agricultural importance. The settlement of the area, its agricultural development, its subsequent decline and the return of the land to what now resembles virgin forest explain the apparently anomalous occurrence of the mbocayá palm under conditions very different from those observed in the Central Zone. As in the Central Zone the palm apparently invaded the area when the land was cleared and put under cultivation. Later, when cultivation ceased, the fields returned to bush and forest, the established palms continued to grow and generally maintain their advantage by pushing their crowns above forest. However, reproduction gradually became repressed because the palm could not compete with the increasing forest vegetation. Eventually many of the palms passed the age of normal growth and reproductivity. Ability to form leaves, flowers and fruit declined with advancing senility, and eventually many of the palms died, some toppled over, others remained erect or semi-erect supported by the forest surrounding them. Actually all facets of this picture could be observed in the area about Curuguaty.

Today the area is not important, neither agriculturally nor as a source of mbocayá palm fruit for the oil mills. The trees produce too little fruit, and such fruit as is produced cannot be gathered without first clearing and keeping clear the dense undergrowth. A depulping and nut cracking plant was erected in Curuguaty about 1947 but operated only two seasons because sufficient fruit could not be obtained. The difficulty of collecting fruit was increased by lack of population, and the isolation of the area made it uneconomical to transport the kernels and dried pulp to the mills for extracting the oil.

## Yield of Fruit

Correlated with the problem of determining the number and distribution of mbocayá palms in Paraguay is that of estimating the annual production of fruit. The oil milling industry is less interested in the number of palms than in the yield and availability of the fruit. The latter is difficult to determine with exactness because of the many factors involved, principal of which is the variation in the yield of fruit per tree. This yield is influenced by the age of the tree, its location, its treatment (cutting of leaves, number and degree of burns it has suffered, severing of roots during plowing and cultivation), climatic conditions, particularly rainfall and temperature throughout the year, the number and severity of attacks by insects and microorganisms, etc. Besides the variation in individual trees there is an annual variation which is a response to climatic conditions and to the cycle of high and low productivity. Consequently the total productivity for two successive years may vary greatly.

Many thousands of trees, especially in the Central Zone, produce exceedingly little fruit, sometimes no more than two or three poorly developed bunches. On the other hand, isolated trees may produce eight to ten large well filled

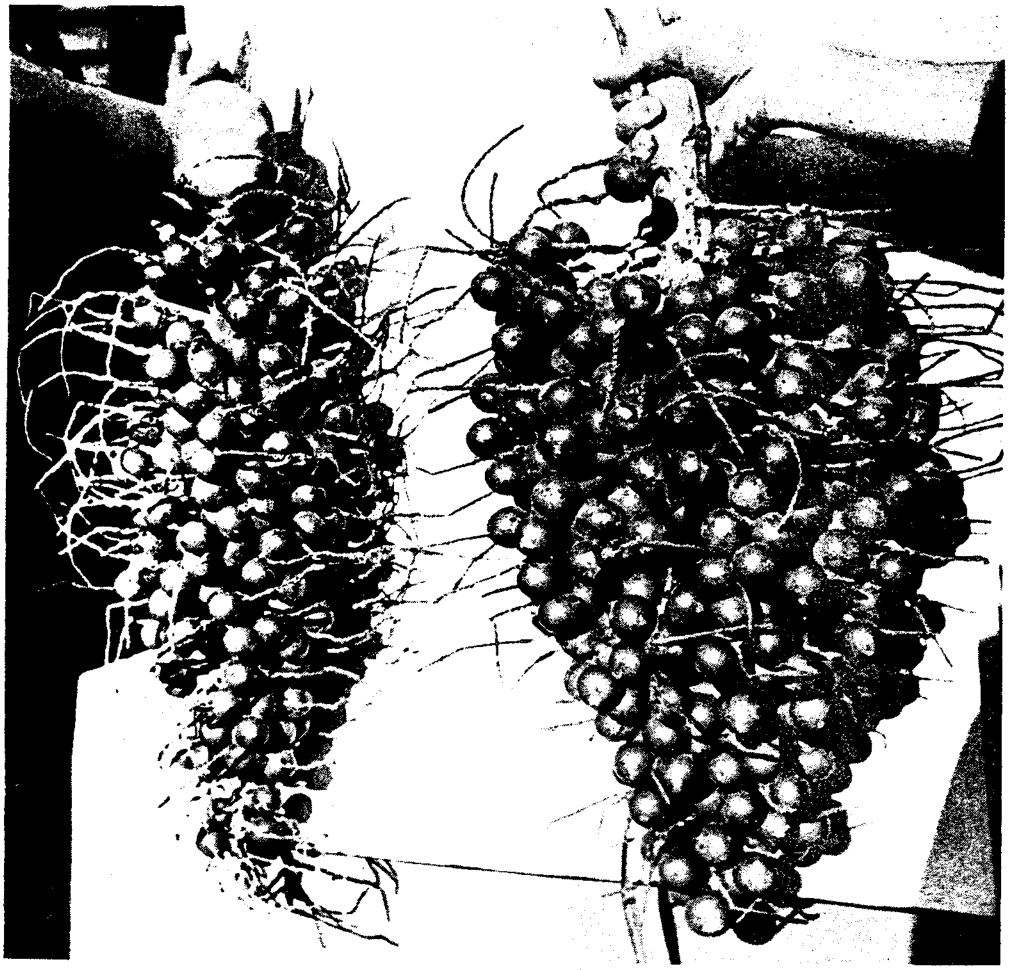

FIG. 7. Bunches of mbocayá fruits (left, 273; right, 520).

bunches. In the older and more intensely cultivated fields of the Central Zone the yield of fruit is generally low and will probably not average more than ten kilos of air-dry fruit per tree. The yield of mature fresh fruit (averaging about 35% moisture content) is, of course, higher. However, it is only the yield of thoroughly mature air-dry fruit which is of interest to the oil miller.

A report attributed to Unilever Ltd. Mission in 1937 estimated a possible annual harvest of 100,000 metric tons of fruit within access of oil mills with possibly an additional 100,000 tons that could be made available by improved transportation. The same year the Banco Agrícola estimated that 500,000 tons of fruit were produced annually by the mbocayá palms of Paraguay. The report " Aceite de Coco en el Paraguay " (21) contains a map on which a figure of 1,200,000 tons of " whole nuts " is indicated, of which 1,000,000 tons is attributed to the Curuguaty area. A more recent report (9) refers to the production " each year of millions of tons of fruit " in Paraguay.

Such figures have usually been calculated on the basis of an assumed number of palms and an assumed annual yield of fruit per tree. The most widely quoted figure is three to five bunches of fruit per tree. This figure was used by Bertoni (4) and appears to be reasonably accurate, at least with respect to the cultivated areas of the Central Zone.

In one field along the Asunción-Caacupé highway, the number of bunches of fruit was observed by the writer to vary from three to eight and averaged five for all of the trees observed. Isolated trees were noted in other places (chicken lots, yards, etc.) which had as many as 17 bunches of fruit. On the other hand, many trees, especially immature and very old ones, had none to at most two bunches of fruit.

Equally variable have been the reports of the number of fruit per bunch. The Unilever Mission estimated that the mbocayá palm produces an average of ten bunches of fruit per year with 500 fruits per bunch. In a recent report (9) two bunches of fruit are shown, one with 520 fruits and the other with 273 (see Fig. 7). Fruit-counts made by the writer on randomly selected well-filled bunches collected in the Central Zone ranged from 75 to 340. Many bunches were noted with no more than a few dozen fruits. No doubt bunches are produced occasionally with 500 or more fruits, but they are relatively rare. As exhibit material they are interesting, but they are of little or no value in arriving at figures for average yields. Perhaps five bunches and 200 fruits per bunch is a good average for mature trees in the Central Zone.

Reported data for the average weight per bunch is likewise very variable. Past reports give figures of 22, 20 to 30, 25 to 35, and 15 to 50 kilos per tree. Whether fresh (mature) or air-dry weight is seldom stated. The fresh mature fruit contains about 35% moisture, but after separation from the tree and air-drying until an equilibrium moisture content is reached under normal climatic conditions in Paraguay, whole fruit will contain eight to ten percent moisture. In other words, fresh fruit will lose 25 to 30% of its weight in drying to equilibrium moisture content.

One oil mill made a careful analysis of the fruit and obtained an average value of approximately ten grams per fruit, having an average moisture content of approximately eight percent. A sample composed of 40 fruits randomly selected by the writer from a group of 300 had an average weight of 9.1 grams and a moisture content of 8.9%.

Using a figure of five bunches of fruit per tree, 200 fruit per bunch, and ten grams per air-dry fruit, the average yield per tree can be calculated to be ten kilos or considerably less than the previously reported 15 to 20 kilos.

If it is assumed that the five and one-half to six million mbocayá palms of the Central Zone each produce an average of ten kilos of mature air-dry fruit per year, the total production would be 55,000 to 60,000 metric tons. If the estimated yield per tree were doubled, as it might be in an unusually good crop year, the total production might be 110,000 to 120,000 tons. The latter figures agree fairly well with the estimate of 100,000 metric tons, within access to oil mills, made by the Unilever Mission in 1937.

Although the annual yield of mbocayá fruit in the Central Zone fluctuates between 55,000 and 120,000 metric tons, it cannot be assumed that this tonnage would be available for processing. In well cultivated fields much fruit is covered up during preparation of the land and cultivation of the crops. In fallowed brushy and wooded areas much of the fruit becomes lost in the undergrowth so that it is difficult or impossible to collect it. This situation occurs in areas like Curuguaty where collection of fruit in the dense forest is practically impossible. Thus a certain percentage of the crop is unavailable for processing. How much of the remainder may be collected and eventually arrive at the oil mill depends on the price, availability of labor, availability and cost of transport, and other factors.

### Structure and Composition of Fruit

Processing mbocayá fruit for oil presents difficulties not generally encountered in most oil-bearing materials. To understand these difficulties it is necessary to understand the structure and composition of the fruit. The fruit of *Acrocomia* palms differs from that of the larger and thicker shelled *Orbignya* (babassu) and *Scheelea* (coroba) and from the smaller and thinner shelled African oilpalm (*Elaeis guineensis*). The fruit of *A. totai,* like that of the African oilpalm, is composed of an outer thin epicarp, a pulpy mesocarp, a hard endocarp or shell, and an inner kernel. However, the epicarp (hull) of the mbocayá fruit is much tougher and more difficult to remove in the fresh state than is that of the fruit of the African oilpalm. The shell of the mbocayá nut or seed is also somewhat thicker and more difficult to crack than is that of the African oilpalm.

TABLE IV

DISTRIBUTION OF COMPONENTS AND MOISTURE IN FRESH MATURE FRUIT OF *A. totai* [a]

| Component | Weight, g. | Weight, % of total | Moisture content, % |
|---|---|---|---|
| Hull (epicarp) .... | 2.5 | 18.1 | 44.3 |
| Pulp (mesocarp) .. | 6.2 | 44.9 | 51.1 |
| Shell (endocarp) .. | 3.9 | 28.3 | 15.2 |
| Kernel ........... | 1.2 | 8.7 | 14.9 |
| Whole fruit ...... | 13.8 | 100.0 | 36.5 |

[a] Data furnished through the courtesy of John L. Young, Algodones S. A., Asunción, Paraguay.

The outer hull and the hard shell of the mbocayá fruit, being essentially cellulosic, are valuable only as fuel or, in respect to the shell, as a possible source of charcoal. The pulp and kernel, however, are rich in glyceride oils and other nutrient materials, and possess considerable economic value.

The weight, the percentage of the total weight, and the moisture content of each component of mature fresh fruit are given in Table IV. Fresh mature fruit (35% moisture) weighs approximately 14 grams, whereas air-dry fruit (8 to 10% moisture) weighs nine to ten grams. The moisture is unequally distributed throughout the various parts of the fruit,

TABLE V

PERCENTAGE OF COMPONENTS OF *A. totai* FRUIT [a]

| Component | Range—Mehl (22) (Av. 8 samples) | Commercial firm [b] (Av. 10 samples) | Commercial firm [c] | Landmann (13) |
|---|---|---|---|---|
| Hull, % ........... | 16.7 | 19.6 | 15.0 | 15–18 |
| Pulp, % ........... | 42.5 | 36.6 | 30.0 | 33–34 |
| Shell, % ........... | 29.0 | 34.3 | 40.0 | 39–41 |
| Kernel, % ......... | 7.6 | 9.5 | 9.5 | 9–11 |

[a] Air-dried to different moisture contents.
[b] Unpublished analytical data (1948).
[c] Yields of products in processing plant located at Tobatí, unaccounted for loss 5.5%.

TABLE VI

OIL CONTENT OF MBOCAYÁ PULP AND KERNELS

| Authority | Pulp | | Kernel | |
|---|---|---|---|---|
| | Moisture, % | Oil, % | Moisture, % | Oil, % |
| Grimme (11) | ... | ... | Not recorded | 58.9 |
| Négri and Fabris (17) | ... | ... | ... | *ca.* 70 |
| Mehl and Cuevas [a] | 18.0 | 16.0 | 14.8 | 58.0 |
| Andrada (2) | 19.4 | 23.8 | ... | ... |
| Landmann (13) | Not recorded | 30–32 | Not recorded | 55–65 |
| Commercial firm [b] | 8.7 | 25.7 | 3.2 | 60.5 |

[a] Quoted by G. T. Bertoni (4).
[b] Unpublished work, 1948

being lowest in the kernel and highest in the pulp and outer hull.

Other workers have determined the percentage distribution of the components of this fruit, apparently air-dried to different moisture contents. Based on these data which are collected in Table V, it can be said that the fruit of the mbocayá palm is composed of 15–20% hull, 30–45% pulp, 28–41% shell, 7–11% kernel, depending on the moisture content. The nut, therefore, represents 40–50% of the weight of the whole fruit.

Bertoni (4) states that the content of moisture and oil of the pulp at the time of processing varies between 12 and 20%, each. He also quotes Andrada (2) to the effect that 10 to 14% of oil is extracted commercially, compared to analytical values up to 24% oil content found in the laboratory. Landmann (13), on the other hand, states that the pulp contains 30 to 32% oil and that 17 to 20% is recovered in the mill. All of these yields are very poor and apparently refer to hydraulic pressing.

Data with respect to the oil content of the pulp and kernels from fruit dried to various moisture contents are collected in Table VI. These figures indicate that air-dry pulp contains 25 to 30% oil or 8 to 10% of the weight of the whole air-dry fruit, and that the kernels contain approximately 60% oil or about 6% of the air-dry weight of the whole fruit.

Because of the gross anatomic similarity of the fruits of *A. totai* and *E. guineensis*, most authors who discuss the commercial exploitation of the former tend to compare it with the latter. These authors, however, fail to present quantitative data with respect to the components and oil contents of the fruits of the two palms, without which the comparisons are meaningless.

The principal components of the fruit of the African oilpalm varies over a wide

TABLE VII

COMPARISON OF *A. totai* AND *E. guineensis* AS SOURCES OF OIL

(Fresh Fruit Basis)

| | *A. totai* | *E. guineensis* |
|---|---|---|
| Hull (epicarp) | | |
| % Whole fruit | 18 | [a] |
| Oil content, % | None | None |
| Pulp (mesocarp) | | |
| % Whole fruit | 45 | [b] |
| Oil content, % | 12–15 | ... |
| Hull and pulp (pericarp) | | |
| % Whole fruit | 63 | 48–73 |
| Oil content, % | 8–11 | 44–73 |
| Kernel | | |
| % Whole fruit | 9–10 | 6–13 |
| Oil content, % | 60 | 42–49 |

[a] Hull (rind) is too thin and soft to be separated from pulp.
[b] Pulp (mesocarp) cannot be separated from soft hull or rind (epicarp).

range, depending on selection or type, soil and climatic factors, cultural conditions, etc., compared to the much narrower range of the uncultivated mbocayá palm (see Table VII). For the African oilpalm the pericarp (outer hull and pulp) comprises 48 to 73%, and the nut 27 to 52% of the fresh mature fruit. The pericarp contains 44 to 73% oil, and the kernel, which comprises 6 to 13% of the whole fruit, contains 42 to 49% oil.

The fresh mature fruit of *A. totai* is composed approximately of 18% outer hull containing little or no oil, 45% pulp containing only 12 to 15% oil, and 9 to 10% kernel containing about 60% oil. The fruit of *A. totai* is a somewhat better source of kernel oil than is that of the African oilpalm, but a comparatively poor source of pulp oil. The average content of combined pulp and kernel oils, on a fresh fruit basis, is approximately 11% for the mbocayá palm compared to approximately 40% for the African oilpalm.

### Processing of Fruit

A great deal of effort has been expended in trying to develop satisfactory equipment for processing mbocayá fruit. Samples of fruit and nuts have been submitted to various manufacturers of African oilpalm-processing equipment in Europe and seed-processing equipment in the United States, but none of the existing standard equipment was found satisfactory and none of the manufacturers was interested in modifying his equipment for use with mbocayá fruit and/or nuts. However, machines for hulling, depulping, cracking and separating the various components of the mbocayá fruit have been developed and built locally. These machines are ingenious in principle, though often poorly made, owing to lack of proper metals and inadequate manufacturing facilities.

Unfortunately the depulping machines operate successfully only with fruit dried to the approximate moisture content which is in equilibrium with the atmosphere. Natural drying of the whole fruit to this moisture content requires weeks and sometimes months, during which time the hydrolytic enzymes in the pulp split a large proportion of the oil into free fatty acids and glycerol. Generally only 40 to 60% of the recovered total oily material (lipids) is neutral oil. The remainder is a mixture of fatty acids.

In order to obtain relatively neutral oil from the pulp, it would be necessary to process the fresh fruit directly from the trees, preferably by harvesting the whole bunches at maturity and processing them immediately, as is done with the African oilpalm. The common practice with the African oilpalm is to harvest the bunches of fruit, sterilize them within a few hours after harvesting to destroy or inactivate the enzymes, mechanically strip the fruit, and then press or centrifuge the pulp oil from the fruit after first cooking it with steam or water.

In the centrifugal process the water-oil mixture is separated from the nuts by centrifuging. The fiber is removed from the wet nuts which are then dried and cracked, and the separated kernels transported to oil mills. The water-oil mixture from the centrifuge is allowed to stand in tanks to separate most of the water. It is then washed with hot water, and the oil is centrifuged to remove the last small amounts of water. In this way pulp oil with as little as two to five percent free fatty acid is obtained.

It was thought that the same process might be used with mbocayá fruit, but when samples were shipped to one manufacturer of African oilpalm-processing equipment in England, it was found that the pulp oil could not be separated by the centrifugal process. This firm reported that cooking with steam and water produced a water-oil emulsion which would not separate, partly because of the low oil content of the pulp and partly because of the presence of a mucilaginous substance which appeared to act as a strong emulsifying agent.

Rapid artificial drying of the whole fruit has been tried, but it is ineffective and costly. It is used, however, with the kernels after their recovery in the water-separation of shells and kernels.

Both the whole fruit and kernels are sold to oil mills. Some kernels are still separated by hand-cracking, but much larger amounts are produced mechanically at the hulling and cracking plants, more than 20 of which are located at strategic points in the mbocayá zone. The dry pulp from the defibering machines and the separated kernels produced by the cracking plants are shipped in bags to oil mills for extraction. Both materials are processed in continuous screw presses, although one firm extracts dried mbocayá pulp in a continuous solvent extractor and some mills still use either hydraulic cage or box presses.

The composition of the various primary products and by-products produced in commercial processing of mbocayá fruit are given in Table VIII.

### The Fruit Oils

**Pulp Oil.** It is difficult to discuss the composition of mbocayá pulp oil or to compare it with other pulp oils, such as that from the African oilpalm, because the pulp of the mbocayá fruit contains a highly active fat-splitting enzyme which attacks the oil soon after the fruit ripens and hydrolyzes it to free fatty acids and glycerol.

If the pulp oil is extracted and analyzed about the time that the fruit is ripe, it will be found to consist principally of neutral oil with 2 to 2.5% free fatty acids. If, however, the fruit is stored or allowed to dry naturally over a period of weeks or months and the pulp oil is then extracted, it will consist of a mixture of 40 to 60% neutral oil and 60 to 40% free fatty acids.

Owing to the inadequacy of present techniques and equipment, it is not possible to process fresh mbocayá fruit. The fruit is generally allowed to lie on the ground to dry partially and is then collected and stored for periods up to six months or more before it is processed (Fig. 8), by which time the oil has largely been converted into free fatty acids.

Oil containing 40 to 60% free fatty acids cannot be refined and is of value only in the manufacture of soap or for the production of distilled or fractionated fatty acids. Even for these purposes it is less valuable than neutral oil

TABLE VIII

COMPOSITION OF COMMERCIAL SAMPLES OF *A. totai* PRODUCTS (14)

| Constituent | Outer hull (Epicarp) | Pulp (Mesocarp) | Pulp, expeller cake | Shell (Endocarp) | Kernel | Kernel, expeller cake |
|---|---|---|---|---|---|---|
| | % | % | % | % | % | % |
| Moisture ($H_2O$) | 6.65 | 4.31 | 5.26 | 6.84 | 3.17 | 7.44 |
| Lipides (oil) | 3.88 | 27.94 | 6.26 | 2.46 | 66.75 | 7.22 |
| Nitrogen | 0.74 | 0.67 | 0.98 | 0.31 | 2.02 | 5.50 |
| Protein (N × 6.25) | 4.62 | 4.18 | 6.12 | 1.94 | 12.62 | 34.38 |
| Crude fiber | 36.00 | 8.82 | 6.83 | 49.69 | 8.60 | 11.65 |
| Sugars (total) | .... | 4.85 | 5.16 | .... | 1.28 | 2.80 |
| Ash | 5.82 | 10.32 | 9.16 | 3.26 | 1.98 | 5.37 |
| Potassium | 2.18 | 2.18 | 2.75 | 1.02 | 1.36 | 1.55 |
| Phosphorus | 0.10 | 0.12 | 0.16 | 0.04 | 0.42 | 1.14 |
| Calcium | 0.07 | 0.09 | 0.10 | 0.04 | 0.08 | 0.27 |

because during the enzymatic hydrolysis the glycerol, which is split from the oil, is lost.

Good grade Sumatran or Malayan plantation palm oils, with which mbocayá pulp oil would be expected to compete in the world market, are sold on a basis of 5% free fatty acids, calculated as oleic acid, and they often contain less than 2%. Congo plantation palm oils are sold on the basis of 10% free fatty acids. African palm oils from wild trees may contain from 12 to 45% free fatty acids and are graded and priced accordingly.

Table IX contains figures for some of the more important physical and chemical characteristics of the pulp oils of *A. totai* (mbocayá) and *E. guineensis* (African oilpalm). The data reported by Landmann refer to oil extracted from fresh fruit. The two pulp oils differ materially in the composition of their respective fatty acid glycerides. The lower titer value and higher iodine value of the pulp oil from *A. totai* indicate a higher content of oleic acid and a lower content of saturated acids as compared with African oilpalm.

The fatty acid composition of the pulp oil of the African oilpalm is rather well known, but only limited compositional data are available with respect to the pulp oil of the mbocayá palm. These data (Table IX) indicate that mbocayá pulp oil is composed of glycerides containing 20% saturated acids and 80% oleic acid, whereas African palm oil is composed of glycerides containing 39 to 50% saturated acids, 38 to 52% oleic acid, and 6 to 10% linoleic acid.

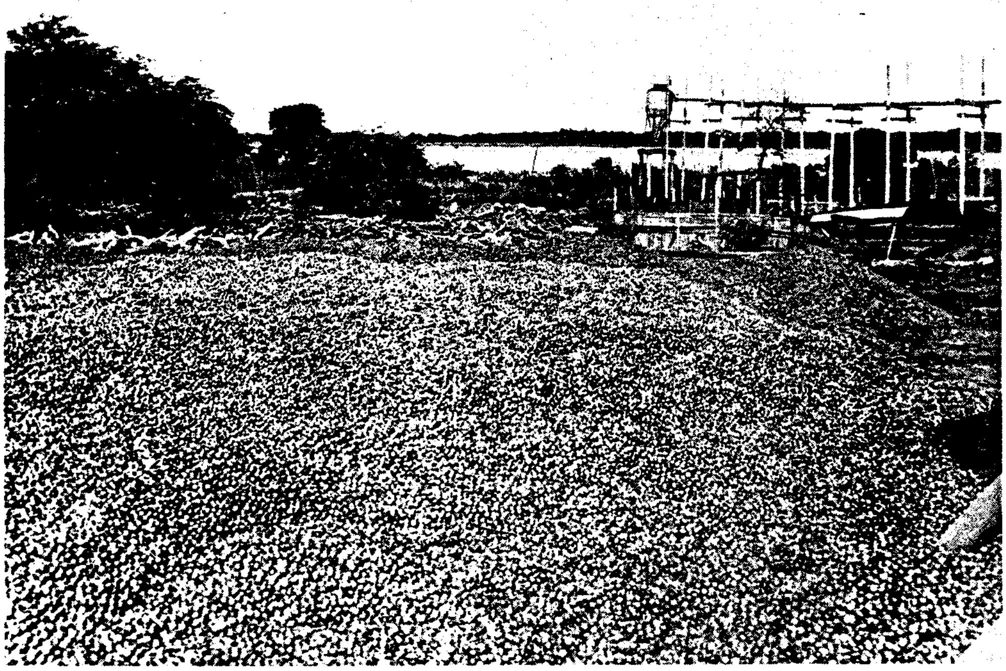

FIG. 8. Mbocayá fruit stored on ground outside of oil mill prior to processing.

**Kernel Oil.** In Table X data are given

TABLE IX

CHARACTERISTICS AND COMPOSITION OF THE PULP OILS OF *A. totai* AND *E. guineensis*

| Characteristic | *A. totai* (14) | *A. totai* (13) | *E. guineensis* [a] |
|---|---|---|---|
| Specific gravity, 40° C. | ..... | 0.9240 | 0.898–0.901 [b] |
| Refractive index, 40° C. | 1.4615 [c] | 1.4582–1.4607 | 1.453–1.456 |
| Titer value, ° C. | ..... | 26.1–33.2 | 40–47 |
| Iodine value | 68.4 | 54.5–66.7 | 44–58 |
| Unsaponifiable matter, % | 0.81 | 0.27–0.55 | < 0.8 |
| Saponification value | 197.0 | 200–209 | 195–205 |
| Free fatty acids, % palmitic | 41.2 | 1–... | [d] |
| Total fatty acids | | | |
| Iodine value | 69.7 | ..... | ..... |
| Thiocyanogen value | 66.6 | ..... | ..... |
| Saturated, % | 20.0 | ..... | 39–50 [e] |
| Oleic, % | 80.0 | ..... | 38–52 [e] |
| Linoleic, % | 0.0 | ..... | 6–10 [e] |

[a] American Oil Chemists' Society Standard for African palm oil.
[b] Measured at 37.8° C.
[c] Measured at 25° C.
[d] Trading in palm oils is based on free fatty acid content. (See text.)
[e] A. E. Bailey, Industrial Oil and Fat Products, 2nd ed., Interscience, New York, 1951, p. 158.

for the more common chemical and physical characteristics of three samples of Paraguayan mbocayá kernel oil (14). Landmann (13) reported a range of properties for this oil which are shown in Table XI, together with those for the better known American palm kernel oils of commerce, and for African palm kernel and coconut oils.

The outstanding difference between the characteristics of mbocayá kernel oil and those of other palm kernel and coconut oils is the higher iodine value and lower melting point of the former. The higher iodine value of mbocayá kernel oil indicates a higher content of oleic acid and a lower content of saturated acids than in the other palm kernel oils. This is reflected also in the lower melting point and titer value. From the compositional data in Table XI it is seen that mbocayá kernel oil is unique among

TABLE X

CHARACTERISTICS AND COMPOSITION OF *A. totai* KERNEL OIL (14)

| Characteristic | Villeta (1943) | | Asunción (1943) |
|---|---|---|---|
| | Crude | Neutralized | Crude, filtered |
| Refractive index (25° C.) | 1.4570 | 1.4579 | 1.4571 |
| Iodine value | 29.2 | 31.3 | 29.8 |
| Thiocyanogen value | 26.9 | 28.1 | 27.9 |
| Saponification value | 243.3 | 241.8 | 242.1 |
| Unsaponifiable, % | 0.40 | 0.32 | 0.38 |
| Hydroxyl No. | 4.9 | 4.2 | 6.5 |
| Color, yellow/red [a] | 70/6.72 | 70/6.12 | 70/20.79 |
| Phosphorus, % | 0.0032 | 0.0006 | 0.0036 |
| Free fatty acids, % oleic | 6.50 | 2.71 | 6.52 |
| Free fatty acids, % palmitic | 5.91 | 2.48 | 5.92 |
| Free fatty acids, % lauric | 4.61 | 1.93 | 4.63 |

[a] Lovibond color units measured in 135-mm. cell.

American palm kernel oils with respect to its content of saturated and oleic acids.

The higher content of oleic acid and lower content of saturated acids strikingly reflect the effect of climate on the composition of the mbocayá oils. All of the kernel oils except mbocayá in Table XI are products of tropical palms, whereas *A. totai* is found abundantly in the South Temperate Zone. In fact, mbocayá is the only species of *Acrocomia* which is indigenous to this climatic zone.

TABLE XI

CHARACTERISTICS OF VARIOUS PALM KERNEL OILS AND COCONUT OIL [a]

| Characteristic | Mbocayá (13) | American palm kernels | | | | | African palm kernel | Coconut |
|---|---|---|---|---|---|---|---|---|
| | | Babassu | Tucum | Murumuru | Ouricurí | Cohune | | |
| Iodine value | 28.0–30.2 | 15.5 | 9–14 | 11.0 | 15.0 | 10–14 | 16–23 | 7.5–10.5 |
| Saponification value | 239–246 | 247.0 | 230–250 | 242.0 | 257.0 | 250–255 | 248.0 | 250–264 |
| Density (60° C.) | 0.915–0.920 [b] | 0.893 | 0.893 | 0.893 | 0.898 | 0.893 | 0.892 | 0.893 |
| Refractive index (60° C.) | 1.451–1.453 [c] | 1.443 | 1.443 | 1.445 | 1.440 | 1.441 | 1.443 | 1.441 |
| Unsaponifiable, % | 0.2–0.4 | 0.2–0.5 | 0.3 | 0.3 | 0.3 | 0.4 | 0.4 | 0.1–0.3 |
| Melting point, ° C. | 20.0–23.0 | 22–26 | 30.0 | 32.0 | 18.0 | 24.0 | 26.0 | 21.8–23 |
| Titer, ° C. | 19.7–21.0 | 23.0 | 27.0 | . . . | . . . | 21.0 | . . . | 20–24 |
| Reichert-Meissl value | 6.2–7.6 | 5–7 | 4.0 | 3.0 | 6.0 | 7.0 | 5–7 | 6–8 |
| Polenske value | 10–14 | 10–12 | 6.0 | . . . | 18.0 | 14.0 | 10–12 | 15–18 |
| Saturated acids, % | 67–68 (14) | 82.5–85.4 | 84.3 | 88.8 | 84.7 | 89.2 | 80.8 | 91.2–91.7 |
| Oleic acid, % | 29–31 (14) | 11.9–16.1 | 13.2 | 10.8 | 13.1 | 9.9 | 18.5 | 5.7–7.5 |
| Linoleic acid, % | 2–4 (15) | 1.4–2.8 | 2.5 | 0.4 | 2.2 | 0.9 | 0.7 | 0–2.6 |

[a] Except for mbocayá kernel oil, data are from A. E. Bailey, Industrial Oil and Fat Products, 2nd ed., Interscience, New York, 1951.
[b] Measured at 20° C.
[c] Measured at 40° C.

## Utilization

**Native Rural.** The mbocayá palm has many uses (1, 19, 22), most of which are not germane to the present report and are mentioned here merely to indicate the importance of this plant in the rural economy of Paraguay. The trunk is used on the farm for the construction of houses, outbuildings and enclosures of various types. The leaflets are fed to oxen and other farm animals, especially during winter (dry season) when the pastures are dry and over-grazed. The leaves are cut close to the trunk of the tree, and the leaflets are stripped from the spiny rachis just beyond the ends of the spines. The leaflets also serve as the source of fiber for cordage of various types, weaving hammocks, mats, bags and fabrics. The flowers are used for decoration, especially at Christmas time, and, according to Bertoni (4), the terminal bud or "cabbage" and base of the involucral leaves are eaten raw in salads.

Although almost all parts of the mbocayá palm are important in the rural economy of Paraguay, it is the fruit that has the greatest value industrially and as a cash crop to the farmer. Like the fruit of most oilpalms in the Western Hemisphere, that of mbocayá was probably utilized by the natives long before the arrival of Europeans. The early settlers no doubt learned of its uses and value from the Guaraní. It has been particularly prized for its sweet pulp which has served as food and feed for man and animals. The aromatic oily pulp is eaten by farm animals and is relished by children and even by their elders. When eaten by humans the tough outer hull of the fruit is removed and the mucilaginous pulp is sucked in the same manner as the mango. The hard inner nut or seed, to which the pulp fibers adhere tenaciously, is often thrown away, but sometimes it is saved and allowed to dry prior to cracking it to remove the inner kernel. Non-ruminant animals suck or chew the fruit to extract the mucilaginous pulp and reject the seed or nut. Ruminants, particularly the ox, beef and dairy cattle, eat the whole fruit and subsequently disgorge the depulped nut during the night or other periods of rest. Occasionally the nut may be passed through the digestive tract and be excreted in the feces. The act of regurgitation or excretion often occurs at some distance from the places where the fruit was ingested, thus providing an effective means of disseminating the plant.

When left undisturbed on the ground the outer hull and pulp of the fruit disintegrate through the action of the elements and attacks by insects and microorganisms, leaving the relatively clean hard nut. The nuts are frequently collected, dried and cracked to release the oil- and protein-rich kernels which are consumed in the home and sold in the markets. The dried nuts can be stored for long periods without deterioration. They are frequently carried by travellers and by workers when employed at considerable distances from their homes.

Recovery of oil from the kernels has been practiced since remote times by the time-honored method of roasting the kernels, grinding them, and boiling the ground meal with water to release the oil which floats to the surface. This practice was followed by aborigines throughout South and Central America wherever oilpalms were prevalent.

**Modern Industrial.** Present-day commercial utilization of mbocayá palm involves recognition of five industrially useful products obtainable from it—pulp oil, kernel oil, kernel meal, kernel cake and extracted pulp. When the fruit was first subjected to commercial exploitation is not known with certainty, but it was not until about 1940 that serious efforts were made to mechanize the processing of the fruit for the two types of oil. The growth of the processing industry can be traced in the figures of Table I. The combined export volume of all mbocayá products in 1949 amounted to 6,188 metric tons.

Kernel Oil. Kernel oil has been used locally in the manufacture of soap for about 50 years, and, according to one report (21), commercial production of it, at least to some degree, was under way as early as 1894. It was known in Europe prior to 1900. A few years previous (17) and a few years later (11), reports were published on the chemistry of the oil. By 1951 production of the oil reached 2,849 metric tons, but in the subsequent two years the output declined as a result of unfavorable weather conditions.

Prior to 1952 the kernel oil was used commercially only for the manufacture of soap, but in that year the oil was refined and marketed for edible use. The excess over domestic consumption was exported, principally to Argentina. In November, 1953, refining of mbocayá oil for edible use was prohibited (10), and the excess over that required by the domestic soap industry was diverted to export. The kernel oil can be refined to produce an edible grade cooking oil. Some efforts have been made to blend it with stearine and soft (yellow) oils to make shortening, but the product leaves much to be desired.

The higher iodine value of mbocayá

kernel oil, or rather the higher content of unsaturated acid glycerides which the iodine value reflects, is advantageous in the culinary use of this oil because it insures that the oil will remain liquid at ordinary atmospheric but not refrigerator temperature. For culinary use careful refining of the oil is essential. The finished oil must be free of traces of soaps and moisture; otherwise slow hydrolysis occurs, with liberation of low-molecular weight fatty acids and development of disagreeable flavors and odors. The higher iodine value, as compared to that of other palm kernel oils, is a disadvantage only in so far as it indicates less oxidative stability (rancidification), especially in the hot months of the year. As a class, palm kernel oils contain little natural antioxidant compared to cottonseed, peanut and other soft or yellow oils.

Although there is great need in Paraguay for protein feeds for livestock, it is only in the past few years that these items have been fed, per se, or in the form of mixed feeds comprising the remaining three mbocayá products, principally to cattle.

Pulp Oil. Commercial production of pulp oil began somewhat later than did that of the kernel oil, and the output of it has not exceeded 1,125 tons in any one year. The oil, which is inferior to that of the kernel, has been used locally for soap, and the excess exported.

Fig. 9. Mbocayá palms in cotton field in Central Zone.

### Economic Importance

It is common belief that when a Paraguayan farmer clears land for agriculture, he carefully preserves the mbocayá palms on it. This is probably true to a degree, especially where the land has been cultivated previously and aban-

FIG. 10. Mbocayá palm recently killed by snout beetles

doned, and has gone back to bush and forest, and therefore contains varying numbers of these palms. More often, however, the mbocayá palm is present in the farmer's fields because it is an exceedingly persistent and extremely difficult plant to eradicate, especially with the implements the farmer has heretofore had at his disposal. Owing to its extensive root system, severing the roots near the surface through cultivation of the land will not destroy it. It withstands fire applied year after year to destroy old crop residues, grass and weeds. It withstands repeated cutting of its leaves for feed for oxen and denudation by leaf-cutting ants and caterpillars.

It is, however, susceptible to a number of natural enemies, and the introduction of the steel plow, disc cultivator and other modern agricultural implements has resulted in a decreased survival of seedlings and to some reduction of the number of palms in the more intensely cultivated fields.

In the past the farmer, especially the small farmer, has not been too interested in controlling the spread of the mbocayá palm, primarily because it has supplied food and feed for his family and livestock, and more recently a cash income through the sale of fruit and kernels for oil milling. He has, however, never considered what the presence of these palms has cost him in loss of productivity of the land in terms of his cultivated crops (Fig. 9).

The mbocayá palm with its efficient root system reaches far from its base for soil nutrients and water which are obtained at the expense of the cultivated crops. Its crown, though less extensive than that of many other trees, nevertheless serves to deprive the cultivated crop of sunshine. The reduced growth and undernourished condition of the crops around the base of each palm is readily observed in almost any field.

Where these crops have little economic value, this loss in potential production may not be important and may be compensated for by the return obtained from the palm. Where the cultivated crop possesses a high economic value, the loss in production may be many times the return gained from the palm.

Besides the soil-depleting effect that

the mbocayá palm has on cultivated farmland, it possesses other hazards to agriculture, such as serving as a host for various insects and microorganisms. The palm is subject to attack by a highly destructive stem borer or snout beetle (*Rhyna barbirostris*), the larvae of which insect, known locally as "mbucú", was reported in 1945 by Molas (16) to attack the mbocayá and pindó palms. Luis S. Alvarez, STICA phytopathologist, noted in 1952 that the borer was prevalent in the vicinity of Caacupé where it had attacked and killed a number of mbocayá palms (Fig. 10). The grubs of the beetle rapidly devour the entire interior of the palm except the long cellulosic fibers (Figs. 11 and 12). The interior becomes filled with a yellowish watery liquid which runs from it in a stream when the dead or dying trunk is incised. The grubs metamorphose to the beetle stage and emerge in large numbers to repeat the cycle in other palms. The activity of these beetles can be detected by the tell-tale holes about a half-inch in diameter along the trunk of the palm.

It has been observed that considerable numbers of mbocayá palms suffer from a leaf-blight apparently caused by a fungus, probably *Phaecophora acrocomiae*, which has been reported to attack *A. sclerocarpa* in Brazil and the yatay palm (*Butia yatay*) in Paraguay. This fungus disease is readily detected by the yellow blotches with black centers which form on the leaves. The fungus appears to spread rapidly, especially at certain seasons of the year. It was observed to be prevalent in the mbocayá palms near Caacupé in the same area where the snout beetle was active. Young trees seem to be more susceptible than older ones. It is not known whether cultivated crops are affected by the same fungus, since no studies appear to have been made of the relation of this palm disease to the leaf-blights which affect the principal field crops of Paraguay.

FIG. 11. Longitudinal section of mbocayá palm showing grubs of snout beetles and destruction produced by them.

There is evidence that the mbocayá palm itself suffers malnutrition which is manifest in many trees in a typical bottle effect of the trunk. So many specimens of mbocayá in the Central Zone exhibited this effect that it appeared superficially to be a species characteristic. The malnutrition results from a variety of causes, including depletion of soil nutrients, severe and prolonged drought, injury through attacks of insects and microorganisms, and fire. It is notable that this characteristic, while evident to various degrees in the intensely cultivated Central Zone, was not observed in the mbocayá palms in the forest around Curuguaty.

FIG. 12. Longitudinal section of mbocayá palm showing complete destruction except for cellulose fibers caused by snout beetles.

The rapid rise of the mbocayá palm-processing industry and the belief that Paraguay possesses untold millions of these palms has attracted considerable capital to the vegetable oil industry. No less than five new factories were erected between 1951 and 1953 to process mbocayá pulp and kernels.

There is a continuing interest in establishing still other mills, although the capacity of the present ones[3] exceeds the supplies of raw material for year-'round operation. The competition for raw materials is resulting in increasingly higher prices being paid to the farmer and in more efficient operation of the mills. It is also forcing the smaller and less efficient mills to discontinue operation.

It seems improbable that the fruit from wild palms can be depended on indefinitely to supply the major portion of raw material of the already over-ex-

[3] In 1953 there was a total of 26 vegetable oil mills in Paraguay.

panded processing industry. To supply sufficient raw material for capacity operation of existing oil mills would require that the mbocayá palm be put under plantation cultivation, that the presently cultivated oilseed crops be expanded or that, new ones be introduced.

Whether the oil-processing industry should continue to depend on spontaneous sources of mbocayá fruit or produce it as a plantation operation is worthy of careful consideration. Since *A. totai* has never been grown even experimentally as a cultivated crop, any discussion of the advantages and disadvantages of such an operation is at best no more than speculation. There are some facts derived from experience with the African oilpalm that are probably applicable to *A. totai.*

In a plantation system the yields of fruit and oil per unit of area can be greatly increased by careful selection of the seed stock, proper cultural practices including spacing pattern, fertilization, pruning, harvesting, etc. In establishing the African oilpalm plantations, selections were made on the basis of the number of bunches of fruit per tree, ratio of pulp to nut, oil content of the pulp, and thickness of the shell of the nut. This program, carried out over many years, raised the production of palm (pulp) oil to more than 3,000 kilos per hectare and kernel oil to more than 300 kilos per hectare.

It does not follow, however, that the same characteristics apply equally in selecting mbocayá seed stock. Respecting African oilpalm, the pulp oil is of primary importance and the kernel oil secondary. At the present stage of development of equipment and methods for processing mbocayá fruit, the kernel oil is more valuable than the pulp oil.

However, it would be desirable to select mbocayá seed stock on a basis of thin hull of the fruit and thin shell of the nut. Minimizing both of these characters would lead to increased ratios of pulp and kernel to the whole fruit. If the oil content of the pulp and kernel could also be increased in the same selections, the total yield of oil per fruit would be appreciably increased.

The proper spacing of mbocayá palms for maximum production of fruit is unknown and would have to be determined by experiment. It is of interest to calculate the theoretical yields of oil per hectare planted with mbocayá palms spaced, four, six, eight and ten meters apart in the row, and rows ten meters apart, and assuming a yield of eight bunches of fruit per tree, 200 fruit per bunch, ten percent pulp oil, and six per-

TABLE XII

CALCULATED YIELD OF OIL PER HECTARE FOR SEVERAL TYPES OF *A. totai* PLANTATIONS

| | | | | |
|---|---|---|---|---|
| Spacing, meters | 10 × 10 | 10 × 8 | 10 × 6 | 10 × 4 |
| Trees per hectare [a] | 100 | 125 [b] | 166 | 250 |
| Bunches of fruit [c] | 800 | 1,000 | 1,328 | 2,000 |
| Number of fruit [d] | 160,000 | 200,000 | 265,600 | 400,000 |
| Weight of fruit [e], kg./ha. | 1,600 | 2,000 | 2,656 | 4,000 |
| Pulp oil [f], kg./ha. | 160 | 200 | 265 | 400 |
| Kernel oil [g], kg./ha. | 96 | 120 | 159 | 240 |
| Pulp and kernel oil, kg./ha. | 256 | 320 | 424 | 640 |

[a] One hectare equals 2.47 acres.
[b] Approximate planting rate for African oilpalm.
[c] Assuming bunches per tree per year.
[d] Assuming 200 fruit per bunch.
[e] Assuming average weight of air-dry fruit is 10 grams.
[f] Assuming pulp oil in air-dry fruit is 10%.
[g] Assuming kernel oil in air-dry fruit is 6%.

cent kernel oil per air-dry fruit. In doing so it should be borne in mind that the number of bunches per tree and of fruit per bunch would probably be affected by the spacing, that is, either the number of bunches per tree or the number of fruit per bunch, or both might increase as the spacing distance increased.

The calculated data are given in Table XII. The combined yield of pulp and kernel oil per hectare for spacings of 10 × 10, 10 × 8, 10 × 6, and 10 × 4 meters are 256, 320, 424 and 640 kilograms, respectively. These figures are not impressive when compared to total yields of pulp and kernel oils of 3,570 kilograms per hectare reported by Cramer (8) from African oilpalm plantations in North Sumatra. If, however, they are compared with the figures in Table XIII it is seen that, for spacings of 10 × 6 and 10 × 4 meters, the calculated production of oil per hectare is greater than the average factory yields from any non-tree oilseed. Planted at spacings of 10 × 8 meters, the calculated production of oil per hectare is greater than the average factory yields for any non-tree oilseed except sesame and sunflower.

Admittedly the calculated figures in Table XII are based on two arbitrary assumptions, namely, production of eight bunches of fruit per tree and 200 fruit per bunch. *A. totai* palms have been observed with up to 17 bunches of fruit per tree and with more than 500 fruits per bunch. It is conceivable, therefore, that the figures in Table XII might be increased considerably through selection of high-yielding seed stock and good cultural practices.

TABLE XIII

AVERAGE FACTORY YIELDS OF OIL FROM VARIOUS OILSEEDS

| Oilseed | Oil, kg./ha. |
|---|---|
| Palm and palm kernel [a] | 2,790 |
| Coconut (copra) [b] | 818 |
| Sesame [c] | 420 |
| Rapeseed (colza) [d] | 392 |
| Sunflower [e] | 308 |
| Peanuts [f] | 230 |
| Flaxseed [f] | 193 |
| Soybeans [f] | 190 |

[a] Netherland Indies, 1936.
[b] Philippine Islands, 1932.
[c] Nicaragua, 1947.
[d] France, 1930–39 average.
[e] France, 1946–47 average.
[f] United States, 1937–46 average.

One advantage of a palm plantation over the same area planted with an annual oilseed crop is that the former, once established, would require much less labor per year to produce a crop. During the first three or four years the palms could be interplanted with market type legumes, such as beans or peas, and later with pasture types for green manure or grazing. These practices would tend to maintain the fertility of the soil, conserve moisture and provide additional revenue.

A further advantage of plantation production of *A. totai* is that the oil mill can be centrally located with respect to the plantings, thus reducing the cost of transportation of the fruit to a minimum. African oilpalm fruit is processed on the plantation, establishment of such processing facilities being necessitated by the perishable nature of the fruit.

The principal disadvantage in the plantation system is the capital investment required to establish it. Establishment of African oilpalm plantations is even more costly, but once in operation, the cost per unit of oil produced in terms of human labor is the lowest of any oilseed crop (8).

## Bibliography

1. Anon. El Cocotero O Mbokayá. Dirección de Tierras y Colonias (Paraguay), Informaciónes para los Agricultores. pp. 10–11, 1923.
2. Aranda, Santiago. El Cocotero o "Mbocayá". *Acrocomia totai* Mart. Revista de Agricultura y Ganadería (Asunción) 1(5): 32–35. 1938.

3. Bailey, L. H. Acrocomia—Preliminary paper. Gentes Herbarum IV (Fasc. XII): 452–461. 1941.
4. Bertoni, Guillermo T. El Mbocayá o Coco del Paraguay (*Acrocomia totai* Mart.). Revista de Agricultura (Asunción) **1:** 36–50. 1941.
5. Bomhard, Miriam L. What palms grow in Louisiana. Louisiana Conservation Review, Winter 1938–39.
6. Bray, G. T., and Elliot, F. L. Some new oil-seeds derived from American palms. Analyst **41:** 298–302. 1916.
7. Covas, G., and Ragonese, G. Las palmeras argentinas del genero "Acrocomia". Ministerio de Instrucción Publica y Fomento Provincia de Santa Fé, Instituto Experimental, de Investigación y Fomento Agrícola-Ganaderia Pub. Tec. No. 27. pp. 12–14, 1941.
8. Cramer, P. J. S. A comparison between oilpalms and coconuts. Landbouwkundig Tijdschrift **52:** 427–448. 1950.
9. Espinosa, S., Arístides, B., and Mendaro, Ernesto. La Exploitación de Cocoteros en el Paraguay. Ministerio de Agricultura y Ganadería (Asunción). pp. 68, 1952.
10. Gorostiaga, J. Bernardino. Ministerio de Industria y Comercio (Asunción) Resolución No. 517. November 19, 1953.
11. Grimme, C. Ueber einige seltene Oelfruchte. Chem. Revue **7:** 156–157. 1907.
12. Junelle, Henri. Les Palmiers à huiles d'Amérique. Les Matieres Grasses. **12:** 5507–5510. 1920.
13. Landmann, Werner. Die Paraguay—Cocopalme. Seifen-Ole-Fette-Wasche **77:** 403–404. 1951.
14. Markley, Klare S. El Aceite de Coco. Ministerio de Agricultura y Ganadería, Asunción, STICA Bol. No. 114. pp. 36, 1952.
15. ———. La Palma "Mbocayá". *Idem.* STICA Bol. No. 162. pp. 20, 1953.
16. Molas, Jerónimo. Revista de la Facultad de Química y Farmacia de Asunción **1:** 36–55. 1945.
17. Negri, G. de, and Fabris, G. Sull'olio de Mocayá del Paraguay. Giorn. farm. Trieste No. 12: 359–361. 1896. (Abst. Chemische Revue. No. 6: 82. 1897).
18. Nogueira, J. Bondar, and Machado, Raul D. Glossário Palmeiras Oleaginosas e Ceríferas. Instituto de Òleos, Ministério da Agricultura, Rio de Janeiro. pp. 37, 1950.
19. Ortiz, Gregorio. El Mbocayá. Ministério de Economia, Cartilla Agro-Pecuaria (Asunción) No. 10–11: 11–15. 1939.
20. Peterson, Lyall E. Vegetable oils in Paraguay. STICA Commodity Report No. 2 rev. (Asunción). 1945.
21. ———. Aceite de Coco en el Paraguay. STICA Special Report No. 3 rev. (Asunción). pp. 25, 1945.
22. Range, Federico H. Las grandes riquezas inexplotadas del Paraguay (Investigaciónes y Estudios)—El Coco o Mbocayá. Revista Agropecuaria (Asunción) 2(2): 40–43. 1930.

## Book Reviews

**Indian Corn in Old America.** Paul Weatherwax. xii + 253 pages. Macmillan Co. 1954. $7.50.

A truly great heritage that modern America, and other parts of the world to a smaller degree, acquired from the aborigines of the New World is corn. Out of the thousands of variations in this extremely mutable plant that very likely existed countless generations ago, the American Indians, especially in the highlands of Peru but also elsewhere, selected and thus preserved for posterity certain more valuable forms. Had it not been for their intervention, modern man might not have corn at all, for the plant cannot exist in the wild without care and cultivation, and the potentially valuable variations among countless useless ones that may have existed at one time might have been lost forever. What was the original plant like and where did it grow? These two questions have plagued botanical science for more than five centuries, and have been the particular concern of a few botanists who have sought the answer. One of these botanists has been Professor Weatherwax of Indiana University, and in this admirably written book he has presented, among many other aspects of corn, a very objective evaluation of the various hypotheses that have been advanced toward answering these two queries.

When the New World was first explored

(*Continued on p. 37*)