FIBER PRODUCTION IN THE WESTERN HEMISPHERE

By

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INTRODUCTION

Cotton and flax, obtained from plants, and wool and silk, of animal origin, are known to nearly everyone, but there are many other fibers, important in commerce for special uses or used locally, that are not so widely known. This publication[3] treats of plant fibers other than cotton and flax that are now produced commercially in the Western Hemisphere and includes brief notes about others produced on a smaller scale. More than a thousand species of American plants have yielded fibers of local uses, but only a small number yield fibers that actually enter commerce. The native production of fibers by laborious hand methods for local use is decreasing, as roads and traffic into hitherto isolated places are bringing in machine-made twines, ropes, and fabrics.

[1] Retired in 1935.

[2] The Division of Fiber Plant Investigations was merged in 1934 with the Division of Cotton and Other Fiber Crops and Diseases.

[3] The illustrations in this publication are from cuts lent through the courtesy of the Pan American Union and made from photographs furnished by the Pan American Union and the United States Department of Agriculture.

CLASSIFICATION OF PLANT FIBERS

Nearly all plant fibers are readily classified by their structure and their origin in different parts of the plant into the following groups:

1. *Long or multiple-celled fibers:*
   - (*a*) Hard or leaf fibers; hard and stiff in texture, extending lengthwise through the pulpy tissues of long leaves or leaf stems of monocotyledonous or endogenous (ingrowing) plants: Henequen, sisal, piteira, fique, yucca, pita floja, and abacá, and the palm fibers, treated in this publication as a separate group. (See p. 4.)
   - (*b*) Soft or bast fibers; soft and flexible in texture, extending through the inner bark of stems or main stalks of dicotyledonous or exogenous (outgrowing) plants: Hemp, cadillo, jute, and ramie.
2. *Short or one-celled fibers.*—Seed hairs or hairs produced inside seed pods: Kapok, pochote, samohu.
3. *Miscellaneous fibers.* Roots and stems: Broomroot and treebeard.

Note.—For Spanish edition of this material see: Dewey, Lyster H. Fibras vegetales y su producción en América. Translated by Maria A. Ruisánchez Masters. Unión Panamericana, Oficina de Cooperación Agrícola Pub. Agric. Nos. 137–140, 101 pp., illus. Washington, 1941.

GENERAL OBSERVATIONS ON HARD AND SOFT FIBERS

The plants yielding hard fibers, such as henequen, sisal, abacá, piteira, and the various palms, are almost exclusively tropical, whereas, of those yielding soft fibers, some, like flax and hemp, grow best in the cooler regions of the Temperate Zone, and others, like jute and ramie, in the warmer parts of the Temperate Zone. The only important hard fibers produced outside the Tropics are phormium, in New Zealand, and the istles, in northern Mexico. None of the soft fibers are produced commercially in the Tropics.

In the Old World the records indicate that the soft fibers flax and hemp were the first produced, flax at least as long ago as 3000 B. C., in central Europe and in Egypt, and hemp at about the same time in northern China. In the New World, henequen and sisal in the Yucatán Peninsula, and other hard fibers from the leaves of agaves, furcraeas, yuccas, and bromelias appear to have been the earliest used. The Western Hemisphere has contributed to the world's fiber production all hard-fiber plants, except abacá and phormium; these include henequen, sisal, cantala, piteira, and others less important commercially. However, none of the important soft-fiber plants are native to America.

Hard fibers are separated by mechanical processes directly from the pulpy tissues of the freshly cut green leaves; they are then dried and baled for shipment. In some places the leaves are rotted in water so that the pulp may be scraped away more easily, but this method produces fiber of inferior quality. Soft fibers surrounded by pectic gums as well as thin-walled tissues in the inner bark of the stems are separated from these materials after the tissues and gums have been broken down by retting. Retting is a biological process, and in actual practice the retting, or rotting, is effected by certain groups of bacteria that are always present. After the outer bark and tissues surrounding the soft fibers have been disintegrated by retting, the fibers themselves must be separated and cleaned by mechanical processes. The processes of beating and scraping, to separate fibers from stalks of hemp, cadillo, and similar plants after they have been retted, are called scutching.

Numerous machines have been devised for separating soft fibers from stalks without retting. This process is called decortication. The soft fibers thus prepared must afterward be treated chemically or retted to reduce the gums and other substances that are subject to fermentation and cause trouble even after the fibers have been spun into yarns. During the past 75 years a great deal of research has been devoted to the production of bast fibers by means of decortication and subsequent chemical treatment. Much progress has been made, especially in recent years, but thus far these processes have not fully passed the experimental stages.

Hard fibers are used chiefly for coarse twines and for cordage. Soft fibers are used for finer twines, for thread, and for yarns to be woven into fabrics.

NAMES OF FIBERS AND FIBER PLANTS

The confusion of names used to designate fibers and fiber-producing plants often causes uncertainty and sometimes financial loss. The same common name is often used to designate different kinds of fibers, and different names are used to designate the same fiber or fiber-producing plant. The name "maguey" is used in many parts of Mexico, Central America, and the West Indies to designate nearly all of the larger leaved species of *Agave* and *Furcraea*, and this use has extended to the Philippine Islands, where an *Agave* species introduced from Mexico has become an important fiber-producing plant. In Yucatán the name "maguey" is rarely used, but the name "henequen" is applied not only to the *Agave* species cultivated there for fiber production but also to species of *Agave* and *Furcraea* that do not yield fibers of any value. The word "pita," of Carib origin, is used in many localities from Brazil to northern Mexico to designate so many different kinds of fibers and fiber plants that it is almost synonymous with the English word "fiber." Likewise the word "cabuya," also spelled "cabulla," is used from Costa Rica to Ecuador to designate several different species of *Furcraea*. From La Plata Valley to the Amazon the words "samohu" and "sumauma," with numerous local derivatives, are used to designate the flossy kapoklike fibers from nearly a score of different trees belonging to the genera *Chorisia* and *Ceiba*. The word "malva" is used for many different fibers from plants of the mallow family, but the "malva blanca" of Cuba, which has received the most attention in the press, is quite different from the malva blanca described in text books.

The confusion of names is not confined to the areas of production; it also extends to the fiber markets and to the statistics published by governments. The name "sisal" is commonly applied to several different hard fibers similar to the true sisal. Generally geographic names indicating the origin of the fiber, as "Java sisal," "African sisal," or "Mexican sisal," suggest the kind of fiber only to one who knows which kind is produced in each locality. The word "hemp" is also very much overworked to designate numerous long fibers as well as the true hemp to which it was first applied.

In this publication an effort has been made to give distinctive common names for each different kind of fiber. In all cases these names were chosen from among those that have been actually used; no new names were coined. The names most commonly used were preferred, provided they are distinctive, correct in accordance with the facts, and do not include a geographic name. It seems rather absurd to call a plant (toquilla) a "Panama hat palm," when it is known that the plant is not a palm and the hats are not made in Panama, or to call a fiber (abacá) "Manila hemp," when it is not produced near Manila and is not hemp.

The botanical name, with its author, is given for each plant, for these names are recognized by botanists in all countries. A few of the botanical synonyms most commonly used are given, but no attempt is made to give a complete list of synonyms.

It is known that many plant fibers not mentioned here are produced in the Western Hemisphere, but generally in very small quantities, for local use only. The following list gives the names of the fibers or fiber plants, classified by groups, in the order in which they are treated in this publication.

LIST OF FIBERS OR FIBER PLANTS

Fiber or Plant	Botanical Name
Long or multiple-celled fibers	
Hard fibers:	
Henequen	*Agave fourcroydes*
Sisal	*Agave sisalana*
Letona	*Agave letonae*
Mezcal	*Agave tequilana*
Zapupe	*Agave zapupe*
Cantala	*Agave cantala*
Lechuguilla	*Agave lecheguilla*
Jaumave lechuguilla	*Agave funkiana*
Piteira	*Furcraea gigantea*
Cabuya	*Furcraea cabuya*
Fique	*Furcraea macrophylla*
Chuchao	*Furcraea andina*
Cocuiza	*Furcraea humboldtiana*
Pitre	*Furcraea hexapetala*
Common yucca	*Yucca filamentosa*
Soapweed yucca	*Yucca glauca*
Palmilla	*Yucca elata*
Banana yucca	*Yucca baccata*
Mohave yucca	*Yucca mohavensis*
Palma pita	*Yucca treculeana*
Palma barreta	*Samuela carnerosana*
Zamandoque	*Hesperaloe funifera*
Chaparral yucca	*Hesperoyucca whipplei*
Pita floja	*Aechmea magdalenae*
Phormium	*Phormium tenax*
Abacá	*Musa textilis*
Palm and palmlike fibers:	
Bahia piassava	*Attalea funifera*
Pará piassava	*Leopoldinia piassaba*
Cabbage palmetto	*Sabal palmetto*
Scrub palmetto	*Sabal etonia*
Corojo palm	*Acrocomia crispa*
Yaray	*Sabal causiarum*
Toquilla	*Carludovica palmata*
Soft fibers:	
Hemp	*Cannabis sativa*
Cadillo	*Urena lobata*
Jute	*Corchorus* spp.
Ramie	*Boehmeria nivea*
Short or one-celled fibers	
Kapok	*Ceiba pentandra*
Pochote	*Ceiba aesculifolia*
Northern pochote	*Ceiba acuminata*
Palo borracho	*Chorisia insignia*
Samohu	*Chorisia speciosa*
Miscellaneous fibers	
Broomroot	*Muhlenbergia macroura*
Treebeard	*Tillandsia usneoides*

LONG OR MULTIPLE-CELLED FIBERS

Hard or Leaf Fibers

The name *Agave*, derived from a Greek word meaning "noble," was used by Linnaeus, in 1753, to designate a group of plants which now includes henequen and sisal, the most important fiber-producing plants of American origin. The agaves have fleshy leaves, usually long and narrow, in rosettes. The leaves of most species have hooked prickles on the margins, and nearly all have well-developed terminal spines. They are often miscalled "cactus" because of the prickles and spines, but they are not related to the cactus family. Most of the yellow tubelike *Agave* flowers are erect in dense clusters at the ends of branches of the tall flower stalks. However, in one section of the genus, including the lechuguillas, the flowers are crowded in slender spikes. All agaves are native to America.

HENEQUEN

(Amaryllis family)

Agave fourcroydes Lemaire.

Agave rigida Auct. Amer., not Mill.

Agave rigida elongata Baker.

In Yucatán, the Maya name for henequen was "sacci" (sak-chee). In Cuba the plant is called henequen or sisal, and in East Africa sisal weisz, or white sisal. In the markets of the United States the fiber is called Mexican sisal or Cuban sisal, but in the London fiber market it is called henequen.

A well-developed, mature henequen plant (fig. 1) has 50 to 100 gray leaves, or as many as 200 before any have been cut. The leaves are 3 to 6 feet (100 to 200 cm.) long and 4 to 6 inches (10 to 15 cm.) wide, $1\frac{1}{2}$ to $2\frac{1}{4}$ inches (3.5 to 5.5 cm.) in vertical diameter at the base, with prickles $\frac{1}{8}$ to $\frac{1}{5}$ inch (3 to 5 mm.) long, hooked either up or down and $\frac{3}{8}$ to $1\frac{1}{8}$ inches (10 to 30 mm.) apart on the margins. The terminal spine is about 1 inch (25 mm.) long, $\frac{3}{16}$ to $\frac{5}{16}$ inch (5 to 7 mm.) thick, flattened or grooved on the face, and nearly black or sometimes gray in age. The young plant consists of a small rosette of leaves rising from the ground, and as it grows older the lower older leaves decay or in cultivated plantations they are cut off and a trunk is developed 3 to $5\frac{1}{2}$ feet (100 to 175 cm.) high.

The point of growth, as in all agaves, is at the base of the leaves in the central bud. The leaves growing at the base are actually pushed up inside of the spindle-shaped bud, attaining their full length in the bud as the preceding leaves split away and lean outward.

The leaves contain about 90 percent moisture, but the fleshy pulp is very firm and the leaves are rigid. The fibers extend lengthwise through the leaves, being most abundant near the upper and lower surfaces.

Henequen plants live 10 to 20 years or even longer. They are monocarpic, that is, they produce flowers but once and then die. Many die without flowering. The flower stalk, or "pole," grows up through the center of the bud to a height of 15 to 25 feet (5 to 8 m.), with rather stout, nearly horizontal branches bearing at their forked ends erect clusters of light-yellow flowers. The flowers are followed by either seed pods or bulbils, or sometimes by both in the same cluster (fig. 2). Suckers grow up from the rootstocks of the plant each year (fig. 1).

FIGURE 1.—Henequen plant 10 years old, from which seven crops of leaves have been cut. Suckers large enough to be transplanted. Cárdenas, Cuba.

The henequen plant was originally native to the Yucatán Peninsula, but it is now found only in cultivated plantations or as an escape from cultivation. In Mexico, about 440,000 acres (175,000 hectares) of henequen are cultivated in the States of Yucatán and Campeche and about 5,000 acres (2,000 hectares) outside the Yucatán Peninsula; in the West Indies, Cuba has about half a dozen large plantations of henequen, comprising about 33,000 acres (13,000 hectares) (fig. 3), this being the only country outside of Mexico where henequen fiber is produced in large quantities. There are small plantations in Jamaica, and a few plants are grown in Tanganyika and Mozambique, in East Africa. Elsewhere the henequen plant is rarely found, even in botanical gardens.

FIGURE 2.—Henequen plants "polling"; pole at right in flower, in center bearing bulbils, and at left bulbils mostly fallen. Habana, Cuba.

Henequen is a tropical plant and requires a dry tropical climate. The average annual rainfall at Mérida, Yucatán, is about 30 inches (750 mm.) and the temperature ranges between 50° and 100° F., rarely falling below 60°. All of the henequen plantations are within the Tropics. Those near Victoria, in Tamaulipas, are almost on the Tropic of Cancer, where there are light frosts of short duration nearly every winter. In the parts of Cuba where henequen is grown, there is an annual rainfall of 40 to 50 inches (1,000 to 1,200 mm.), but the conditions are generally arid and the ground dries quickly after a rain. Henequen endures dry conditions better than most other plants, but in a prolonged drought the leaves become leathery, making it impossible to clean the fiber properly. Clear sunshine is required to dry the fiber well. Harvesting is usually discontinued during the rainy season because of difficulty in drying the fiber.

Henequen requires a well-drained soil, preferably of limestone formation. In Yucatán many of the plantations are on porous lime rock too hard to be plowed or cultivated. Most of the plantations in Cuba are on clay loam soils with many limestone outcrops. Henequen plants sometimes grow well in sandy soils containing abundant sea shells, but they do not grow well in sand without shells or lime. Henequen will not grow well in a compact or water-soaked soil, for the roots require air.

As henequen fiber is now produced, an area of at least 1,250 acres (500 hectares) of the plants is required for profitable operation. There is a tendency to use larger and more efficient fiber-cleaning machinery, requiring still larger numbers of leaves for continuous operation. The land must be fairly level so as to permit easy transportation of the leaves from the field to the cleaning machine.

Henequen plants grow best in full sunlight. All trees, bushes, and other vegetation must be cleared off. Vines that may twine around the buds and prevent the leaves from spreading should be exterminated before henequen is planted. The land is laid out in convenient units, usually 1,000 mecates (about 100 acres or 40 hectares) in Yucatán, or caballerias (about 21 acres or 14 hectares) in Cuba. The size of units and number of plants per unit are the basis of all field labor and estimates of production. Roads for carts or plantation railways are laid out from the central fiber-cleaning mill to all parts

FIGURE 3.—Field of henequen. Plants, nearly 3 years old with leaves 20 to 40 inches long, grown from suckers (hijos) and photographed about a year before the first crop of leaves may be harvested. Matanzas, Cuba.

of the plantation. The transportation of about 100 pounds (45 kilos) of leaves for every 3 pounds ($1\frac{1}{4}$ kilos) of fiber is an important item.

Henequen plants may be propagated from seeds, bulbils, or suckers. As plants grown from seeds are less uniform than those grown from bulbils or suckers, seeds are used only in experiments. Bulbils have to be cultivated in a nursery 1 or 2 years before they are set out in the field. They serve best where it is necessary to transport them long distances to start plantations in new areas. In actual practice suckers are used almost exclusively.

The suckers, called hijos, are dug out when 16 to 24 inches (40 to 60 cm.) high. The roots and nearly all of the leaves are trimmed off (fig. 4). They are then planted in rows about 10 feet (4 varas or about 3.3 m.) apart and 4 feet ($1\frac{1}{2}$ varas or about 1.25 m.) apart in the row, making 96 plants per mecate or about 960 per acre (2,400 per hectare). Sometimes the plants are set out in pairs of rows closer together, with wider spaces left between the pairs of rows through which to carry the leaves out to the roads. In rocky land it is often necessary to make holes with a pick and then prop up the suckers with stones.

FIGURE 4.—Henequen suckers trimmed and ready for planting. Cárdenas, Cuba.

The suckers are usually set out at the beginning of the rainy season, so as to have sufficient moisture for development of the roots. The young plants must be looked over at intervals of about 10 days, and especially after storms, so that missing ones may be replaced and any that have been blown down straightened up. After the plants have become firmly rooted they will withstand winds and tropical storms better than most other tropical crops.

In most henequen plantations in Yucatán the land is too rocky to permit the use of large cultivating tools. Weeds, grasses, and bushes are cut with machetes. Perennial bushes and twining vines are exterminated as completely as possible. Cultivators are used to some extent in Cuba, but weeds close around the plants must be cleared by hand. It is usually necessary to clear out weeds and other vegetation two to four times each year, or more frequently in regions of greater rainfall, until the first harvest of leaves. Afterward the weeds are cut at the time of each harvest.

Henequen is not irrigated, and fertilizers are not regularly applied. Well-rotted bagasse, or waste from cleaning the fiber, is sometimes spread on the fields. Low leguminous annuals, like Japan clover, may be grown between the rows to add nitrogen to the soil and to aid in keeping down weeds.

The sisal weevil, *Scyphophorus acupunctatus* Gyll., which bores into the bud, and black rot, *Colletotrichum agaves* Cav., a fungus that attacks the leaves, especially after they have been punctured by scale insects, are the most destructive pests on henequen plants. The scale insect *Pseudischnaspis bowreyi* Ckll. is often abundant on henequen leaves in the dry season, but it disappears in the rainy season, causing little injury except that its punctures permit the entrance of black rot and other fungi.

In the arid climate of Yucatán the first crop of henequen leaves for fiber production is cut in the sixth or seventh year. Successive crops are cut about twice a year for periods of 10 to 20 years, or until the plants cease to yield good leaves. In Cuba, with a heavier rainfall, the plants grow more rapidly, and the first crop is cut usually in the fourth year and afterward about every 6 months for a period of 10 to 15 years. At the first harvest all leaves are taken, up to those leaning out at an angle of about 45°, and afterward about 2 tiers around the plant (fig. 5). The leaves are cut one at a time by hand, usually with an ordinary butcher knife. Curved knives with longer handles have been made for this work, but the butcher knives are cheaper. The terminal spine and marginal prickles are trimmed off, and the leaves are tied in bundles of 25 or 50. One man with two assistants will cut, trim, count, tie in bundles, and carry to the roadway 3,000 to 4,000 leaves a day.

The bundles of henequen leaves are brought from the fields by cart, truck, or plantation railway directly to the cleaning machines. The fiber is usually cleaned within 24 hours of the time the leaves are cut, as the work of cleaning is easier and more efficient if done before the leaves have begun to dry. The epidermis, or skin, of the leaves prevents them from drying rapidly, but if the leaves become leathery it is impossible to clean the fiber properly.

The machines used for cleaning the fiber obtained from henequen and sisal leaves are the most efficient devised thus far for separating plant fibers from the surrounding tissues. With henequen, sisal, and similar leaves, the work consists of crushing, beating, and scraping away the pulp. This was done

FIGURE 5.—Harvesting henequen leaves; usually 2 tiers (about 16 leaves) are cut from each plant. Acanceh, Yucatán, Mexico.

first by hand methods, then by a raspador consisting of a large revolving drum with lugs on its periphery and a plate with a curved apron separated by about the thickness of a fiber from the rapidly moving lugs. The leaves were held by hand, first one end and then the other, against the revolving drum. Sr. Manuel Prieto, of Yucatán, put two raspadors together and arranged a pair of chains that grasped the leaves near the middle and carried them sidewise past the first drum, cleaning the fiber from the basal end of the leaf. Then a second pair of chains grasped the cleaned fiber, carrying the upper part of the leaf past the second drum. The fiber, clean and straight, came out sidewise, ready to be dried in the sun and then baled for shipment. Numerous improvements have been made in these machines until now machines in actual operation clean as many as 20,000 leaves an hour, delivering 800 to 1,000 pounds of perfectly cleaned fiber. It requires the leaves from 10,000 to 15,000 plants to keep one of these machines in operation during an 8-hour day. In many machines a jet of water plays on the fiber as it passes the drums. This aids in washing away the loosened pulp and also in washing the waste from the machine. The disposal of the waste, constituting about 97 percent of the weight of the leaves, is an important problem. About 90 percent of the green weight of the leaf is moisture, and the waste, or bagasse, as it leaves the machine, is very wet and heavy. The solid material is chiefly cellulose, but it contains too much silica to be used by present methods in the manufacture of paper. It contains some lime, potash, and other fertilizing elements, and in some places it is returned to the field for fertilizer, but its acidity detracts from its fertilizing value. Repeated efforts have been made to use it in the production of alcohol, but its sugar content is too low for it to be used profitably for this purpose. Owing to its irregular consistency and disagreeable odor, it is not suitable for upholstery tow. In some places the waste is piled in great heaps and burned when dry; sometimes it is pitched over cliffs, and sometimes into rivers, which carry it out to sea.

The wet fiber coming from the machine is carried directly to the drying yards and hung on poles or galvanized wire. The yards are usually paved to keep the fiber clean and free from dust (fig. 6). In dry weather the fiber dries in 2 days or less. The work of cleaning is usually discontinued in the rainy season. After poorly cleaned or discolored wisps of fiber are discarded, the clean dry fiber is gathered up from the drying racks. It is sorted into two or three grades by length, color, and cleanness, and baled for shipment (fig. 7). It is important that the fiber be placed as straight as possible in the bale, or with only the tips bent over. If a hank is bent near the middle and so packed, the bend will be retained, making the material more difficult to handle and causing waste and loss in the spinning mill. A standard bale is supposed to weigh 375 pounds (about 170 kilos), but the various baling presses on different plantations make bales ranging from 275 to 575 pounds (130 to 260 kilos). Therefore statistics based on the number of bales are not very satisfactory.

Henequen fiber consists of reddish-yellow to nearly white strands 2 to 5 feet (60 to 160 cm.) in length and $\frac{1}{200}$

FIGURE 6.—Henequen fiber drying in clean paved yard. Yucatán, Mexico.

FIGURE 7.—Henequen fiber in bales, entering the dock for shipment from Progreso, Yucatán, Mexico.

to 1/50 inch (1/8 to 1/2 mm.) in diameter, coarser at the base, angular or nearly cylindrical. Each strand is composed of one or usually more fibrovascular bundles, and these in turn are composed of many elongated thick-walled cells 6/100 to 8/100 inch (1.5 to 4 mm.) long and 20μ to 30μ in diameter, or with a mean ratio of length to diameter of about 100. The ends of these ultimate cells as viewed under a microscope are rather blunt. Tests for strength, in which the average breaking strain per strand is divided by the average weight per meter of the strands tested, show henequen fiber from Yucatán has an average breaking strain of about 20.000 gm. per gram-meter.

Henequen is used chiefly in the manufacture of binder twine for tying sheaves of wheat, oats, rice, and other small grain into bundles as they are harvested. Binder twine made of henequen is mostly 500 feet per pound (330 m. per kilo). It is also made into other hard-fiber twines and ropes up to 1 inch (25 mm.) in diameter. In Mexico it is softened and spun into yarns that are woven into sacking. It is also used in coarse rugs.

The production of henequen fiber is confined almost exclusively to the Yucatán Peninsula and Cuba, with relatively small quantities produced in Mexico outside of Yucatán and in Jamaica. Accurate statistics of production are difficult to obtain, because increasing quantities are consumed in the cordage mills in Cuba and Yucatán, and these quantities do not enter into the statistics of exports. The production of henequen fiber from 1930 to 1939, inclusive, is estimated as follows:

Year	*Metric tons*	*Year*	*Metric tons*
1930	108,600	1935	96,000
1931	76,300	1936	102,000
1932	94,000	1937	107,000
1933	99,000	1938	91,000
1934	102,000	1939	95,000

The principal market for henequen fiber is in the United States, but in recent years considerable quantities have been shipped to Europe. It is quoted in the fiber markets of the United States under the name "Mexican sisal" or rarely "Yucatán sisal." Henequen from Cuba is not quoted separately. The maximum and minimum quotations in New York from 1930 to 1937 were as follows:

Year	*Cents per pound* *Maximum*	*Minimum*
1930	8¼	4½
1931	4¾	2⅜
1932	2½	2¼
1933	3¾	2½
1934	3⅞	3
1935	6⅛	2¾
1936	6⅜	6⅛
1937	6	5⅞

The demand is governed largely by the condition of the grain crops that affect the demand for binder twine.

SISAL

(AMARYLLIS FAMILY)

Agave sisalana Perrine.

Agave rigida sisalana Engelm.

Both sisal and henequen were incorrectly referred to *Agave rigida* by botanists who had never seen the plants growing in the Tropics, and even in present-day literature sisal is often called *Agave rigida sisalana.* The name "sisal" is from the old seaport, Sisal, in Yucatán, from which the fiber was formerly shipped. The Mayas of Yucatán called the plant and its fiber yacci (yak-chee). Outside of the Yu-

FIGURE 8.—Well-developed 5-year-old sisal plants with leaves about 5 feet (150 cm.) long; plant on left with flower stalk. Mayagüez, P. R.

catán Peninsula it is generally called sisal, or sometimes green sisal to distinguish it from the gray-leaved henequen. The fiber produced in different regions is called Bahama sisal, African sisal, Java sisal, and Haitian sisal.

A well-developed sisal plant (fig. 8) has 75 to 150 dark-green leaves, 30 to 60 inches (75 to 150 cm.) long and 4 to 6 inches (10 to 15 cm.) wide, with smooth margins or very small marginal prickles. The terminal spine is $\frac{4}{5}$ to 1 inch (20 to 25 cm.) long and $\frac{4}{25}$ to $\frac{5}{15}$ inch (4 to 5 mm.) thick, slightly notched at the base and dark chestnut in color. The base of the leaves is rarely more than $1\frac{3}{8}$ inches (4 cm.) in vertical diameter. The leaves grow from the base in the bud in the same manner as those of henequen. Sisal is shorter lived than henequen and rarely develops a trunk more than 40 inches or 1 m. high. When the plant is 5 to 10 years old a flower stalk grows up through the bud, attaining a height of 10 to 25 feet (3 to 7 m.) (fig. 9) with rather slender ascending branches, bearing at their forked ends erect clusters of yellow flowers. The flowers are followed by bulbils, but not by seed pods under normal conditions. The plants die after flowering. If the flower stalks are cut out as soon as they appear, the leaves surrounding the stalk in the bud may develop so as to yield fiber, instead of shriveling, as they otherwise would, but the life of the plant is not prolonged.

Sisal originated in the Yucatán Peninsula and is still cultivated to a

FIGURE 9.—Sisal plant in flower, with buds on the upper branches. Snead Island, Fla.

limited extent in Campeche and in some parts of the State of Yucatán, but the region where most of the henequen is grown is generally too dry for the best growth of sisal.

Both sisal and henequen were introduced into southern Florida about 1834, by Dr. Henry Perrine, who was then United States consul at Campeche. Very few henequen plants survived the abundant summer rains in Florida, but the sisal plants thrived and became naturalized. They are abundant in many places on the Florida Keys and also in some places on the mainland, near the coast of southern Florida. The self-binder for harvesting grain and tying the sheaves with twine instead of wire came into general use between 1885 and 1890. This resulted in a greatly increased demand for hard fibers and in efforts to produce these fibers in many tropical colonies. Yucatán, having the monopoly of henequen production, would not permit propagating stock of the plants to go out of that country. Bulbils from the sisal plants growing wild in southern Florida, however, were available in great numbers at prices as low as $4 per thousand. At that time botanists did not generally recognize henequen and sisal as different species. Sisal bulbils from Florida went to the Bahamas, Haiti, Curaçao, Hawaii, East Africa, Algeria, India, and many other warm countries. All cultivated sisal outside Mexico may be traced directly or indirectly to Florida. Sisal has been distributed very widely, whereas henequen is comparatively rare outside Yucatán and Cuba.

Sisal is now cultivated commercially on large plantations in the State of Campeche, Mexico, and in Haiti in the American Tropics; in Kenya, Tanganyika, Mozambique, Togoland, and Senegal in Africa; and in Java and Sumatra in the Netherlands Indies. There are numerous other places where the cultivation of sisal has been tried but abandoned because the production of the fiber with small or inefficient machines could not compete successfully with its production on large, well-equipped plantations under more favorable conditions.

Sisal is a tropical plant, and all sisal plantations now in operation are within the Tropics. Sisal does not endure severe drought as well as henequen, but it endures excessive rainfall better. The plants grow best under semiarid conditions and in open sunlight. Dry air and abundant sunshine are necessary for drying and bleaching the fiber. Although hurricanes sometimes break them down, sisal plants endure storms better than do most tropical crops.

Sisal grows well on a wider range of soils than henequen, but it grows best in a well-drained soil of rather loose or open texture, allowing aeration of the roots. Many of the best sisal plantations are on soils sufficiently free from rocks to be plowed and cultivated.

Sisal plantations are laid out in practically the same manner as those for henequen. Successful commercial production of the fiber requires an area of at least 2,500 acres (1,000 hectares) of land suitable for growing the plants, within easy hauling distance of the central cleaning machine and a plentiful supply of fresh water for washing the fiber. Availability of efficient labor and means for transportation of the fiber to market must also be considered.

Sisal plants may be propagated by bulbils (fig. 10) from the flower stalks, or by suckers, which grow up from the rootstocks. Bulbils must be cultivated in a nursery (fig. 11) 12 to 24 months before being transplanted to the field. Suckers are sometimes cultivated in a nursery to give opportunity for better selection. The land to be planted is thoroughly cleared and is often plowed and cultivated. The plants are then set out in rows, in the same manner as henequen or sometimes a little closer together, at the rate of about 1,000 to 1,200 per acre (2,500 to 3,000 per hectare). The land is cultivated or the weeds are cleared out three or four times each year until the first harvest, 2½ to 4 years after the young plants are set out, and afterward at the time of each harvest, about twice each year.

The sisal beetle, *Scyphophorus acupunctatus* Gyll., and the black rot attack sisal, but generally less severely than they attack henequen. The yellows, or yellow spot disease, sometimes

FIGURE 10.—Sisal bulbils about 4 inches (10 cm.) long, partly rooted after falling from the flower stalk. Boca Chica, Fla.

FIGURE 11.—Sisal bulbils growing in nursery beds; plants about 16 inches (40 cm.) high before transplanting to the field. Mayagüez, P. R.

referred to as mosaic, though no definite cause has been found for it, is much more destructive to sisal, especially if the plants are growing under unfavorable conditions. The first crop of leaves is harvested 2 to 4 years after the young plants are set out, and successive crops are harvested about twice each year, for periods of 4 to 6 years, or until many of the plants send up flower stalks and die. The sisal leaves, having no marginal prickles and being more easily cut than henequen, are harvested a little more rapidly.

Sisal fiber is cleaned in the same manner as henequen and by the same kinds of machines. The sisal leaves average a little more than one-half the thickness of henequen leaves at the base, and the pulp is scraped away more easily, so that less power is required for cleaning sisal. The green sap adheres to sisal fiber, so it is necessary to wash the fiber as it is cleaned. On some plantations where there are frequent rains the fiber is dried by means of centrifugals and hot-air driers. Most of the fiber is brushed on brushing machines after it is dry. This brushes away adherent dust and weak fibers and brings out the luster of the fiber. The fibers beaten out in the brushing process are sold as sisal waste.

A well-grown sisal plant yields 140 to 200 leaves during its entire life. The leaves average about 1½ pounds (0.75 kilo) in weight. The yield of fiber ranges from 2.5 to 4 percent of the weight of the green leaves, averaging about 3 percent. On the best plantations in eastern Africa and Java the yield of dry clean sisal fiber is about 1,760 pounds per acre (2,000 kilos per hectare) per annum during the period of production, which is two-thirds to three-fourths of the lifetime of the plants.

Sisal fiber is cream white to clear white. 24 to 64 inches (60 to 160 cm.) in length. and $\frac{1}{200}$ to $\frac{1}{50}$ inch ($\frac{1}{8}$ to $\frac{1}{2}$ mm.) in diameter. It is generally a little more flexible than henequen. The ultimate cells composing the fiber are slightly finer than those of henequen. The cellulose content of sisal fiber is about 77 percent and that of henequen about 73 percent. The average breaking strain of single strands, as computed from a series of tests. is 32.773 gms. per gram-meter. Sisal fiber absorbs water and swells more quickly than abacá, but it swells very slightly, so that in marine cordage it does not cause serious trouble in the pulley blocks. It is resistant to injurious action of sea water.

Sisal has been used most extensively in binder twine. It makes binder twine "600 feet per pound" or 408 m. per kilo. Its use is increasing in heavier twines and ropes and even in marine cordage. Carefully conducted tests, as well as actual use on ships, indicate that it is the most satisfactory substitute for abacá (manila rope) in marine cordage. In recent years the practice has been adopted of softening the fiber by various treatments. These treatments do not make a really soft fiber out of sisal, but they have made it possible to spin sisal yarns soft enough to be woven into sacks for coffee. Sisal has been used in bagging to cover bales of cotton, and this covering. although not received with much favor by the cotton spinners of Lancashire, England, is preferred to jute. A comparatively new use is in floor coverings, especially summer rugs. The fiber is used in brushes; sisal waste. beaten out in brushing, is used in cheap twines and in upholstery tow.

The production of sisal, chiefly in East Africa and the Netherlands Indies. begun after 1900. increased to nearly 30,000 tons per annum before World War I, then it dropped off. especially in Tanganyika. Since 1920 the production has been increasing. The world production from 1930 to 1939, inclusive. is estimated in metric tons as follows:

Year	Metric tons	Year	Metric tons
1930	131,000	1935	224,000
1931	149,000	1936	227,000
1932	161,000	1937	228,000
1933	193,000	1938	240,000
1934	201,000	1939	247,000

This annual production is greater than that of any other plant fiber except cotton, jute, and flax.

The principal markets for sisal are in Great Britain, continental Europe, and the United States. The maximum and minimum quotations, in cents per pound, for sisal fiber in New York City from 1930 to 1939. inclusive, were as follows:

Year	Cents per pound: Maximum	Cents per pound: Minimum
1930	$8\frac{7}{8}$	$4\frac{3}{4}$
1931	$4\frac{1}{4}$	$2\frac{1}{2}$
1932	$2\frac{3}{4}$	$2\frac{3}{8}$
1933	$4\frac{3}{8}$	$2\frac{1}{2}$
1934	$4\frac{1}{2}$	$3\frac{3}{8}$
1935	$6\frac{3}{8}$	$3\frac{1}{2}$
1936	$6\frac{1}{2}$	$5\frac{7}{8}$
1937	$6\frac{1}{2}$	$5\frac{3}{4}$
1938	$4\frac{7}{8}$	$3\frac{9}{16}$
1939	$5\frac{3}{8}$	$3\frac{3}{16}$

The increase in the number of uses for sisal has made the market demand for this fiber less dependent upon the demand for binder twine.

LETONA

(Amaryllis family)

Agave letonae F. W. Taylor.

The letona plant and its fiber have been called Salvador henequen and Salvador sisal under the supposition that it was the same species as the henequen of Yucatán, but the leaves are more slender, the terminal spines more angular, the fiber softer and finer, and there are specific differences in the flowers and seed pods.

The letona plant develops a trunk up to 60 inches (150 cm.) high. The leaves are bluish glaucous, 3 to 4 inches (8 to 10 cm.) wide and 50 to 80 inches (125 to 200 cm.) long, slightly concave, with marginal prickles ⅗ to 1⅖ inches (15 to 35 mm.) apart and a terminal spine about 1 inch (25 mm.) long, round-grooved on the face and have acute edges extending slightly into the green tissue at the tip of the leaf. The flower stalks are 20 to 27 feet (6 to 8 m.) tall, and the flowers are followed by seed pods.

This species has been grown from early times by the Indians in El Salvador, and it is not known now as a native wild plant. It has not been reported anywhere outside of El Salvador. It is grown on a small scale for the production of fiber for local use in many places in El Salvador (fig. 12). It is cultivated on large plantations for the production of fiber on a commercial scale. One of the largest is "Letonia," near San Miguel, El Salvador. The plants are propagated by suckers and cultivated in practically the same manner as henequen in Yucatán. The fiber is prepared by the same kinds of machines that are used on the henequen plantations in Yucatán.

Figure 12.—Small machine for spinning letona fiber into yarns or twines. El Salvador.

Figure 13.—Interior of a factory for preparing letona fiber ("Salvador henequen") for spinning into twines. El Salvador.

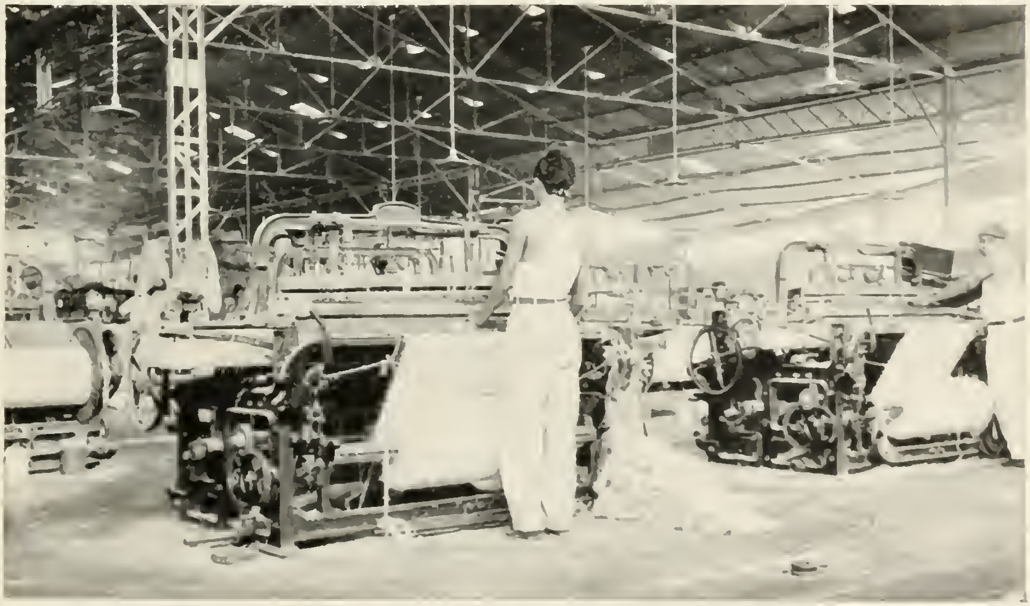

Figure 14.—Weaving fabric for coffee sacks from yarns of letona fiber. El Salvador.

Letona fiber is similar to henequen in general appearance, but it is finer and softer and may be used in making softer yarns. The production of letona fiber in El Salvador in 1934 amounted to nearly 2,700 metric tons. This was used mostly for home consumption in the manufacture of sacks for coffee and sugar and in twines and rope (figs. 13 and 14).

MEZCAL

(Amaryllis family)

Agave tequilana Weber, A. pseudotequilana Trel., A. palmaris Trel., and A. pes-mulae Trel.

This mezcal group of agaves is cultivated in western Mexico, from Sinaloa to Jalisco, primarily for the production of the alcoholic beverages mezcal and tequila, distilled from the roasted bases or trunks of the plants. The production of fiber from the leaves is incidental (fig. 15). *Agave tequilana* is called mezcal azul or chino azul; *A. pseudotequilana* is called mezcal blanco or mezcal cucharo; *A. palmaris* is called mano larga or chino bermejo; and *A. pes-mulae* is called pata de mula or pié de mula.

The plants all bear a general resemblance to henequen and sisal. All have short and relatively thick trunks. The leaves of mezcal azul are light bluish green, thin, and nearly flat, 3 to 4 inches (8 to 10 cm.) wide, and 45 to 50 inches (125 to 150 cm.) long. Mezcal blanco has yellow-green glaucous leaves, rather thick, slightly concave, nearly 6 inches (15 cm.) wide, and 70 to 80 inches (175 to 200 cm.) long. Mano larga has darker green leaves, somewhat glaucous, 4 to 6 inches (10 to 15 cm.) wide, and about 70 inches (175 cm.) long

Figure 15.—Mezcal plantation. Left, mezcal blanco; right, mezcal azul. Tequila, Jalisco, Mexico.

(fig. 16). Pata de mula has blue-green leaves 2½ to 3 inches (6 to 8 cm.) wide and 40 to 60 inches (100 to 150 cm.) long. All have red or purple marginal prickles mostly upcurved and about ⅛ inch (3 mm.) long, or longer on mezcal blanco. All four species are cultivated together in the same fields, mezcal azul being more prevalent in the southern part of the range and mezcal blanco more abundant in the northern part. The large leaves of mezcal blanco and mano larga are best for fiber production.

When the plants are about to send up a flower stalk, at the age of 8 to 10 years, the short trunks are well stored with sugar. The leaves are then all cut off, and the trunks, looking like very large pineapples, are collected to be roasted. Some of the mezcal plantations are equipped with fiber-cleaning machinery, and when there is a good demand for fiber at favorable prices the leaves are collected and fiber is prepared in the same general manner as has been described for henequen and sisal. The leaves from the different kinds of plants growing together in the field are not kept separate, and the fiber is mixed as they are all cleaned together. Furthermore the leaves, all harvested at one time, include many long past maturity and others too young to yield the best fiber. The fiber, therefore, lacks uniformity. It is normally softer and a little finer than henequen. As it is generally regarded as merely a byproduct on the mezcal plantations, it is not often prepared as carefully as henequen and sisal.

Mezcal fiber is used chiefly for mixing with other fibers in hard-fiber twines. It is exported, but it is not quoted in the fiber markets.

FIGURE 16.—Mano larga mezcal plant, 10 years old and soon to send up a flower stalk as indicated by the shorter central leaves. Mazatepec, Mexico.

ZAPUPE

(AMARYLLIS FAMILY)

Agave zapupe Trel., A. lespinassei Trel., and A. deweyana Trel.

Much interest in the cultivation of the zapupe-fiber agaves was aroused in Mexico from about 1902 to 1910. Several plantations of zapupe were started, chiefly in the States of Veracruz and Tamaulipas in eastern Mexico. Some fiber-cleaning machines were installed, but mostly of the smaller and less efficient types; at least, most of the machines were not well adapted for the preparation of zapupe fiber. The fiber never came on the market in regular commercial quantities, and its production was discontinued.

Zapupe azul (*Agave zapupe*) is also known as zapupe estopier. It has blue leaves, yielding an attractive, fine, white fiber, not strong enough, however, to withstand the straining of the cleaning machines then available (fig. 17). Zapupe de Tepetzintla (*Agave lespinassei*) is sometimes called zapupe vincent. It has green leaves yielding fiber more nearly like sisal. This plant grows well on the sandy soils along the coast of the Gulf of Mexico. Zapupe verde (*Agave deweyana*) is also known as zapupe de Tantoyuca. It has green leaves, yielding fiber similar to henequen or slightly finer and softer. This plant has been cultivated a century or more by the Tantoyuca Indians in the mountains of northern Veracruz, where there are light frosts in winter, but when cultivated in the plantations of henequen near Ciudad Victoria about 140 miles (200 kilometers) farther north, it was injured by light frosts fully as much as henequen, introduced there from Yucatán, where the temperature never approaches freezing (fig. 18).

FIGURE 17.—Zapupe azul. The leaves yield a fine white fiber. Tuxpan Valley, Veracruz, Mexico.

FIGURE 18.—Zapupe verde plant, 8 years old, with bulbils killed by frost, near Ciudad Victoria, Tamaulipas, Mexico.

CANTALA

(AMARYLLIS FAMILY)

Agave cantala Roxb.

The Malay name cantála, also spelled kantala and cantula, is used in Java and to some extent elsewhere in Malaysia. In the Philippine Islands, where this plant is most extensively cultivated, it is called maguey, and the fiber exported from the Philippines is known in the markets as Manila maguey or Cebu maguey. The fiber exported from Java is called cantala and, according to a regulation issued by the Philippine Government, the machine-cleaned fiber produced there is officially called cantala. The name maguey is used so generally in tropical America to designate many different kinds of plants that it is confusing to apply it to this particular species.

The cantala plant has a short trunk with rather thin gray leaves 2½ to 4 inches (6 to 10 cm.) wide and about 60 inches (150 cm.) long, often curved sidewise, and bearing upcurved prickles on the margins (fig. 19). The terminal spine is bent slightly forward, and in pushing up through the bud these spines often pierce the opposite leaves and prevent the buds from opening.

This species is rare in Mexico, where it originated. It is supposed to have been introduced into Malaysia in early times and was first described from plants cultivated in India. It is now cultivated for fiber production in the Philippine Islands, the Netherlands Indies, and to a less extent in French Indo-China, India, and Madagascar. It is cultivated as a fiber plant more than any other fiber-producing agave except henequen and sisal.

The cantala plant grows best in well-drained limestone soils under tropical semiarid conditions.

In Java most of the cantala fiber is cleaned with raspadors or by the larger automatic machines that are used for sisal. The machines do not work as well with cantala as they do with sisal. In the Philippine Islands and most other places outside of Java the leaves are rotted in sea water and the fiber is cleaned by hand (fig. 20). The rotted leaves are beaten on stones, the pulp is washed away in the water, and the fiber is dried in the sun. The fiber thus prepared is inferior in quality to that prepared by machines scraping away the pulp from the freshly cut green leaves.

FIGURE 19.—Cantala plants. Cutting leaves from plants not previously harvested. Photograph by M. M. Saleeby, Philippine Bureau of Agriculture.

FIGURE 20.—Cantala leaves rotting in sea water, with stakes to keep them from floating away; fiber cleaned by hand, ready to send to the local market.

The fiber is finer and softer than sisal, but weaker. When the leaves are rotted in sea water the fiber lacks luster and is often rough, harsh, and dusty.

Cantala is used chiefly in hard-fiber twines. It has been tried in binder twine, but the salt in the sea-rotted fiber attracts crickets, which eat the bands as the bundles of grain are drying in the field.

Cantala fiber, under the names of Manila maguey and Cebu maguey, was exported from the Philippine Islands to the amount of 12,000 to 24,000 tons annually. It is regularly quoted in the American fiber markets at prices 25 to 33 percent below the quotations for Yucatán henequen.

In commercial importance, or quantity of fiber produced and placed upon the market, cantala is exceeded only by sisal, henequen, and abacá among the hard fibers, but it is not produced in America. It is not recommended for cultivation under American conditions, but is included in this publication because it is an American plant, although it was taken abroad and developed to commercial importance.

LECHUGUILLA

(AMARYLLIS FAMILY)

Agave lecheguilla Torr.

The common name of the plant, lechuguilla, means "little lettuce," whereas the specific botanical name *lecheguilla*, suggests "little milk." The fiber is called ixtle (eesh-tley) in Mexico, but in the markets of the United States it is called Tula istle (generally mispronounced "issel" instead of "iś-tley"). The name Tampico fiber is applied to this and other fibers shipped from Tampico, Mexico.

The lechuguilla plant (fig. 21) consists of a rosette of 25 to 50 green or bluish leaves with no trunk above the ground. The leaves are 12 to 20 inches (30 to 50 cm.) long and 1 to 1½ inches (3 to 4 cm.) wide, rather thick, and nearly always curved inwardly and often sidewise. A light-colored stripe often extends lengthwise on the face, and on the back there are numerous narrow dark-green lines 1 to 2 inches (25 to 50 mm.) long. Each leaf terminates in a spine 1 to 1½ inches (25 to 40 mm.) long. The base of the spine extends as a horny margin down each side of the leaf bearing curved prickles $\frac{3}{25}$ to $\frac{7}{25}$ inch (3 to 7 mm.) long and ¾ to 1½ inches (20 to 40 mm.) apart. The flower stalk is 5 to 7 feet (1.5 to 2 m.) high, bearing light-yellow flowers in a close spike (fig. 22). The flowers are followed by seed pods, but never by bulbils.

Figure 21.—Lechuguilla plant from which the leaves forming the bud or cogollo have been broken out and a new bud is starting. Saltillo, Mexico.

Figure 22.—Lechuguilla plants in flower. The flower stalks bend downhill. Saltillo, Mexico.

Lechuguilla grows on dry limestone mesas, from the region of San Luis Potosi northward across the high tablelands of central Mexico to western Texas, southern New Mexico, and southeastern Arizona. It is not cultivated.

Lechuguilla grows in an arid or semiarid climate, enduring snow and light frosts and sometimes severe frosts in the northern part of its range.

The fiber is obtained from the young leaves forming the central bud or cogollo. The pulp in the outer leaves is too hard and firm to be scraped away by hand. The bud is tender at the base, which is the point of growth.

FIGURE 23.—Cleaning istle fiber by pulling the leaf under a knife pressed against a block of wood. Jaumave, Mexico.

A ring on a long handle is slipped over the bud and given a quick jerk, breaking out the entire cogollo and leaving a cogollito to begin a new growth. (See fig. 21.) A basketful of cogollos are collected. The horny borders, including the marginal prickles and terminal spine, are stripped off. The leaves are then pulled, one at a time, about five times between a blunt knife and a block of wood, scraping the pulp away from one end. The fiber thus cleaned is wound around a small piece of wood for a handhold, and the other end of the leaf is drawn five times under the knife (fig. 23). The cleaned fiber is spread on the ground to dry in the sun, after which it is tied into bundles. An expert workman cleans 66 to 88 pounds (30 to 40 kilos) per week. The bundles of fiber are packed by hand into bales of about 110 pounds (50 kilos) covered with a coarse fabric made by hand from the lower grades of istle. Numerous machines have been devised for cleaning istle, but thus far none of them seem to be entirely successful in preparing a satisfactory fiber for brushes. Most of them crush the fiber and thus destroy its resiliency. The leaves are too short for the fiber to be cleaned by the machines designed for henequen and sisal.

In Mexico, Tula istle is spun by hand into coarse yarns that are woven by hand into fabrics for covering bales of the fiber, or into closer woven fabrics which are made into sacks for corn, coffee, and numerous other products. The yarns are also twisted into two-ply or three-ply rope for domestic use or for export (fig. 24). Outside of Mexico the fiber is used almost exclusively in the manufacture of brushes; the waste fiber beaten out in straightening the fiber for brushes is used for upholstery tow.

In the New York fiber market Tula istle is regularly quoted. During the past 10 years the prices have ranged from 4 to 9 cents a pound (8.8 to 19.8 cents per kilo).

JAUMAVE LECHUGUILLA

(AMARYLLIS FAMILY)

Agave funkiana Koch and Bouché.

The plant is called Jaumave lechuguilla (how-u-máh-ve lech-u-geél-ya) and the fiber, istle de Jaumave. In the market the fiber is usually called Jaumave istle.

The Jaumave lechuguilla plant (fig. 25) is very similar to the common lechuguilla except that its leaves are usually straight and longer, often 30 to 40 inches (75 to 100 cm.) long, but rarely more than 2 inches (5 cm.) wide,

FIGURE 24.—Spinning istle; men walk backward, paying out the fiber, which is twisted into yarn by spindles turned by women and children. Tula, Tamaulipas, Mexico.

FIGURE 25.—Jaumave lechuguilla is similar to common lechuguilla except that its leaves are longer and yield a better fiber. Jaumave, Tamaulipas, Mexico.

and the terminal spines are smaller. The downward-hooked marginal prickles are borne on a brown horny border about $\frac{1}{25}$-inch (1 mm.) wide, which, like that of the common lechuguilla, is easily stripped off.

Jaumave lechuguilla grows in a limited area on the mountainsides surrounding the Jaumave and Las Palmas Valleys in the State of Tamaulipas and also in the State of Nuevo León. It is not cultivated.

It grows in a semiarid climate and is subjected to snow and light frosts nearly every winter.

The fiber is cleaned by hand in the same manner as Tula istle (fig. 23). Nearly all of it is taken to Ciudad Victoria, where it is sorted according to length and quality and packed into bales for shipment.

The fiber is light reddish-yellow or nearly white, 12 to 30 inches (30 to 75 cm.) long, cylindrical, $\frac{1}{200}$ to $\frac{1}{50}$ inch ($\frac{1}{8}$ to $\frac{1}{2}$ mm.) in diameter, stiff and resilient. It is more nearly uniform throughout its length than Tula istle and not so coarse and rigid at the base. When used in brushes, it resembles animal bristles more nearly than does any other vegetable fiber.

Nearly all of the Jaumave istle is exported and used in brushes of high quality.

In the New York fiber market Jaumave istle is regularly quoted at prices ranging from 6 to 10 cents per pound (13.2 to 22 cents per kilo).

FURCRAEA

The genus *Furcraea* was named by Etienne Pierre Ventenat, in 1793, in honor of Count Antoine de Fourcroy, chemist at the Jardin du Roi, in Paris. The name of the genus is often spelled *Fourcroya*, but in the original publication it was spelled *Furcraea*, and this form is preferred in accordance with the rules of botanical nomenclature. The plants of this genus have rosettes of large fleshy leaves resembling those of the agaves, except that they terminate in very small horny tips instead of well-developed spines; and the greenish-yellow or white flowers are scattered along the branches, with petals spread out instead of being nearly closed and in erect clusters like those of the agaves.

PITEIRA

(AMARYLLIS FAMILY)

Furcraea gigantea Vent.

Furcraea foetida (L.) Haw.

Furcraea gigantea willemettiana Roem.

The plant is called piteira (pee-té-ra) or piteira gigante in Brazil and other Portuguese-speaking countries, and the fiber is called pita. In Mauritius the plant is called aloe vert, aloe creole, and aloe malgache, and the fiber is called aloe fiber, although the plant bears only a faint resemblance to the true aloe, native to Africa. The true aloe does not yield fiber. The fiber produced in Mauritius is known in the market as "Mauritius hemp," a misleading name, for the plant is not native to Mauritius and the fiber is very different from true hemp. In Venezuela a variety without marginal prickles is called cocuiza mansa.

The young piteira plant consists of a rosette of bluish-green, thick, fleshy leaves (fig. 26). As the plant grows older it develops a short trunk bearing 75 to 150 leaves 50 to 80 inches (150 to 200 cm.) long and 6 to 8 inches (16 to 20 cm.) wide at the widest part, near the middle, narrowing to about 4 inches

FIGURE 26.—Piteira plant 3 years old, with leaves 47 by 7 inches (120 by 18 cm.), from bulbil received from Mauritius and planted at the Federal Experiment Station, Mayagüez, P. R.

(10 cm.) wide, and $2\frac{1}{4}$ to 3 inches (6 to 8 cm.) in vertical thickness, near the base. Above the thick base the leaf is thinner, with faint lines or ridges, concave, light green, rough on the back, and terminating in a sharp horny tip about $\frac{1}{8}$ inch (3 mm.) long. The typical form of the species, known in Mauritius as "aloe creole," bears a few scattered prickles on the margins, mostly near the base; whereas the variety *Furcraea gigantea willemettiana*, called "aloe malgache," has strong upward-hooked prickles about $\frac{3}{8}$ inch (10 mm.) long and $\frac{7}{8}$ to 2 inches (20 to 50 mm.) apart. The flower stalks 20 to 30 feet (6 to 10 m.) tall, bear abundant bulbils, nearly $\frac{4}{5}$ inch (20 mm.) in diameter from which the plants are propagated (fig. 27). High temperature and semi-humid conditions are essential requirements for the growth of piteira. The plants grow rapidly in open tropical sunlight, but not in shade, in a wide variety of soils.

Piteira was cultivated for fiber production by the Dutch, who occupied Pernambuco and Ceará in Brazil in the seventeenth century. They introduced piteira into other Dutch colonies, and it was widely distributed in the Tropics of both hemispheres. Dr. Pio Correa, an authority on the fiber plants of Brazil, thinks that this species is the same as the cabuya of Costa Rica and that it was introduced into Brazil. It grows in the coast region of northern Colombia. Piteira is cultivated on a few plantations in eastern Brazil; on the island of Mauritius, in the Indian

FIGURE 27.—Piteira plants with flower stalks bearing scattered flowers and bulbils. Mayagüez, P. R.

Ocean; in Natal, Union of South Africa; and in India.

Piteira is propagated by the bulbils. These are collected as they fall from the flower stalks, and are cultivated about a year in nursery beds, or they are dug up where they have taken root and begun to grow around the mother plants. The land where they are to be planted must be thoroughly cleared, for piteira cannot thrive in shade. In Mauritius, the young plants are set out in quincunx, about 51 inches (1.3 m.) apart. The land between the plants is cleared two or three times each year until the first crop of leaves is harvested in the fourth year, and from then on the land is cleared each time the leaves are harvested, or about twice each year. The plants continue to yield leaves for 12 to 16 years, when they send up flower stalks and die. The cultivated plantations of piteira are not large, and many of the leaves used for fiber production are obtained from plants growing wild.

The leaves of piteira are too large and too thick at the base to be handled successfully by machines designed for henequen and sisal. In Brazil, large machines are used, in which the leaves are crushed and the pulp scraped away by large revolving drums similar to those in the sisal-cleaning machines. The fiber thus cleaned and dried in the sun is about as coarse as henequen, but somewhat softer and generally longer.

In Mauritius the production of piteira, or "aloe fiber," as it is there called, is the most important industry in the island, next to the production of sugar. A machine called a gratte is used. This consists of two scraping drums on one shaft, similar to a double raspador. The leaves are delivered in bundles of 8 to 18 leaves each. The thick bases of the leaves are crushed. Two men, called gratteurs, work at each machine, feeding the leaves endwise by hand, often two leaves at a time. The basal ends are cleaned first and withdrawn; then the leaf is reversed and held by the fiber while the gratte scrapes away the pulp from the remainder of the leaf. An expert gratteur, working 4 to 6 hours, produces 440 to 550 pounds (200 to 250 kilos) of fiber a day. An average piteira leaf is nearly twice as large as a sisal leaf but yields only about the same amount of fiber. The yield of dry fiber ranges from 1.5 to 2.5 percent of the weight of the green leaves. The average yield is about ½ long ton per acre or 1.25 metric tons per hectare. The fiber coming from the gratte is tied in small bundles and washed in clear water. It is then soaked 36 to 48 hours in a solution of soap and water and again washed in clear running water, after which it is dried and bleached in the sun. It is then brushed, graded, and baled for market. The fiber thus produced is white and is finer and much softer than sisal or henequen, but weaker.

The piteira fiber produced in Brazil is used chiefly in that country in the manufacture of twines and cordage. In Mauritius the fiber there produced is used extensively in the manufacture of sacks for sugar. The piteira fiber exported from Mauritius is used in other countries chiefly for mixing with other hard fibers to improve the color in twines and cordage. It is also used in unoiled "paper twines" for tying bundles of wallpaper and newspapers.

Piteira fiber is quoted in the fiber market in New York at prices usually 20 to 30 percent below the quotations for henequen, but very little of this fiber has been imported into the United States in recent years.

CABUYA

(AMARYLLIS FAMILY)

Furcraea cabuya Trel.

Furcraea cabuya integra Trel.

Both the plant and its fiber are called cabuya, cabuia, or cabulla. A variety without prickles on the margins of the leaves, *Furcraea cabuya integra*, is called cabuya olancho, cabuya blanca, and cabuya sin espina.

The cabuya plant is similar to piteira, *F. gigantea*, but is often larger. It has a short trunk bearing 50 to 100 wide-open concave green leaves, often with margins turned out or rolled slightly back, 60 to 100 inches (150 to 250 cm.) long and 6 to 8 inches (15 to 20 cm.) wide, narrowed at the base to about 2¾ inches (7 cm.) wide and 1½ to 2¼ inches (4 to 6 cm.) in vertical thickness, smooth and slightly glossy on the upper surface, and sometimes slightly roughened on the back. The end spine, when developed, is minute, barely ⅛ inch (3 mm.) long. The typical form has coarse upward-hooked prickles on the margins, except near the apex. The prickles are yellow, with orange or chestnut points. The variety *F. cabuya integra*, called cabuya olancho or cabuya blanca, has leaves generally smaller, narrower, and thinner at the base, and with very few or no marginal prickles (fig. 28). This variety is more widely cultivated than the typical form, because the leaves, being without prickles, are more easily handled, and being narrower, yield more fiber.

Cabuya grows in Costa Rica and Panama and in the coast region of northern Colombia. It is found from the semiarid coastal plains up to an altitude of 6,000 feet (1,800 m.) in the mountains. It is reported to be abundant only in Costa Rica, which is the only country where it is cultivated in large plantations for fiber production.

Cabuya plants are propagated from bulbils produced on the flower stalks and also from suckers, called hijuelos. The bulbils must be cultivated in nurseries before they are set out in the field (fig. 28). Suckers are preferred because they are thought to produce longer lived plants. The first crop of leaves is harvested 3 to 5 years after the young plants are set out, and 20 to 30 leaves per plant are harvested annually for 5 to 8 years. It is difficult to clean the fiber from the thick bases of the leaves; therefore the leaves are often cut leaving 8 to 16 inches (20 to 40 cm.) of the best fiber-yielding portion attached to the trunk of the plant

FIGURE 28.—Cabuya olancho: Old plants from which several crops have been cut; bulbils growing in nursery rows. Near San José, Costa Rica.

(fig. 28). Several different kinds of machines designed for cleaning sisal fiber have been tried for cabuya, but without satisfactory results. A machine designed especially for cabuya and built in Costa Rica has proved to be the most successful in cleaning this fiber.

The leaves yield from 1.5 to 3.5 percent of their green weight in clean dry fiber. The fiber is 60 to 90 inches (1.5 to 2.25 m.) long and generally coarser than henequen fiber. It is longer than any other kind of furcraea or agave fiber produced in quantity.

Practically all of the cabuya fiber produced in Costa Rica is used there for making twines, ropes, saddlebags, cinches, halters, and hammocks. In 1937 only two companies were reported to be carrying on this work commercially, but cabuya fiber is prepared by hand and made up into twines and woven articles as a household industry in places where the plants grow abundantly.

FIQUE

(AMARYLLIS FAMILY)

Furcraea macrophylla Baker.

The name fique is used in Colombia to designate both the plant and its fiber, but this name is also used there for other species such as cabuya, *Furcraea cabuya*, and piteira, *Furcraea gigantea*. In some places all of these plants are called maguey.

The mature fique plant has a short trunk, rarely more than 12 inches (30 cm.) high. The leaves are green, mostly smooth on the face and rough on the back, 60 to 80 inches (150 to 200 cm.) long, 3 to 5½ inches (8 to 14 cm.) wide measured around the convex back, a width less than one-tenth of the length, and narrowed at the base about one-third of the entire length (fig. 29).

Coarse red-brown prickles on the margins are 1½ to 3 inches (4 to 8 cm.) apart and are hooked upward; some smaller prickles, near the base of the leaf, are hooked downward. The flower stalks, 20 to 30 feet (7 to 10 m.) high, bear both seed pods and ovoid bulbils. This species may be distinguished from others mentioned in this publication by the leaves, which are narrower in proportion to their length than in other species with concave leaves rough on the back, and have a long, narrow, stemlike base. The leaves are longer than those of Yucatán henequen, about the same width but thinner above the base, and with less pulp. The fiber is finer in texture than henequen and is lustrous and of excellent quality when well cleaned.

This species was first described in 1907 at the British Museum in London, from specimens received from the Bahamas. The plant was introduced into the Bahamas and Jamaica but does not grow as large in those islands as it does in its native habitat in Colombia. It is reported to be most abundant in the region of Riohacha, in northern Colombia, and in Cundinamarca, in central Colombia. It is cultivated to some extent, but not in large plantations. The leaves are collected from either wild or cultivated plants and taken short distances to the places where the fiber is extracted (fig. 30).

The most common method of preparing the fiber is by means of the carrizo (fig. 31). The leaves are split into narrow strips, and these are pulled between two sticks pressed together to scrape away the pulp. A workman may clean about 110 pounds (50 kilos) of fiber per day by this method, but the constant contact with the strong acrid juice makes his hand so sore that he can work only about 2 days a week. In some places a device consisting of metal plates pressed together by springs is used. With this the workman may use both hands to pull the strip of leaf. Raspadors (fig. 32) are also used; they have a capacity of about 110 pounds (50 kilos) of fiber an hour. After the pulp has been scraped away the fiber is hung on poles to dry in the sun (fig. 33).

Figure 29.—Fique leaves, narrowed nearly one-third up from the base.

Fique fiber produced in Colombia is used there in twines, ropes, hammocks, saddle girths, halters, and sandals and

FIGURE 30.—Transporting fique leaves, typical scene in the fields of Cundinamarca, Colombia. Photograph from Sr. Adel López Gómez, of the Ministry of National Economy of Colombia.

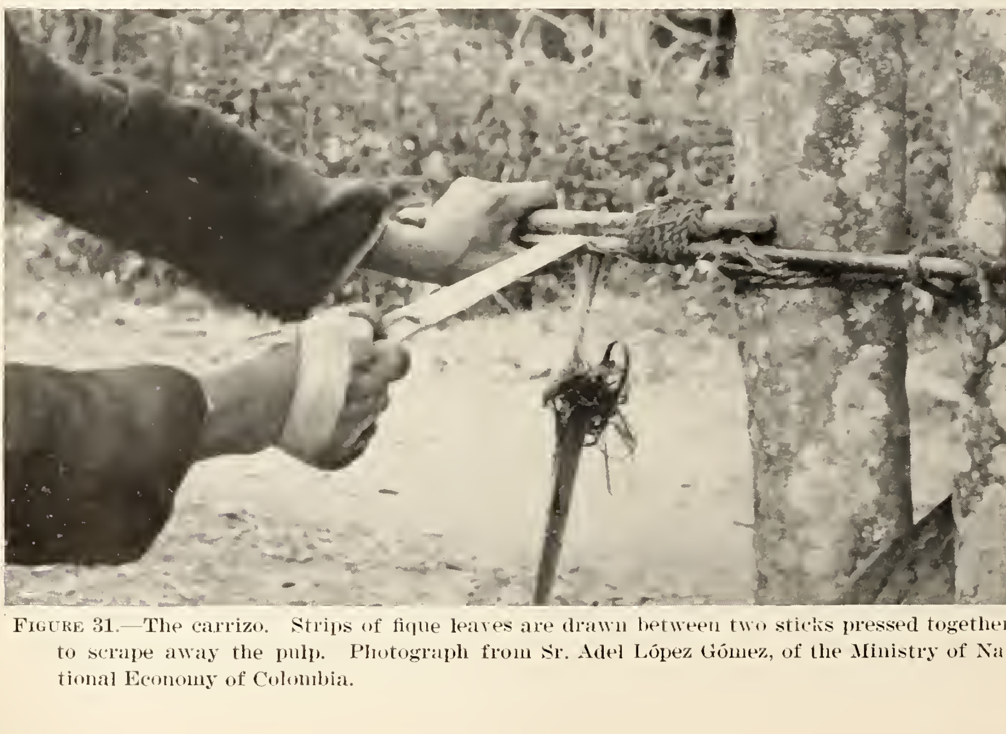

FIGURE 31.—The carrizo. Strips of fique leaves are drawn between two sticks pressed together to scrape away the pulp. Photograph from Sr. Adel López Gómez, of the Ministry of National Economy of Colombia.

FIGURE 32.—A mechanical defibrator, or raspador, made in Colombia. It has a capacity of about 110 pounds (50 kilos) of fique fiber an hour. Photograph from Sr. Adel López Gómez, of the Ministry of National Economy of Colombia.

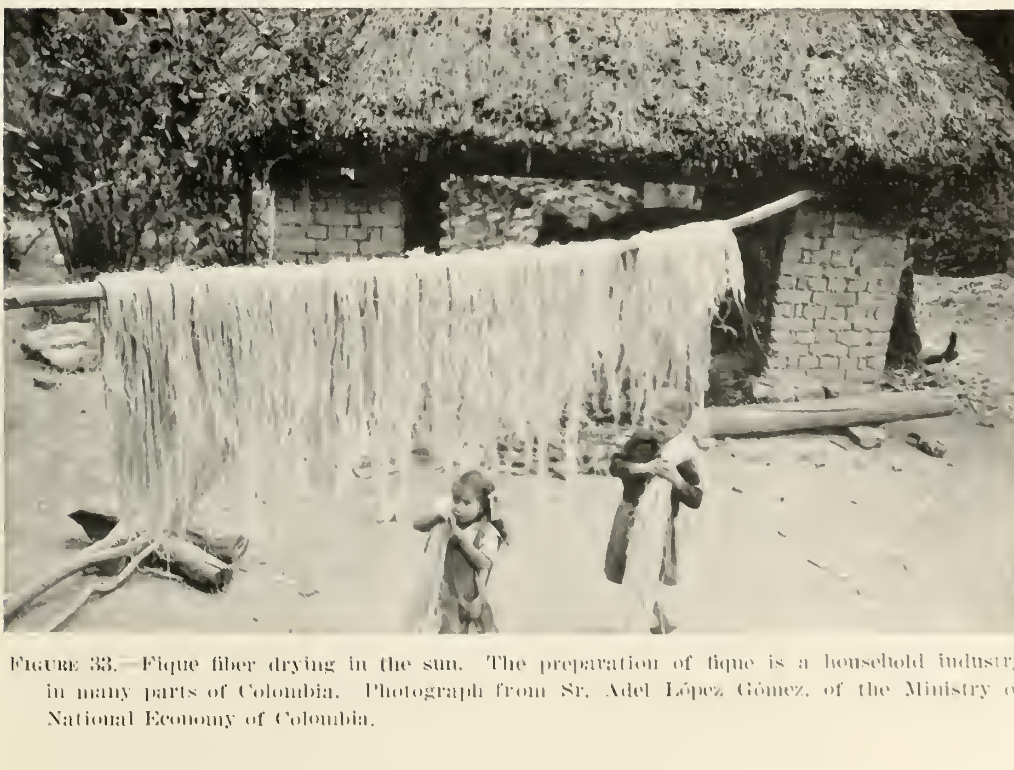

FIGURE 33.—Fique fiber drying in the sun. The preparation of fique is a household industry in many parts of Colombia. Photograph from Sr. Adel López Gómez, of the Ministry of National Economy of Colombia.

FIGURE 34.—Chuchao bulbils from the eastern slopes of the Andes in Peru.

in sacks for coffee, cacao, corn, and sugar. The fiber has not been exported in sufficient quantity to establish market quotations.

CHUCHAO

(AMARYLLIS FAMILY)

Furcraea andina Trel.

The names chuchao (chu-chów), cabuya, and maguey are used to designate the chuchao plant and its fiber in Ecuador and Peru. The name chuchao is preferred as it originated in Ecuador, where the plant is native, and designates this one species, whereas the other names originated in countries farther north, where they also apply to other species.

Chuchao has a very short trunk, bearing leaves openly concave or nearly flat, 50 to 70 inches (120 to 170 cm.) long and 4 to 6 inches (10 to 15 cm.) wide, narrowed at the base, but the narrow portion not elongated as in fique. The marginal prickles are hooked mostly upward and are $\frac{1}{5}$ to $\frac{1}{3}$ inch (5 to 8 mm.) long and $\frac{3}{5}$ to $\frac{4}{5}$ inch (15 to 20 mm.) apart. The ovoid conical bulbils (fig. 34), borne on the flower stalks, often produce small leaves before falling.

Chuchao grows in eastern Peru and in Ecuador and is abundant in many places from near sea level to the high passes in the Andes. It has been cultivated and the fiber extracted as a household industry in Ecuador from the earliest recorded times. The best fiber comes from Ibarra, north of Quito, where it is carefully prepared, but the plants are more abundant farther south in the region of Riobamba and Ambato.

The fiber is prepared mostly by hand, but in some places raspadors are used. It is necessary to crush the bases of the leaves to obtain the best results with raspadors. The fiber is 40 to 60 inches (100 to 150 cm.) long, finer and more flexible than henequen, lustrous and of good strength when well cleaned from the freshly cut green leaves, but dull and rather brittle if the leaves are rotted in water to reduce the work of scraping away the pulp.

Practically all of the chuchao fiber produced is used in the home industries in Ecuador in the manufacture of twines, rope, pack-saddle blankets, saddle girths, and sacks. About 1911 an experimental shipment of chuchao fiber was sent to the United States where it was made into binder twine of very satisfactory quality.

Chuchao fiber has not been exported regularly and is not quoted in the fiber markets. Cordage and twine manufacturers who have examined the fiber state that, if well prepared, it should command a price about equal to that of henequen. Chuchao, as it grows in Ecuador, is regarded as promising for fiber production on a larger scale, provided machines can be adapted to prepare the fiber as efficiently as sisal and henequen are now prepared.

COCUIZA

(Amaryllis family)

Furcraea humboldtiana Trel.

Furcraea geminispina Jacobi.

Agave (*Furcraea*) *cubensis* Humb.

The cocuiza plant is called cocuiza brava or simply cocuiza or cocuisa and sometimes maguey de cocuiza. The fiber is generally called cocuiza.

Mature cocuiza plants have trunks 3 to 9 feet (1 to 3 m.) high. The leaves are nearly flat, 40 to 70 inches (100 to 175 cm.) long, 4½ to 6 inches (12 to 15 cm.) wide near the middle, and about 3 inches (8 cm.) wide by 1½ inches (4 cm.) thick near the base. They are light green or grayish on both sides, rough on the back and on the face near the base. The marginal prickles, ⅗ to 2 inches (15 to 50 mm.) apart, are mostly in pairs hooked in opposite directions near the base of the leaf, and farther up on the margins the prickles are often single and pointing upward. This species may be identified usually by the twined prickles.

Cocuiza plants are abundant in many localities, chiefly in well-drained limestone lands from the coastal plains to an altitude of about 4,000 feet (1,200 m.) in Venezuela. The plant grows wild in many States of the Republic of Venezuela, particularly in Carabobo, Yaracuy, and Lara. It is plentiful on the hills around Caracas. It has not been reported outside of Venezuela.

About 2,000 acres (800 hectares) of cocuiza are cultivated chiefly in Lara. On these cultivated plantations the leaves are harvested twice a year, yielding about 880 pounds an acre (600 to 1,000 kilos of fiber per hectare) annually. The leaves are generally run through a crushing machine, which removes most of the pulp. The fiber is then washed in water and spread on wooden platforms to dry in the sun. The fiber is about the same length as henequen, somewhat finer, and lustrous and strong if well cleaned.

The annual production of cocuiza fiber in Venezuela is estimated at 2,200,000 (1,000,000 kilos). It is used in that country chiefly in the manufacture of sacks, twines, ropes, and halters.

PITRE

(AMARYLLIS FAMILY)

Furcraea hexapetala (Jacq.) Urb.

Furcraea cubensis (Jacq.) Vent.

The name pitre (peé-tray), which is used to designate this plant in Haiti, is taken as the common name, although it is too nearly like piteira, *Furcraea gigantea*, to be quite satisfactory. The fiber is often called pita in Haiti, but the name pita is used in many places to designate different kinds of fibers. The plant, and sometimes the fiber, is called cabulla in the Dominican Republic and maguey in Cuba, but these names are used also for other plants. This is believed to be the species called henequén or jenequén by Oviedo in his Historia general de las Indias, published in 1535.

The pitre plant has a very short trunk bearing smooth, bright-green, narrow, flat leaves, 40 to 70 inches (100 to 175 cm.) long and 2¼ to 4 inches (6 to 10 cm.) wide, and nearly cylindrical for 8 to 12 inches (20 to 30 cm.) above the base. The margins, except near the apex, bear prickles or nearly straight teeth, sometimes hooked at the end, $\frac{2}{25}$ to $\frac{4}{25}$ inch (2 to 4 mm.) long and ⅗ to 1 inch (15 to 25 mm.) apart. The flower stalk, 15 to 30 feet (5 to 10 m.) tall, bears flowers in abundance, followed by a much smaller number of bulbils and seed pods. This species may be distinguished from other furcraeas by the long, narrow, flat leaves with small prickles projecting straight out from the margins.

Pitre grows in dry limestone soils, often in partial shade, where the rainfall is from 20 to 30 inches (50 to 75 cm.) in Cuba, Haiti, and the Dominican Republic. It has not been recorded as native anywhere on the mainland.

The pitre plant is not cultivated. The fiber is prepared by hand, chiefly by beating, scraping, and washing. Fiber of inferior quality has been produced by rotting the leaves in sea water so that the pulp can be scraped away more easily.

The fiber is finer, softer, and more flexible than henequen. It is lustrous and of good strength if prepared from freshly cut green leaves that have not been rotted in water.

Most of the pitre fiber is used in hand-made twines, mats, sacks, halters, and other domestic articles. It has been exported from Port de Paix under the name pita, but not in sufficient quantities to establish market quotations.

The narrow pitre leaves, not thicker than henequen, probably could be treated with machines designed for henequen and sisal, but it might be difficult to propagate the plant in sufficient numbers because of the small number of bulbils produced.

YUCCA AND RELATED PLANTS

About forty different species are recognized as belonging to the genus *Yucca* and to the closely related genera *Samuela*, *Hesperaloe*, and *Hesperoyucca*. Nearly all these are native to the southern United States or northern Mexico. Two or three species are found also in Central America.

In Mexico the name palma is used to designate yuccas as well as palms. In the United States the smaller species are called beargrass and most of the larger ones Spanish-bayonet and Spanish-dagger.

All of the yuccas have long slender leaves containing fiber, and many of them have been used for fiber production in a primitive way when commercial twines were not available. Palma barreta and palma pita are regularly used for commercial fiber production in Mexico, and efforts have been made to develop fiber production on a commercial scale with other species. Most of the yuccas grow very slowly in arid or semiarid regions. Unlike the agaves and furcraeas, most of the yuccas continue to live after flowering.

COMMON YUCCA

(LILY FAMILY)

Yucca filamentosa L.

Common yucca is the Eve's thread or Adam's needle of old gardens, and it is one of the species commonly called beargrass. The early settlers in Virginia called it silk grass. It is abundant in sandy soils in many places, from Virginia to Georgia and Alabama. The flat green leaves are 12 to 28 inches (30 to 70 cm.) long and 3/4 to 1½ inches (2 to 4 cm.) wide, with numerous white or gray filaments on the margins. The flower stalks are 3 to 6 feet (1 to 2 m.) high, bearing many cream-white flowers. Because of its flowers, the species is cultivated extensively as an ornamental plant.

The farmers in the regions where this yucca grows abundantly sear the leaves over fire and use them in place of twine to hang up hams and shoulders in the smokehouse. Since 1920 this species has been introduced into Germany, where efforts have been made to develop it into a hard-fiber-producing plant adapted to the climate of that country.

The fiber is 10 to 20 inches (25 to 50 cm.) long and is finer than most hard fibers now on the market. Thus far the fiber has not been produced in commercial quantities, and no regular uses have been established for it.

SOAPWEED YUCCA

(LILY FAMILY)

Yucca glauca Nutt.

Yucca angustifolia Pursh.

Soapweed yucca is so called because of the abundant saponaceous matter in its short rootstocks. It is more often called beargrass in the region where it grows, from northern Texas and northern New Mexico to the Badlands of western South Dakota. It is increasing in abundance in sandy soils on overstocked ranges (fig. 35). Its leaves, arising in large clusters from rootstocks, are 16 to 32 inches (40 to 80 cm.) long, about 3/8 inch (1 cm.) wide, and nearly triangular in cross section.

Its fiber is finer and softer than other hard fibers now in use. It was used extensively as a substitute for jute in bagging to cover cotton bales when conditions during World War I made it impossible to obtain adequate supplies of jute from India. The methods used for preparing the fiber at that time were too expensive for economic use in competition with jute and other fibers under normal conditions. The fiber is too short and weak for high-grade twines, but if it could be prepared cheaply enough it might be used in low-grade twines and upholstery.

PALMILLA

(LILY FAMILY)

Yucca elata Engelm.

Yucca radiosa Trel.

The palmilla is abundant in sandy soils, from western Texas across southern New Mexico to southeastern Arizona, and on the plains of northern Chihuahua in Mexico. The mature plants have trunks 3 to 15 feet (1 to

FIGURE 35.—Soapweed yucca; well-developed plants, with leaves 20 to 28 inches (50 to 70 cm.) long, in sandy soil near Tucumcari, N. Mex.

FIGURE 36.—Palmilla; large branching plants in land occasionally irrigated. Tucson, Ariz.

5 m.) high, mostly simple, but the larger ones often branching (fig. 36). The main trunk or the branches terminate in dense clusters of narrow, white-margined leaves 12 to 24 inches (30 to 60 cm.) long and about 3/8 inch (1 cm.) wide.

The trunks are shredded and fed to stock in times of drought, but the leaves have very little food value and stock rarely eat them. The fiber is fine and similar to that of the soapweed yucca. This palmilla fiber was also used as an emergency substitute for jute in the manufacture of bagging for covering bales of cotton in the first World War. Since then it has been extracted by crushing and washing processes and prepared for use as upholstery tow.

BANANA YUCCA

(LILY FAMILY)

Yucca baccata Torr.

The banana yucca is often called the blue-leaved yucca to distinguish it from the Mohave yucca with green leaves, growing in the same region. The dark blue-green leaves, arising in scattered clusters from creeping rootstocks (fig. 37), are rigid, 20 to 50 inches (50 to 125 cm.) long, and about 1½ inches (4 cm.) wide; many are curved sidewise. The fruits are fleshy and 4 to 6 inches (10 to 15 cm.) long, suggesting the name banana yucca.

FIGURE 37.—Banana yucca plants, with leaves about 3 feet (1 m.) long, on dry limestone land near Ledge, Calif.

The banana yucca grows in gravelly or rocky soils at altitudes about 7,500 feet (2,500 m.) above sea level, or higher than most other yuccas, from eastern California across northern Arizona to northern New Mexico.

Fiber from the banana yucca is 15 to 40 inches (40 to 100 cm.) long, about as coarse as henequen or sisal, and rather stiff as prepared. It is not produced in commercial quantities.

MOHAVE YUCCA

(LILY FAMILY)

Yucca mohavensis Sarg.

The name mohave yucca is also spelled Mojave, which is likewise pronounced mohave. The plant is also called the green-leaved yucca to distinguish it from the blue-leaved banana yucca, near which it grows in some parts of its range.

FIGURE 38.—Mohave yucca, from which leaves are being cut for fiber production near Ledge, Calif.

The mohave yucca develops a trunk usually 3 to 6 feet (1 to 2 m.) high and usually simple, or sometimes up to 12 feet (4 m.) high, with short branches. The simple trunk or branches bear at the top 50 to 75 coarse, rigid, light-green, smooth leaves 24 to 40 inches (60 to 100 cm.) long and 2 to 2¾ inches (5 to 7 cm.) across the curved back (fig. 38).

This species grows on the mountainsides and dry upland plains, from northern Arizona, across southern California, especially on the mountains surrounding the Mojave Desert, to the northern part of Baja California. It is generally scattered, but is most abundant at altitudes a little lower than those at which the banana yucca is found.

The fiber of the mohave yucca is similar to that of the banana yucca but is a little finer, softer, and weaker. Soon after the first World War, when prices were abnormally high, fibers from the leaves of both of these yuccas were extracted and prepared by mechanical processes at Ledge, Calif., and by combined chemical and mechanical processes at Kingman, Ariz. The fibers produced were inferior in quality to henequen from Yucatán, and the processes used were much more expensive and less efficient than those used for henequen. The simple mechanical treatment, consisting of crushing, scraping, and combing, gave better results than the chemical treatment.

PALMA PITA

(LILY FAMILY)

Yucca treculeana Carrière.

The names palma pita and pita palma are used to designate this plant and its fiber. The plant is called palma de dátiles because of its fleshy fruit, and palma loca, a name often used to designate other tree yuccas that are scattered in northern Mexico. It is also called Spanish-bayonet.

The palma pita has a trunk 3 to 15 feet (1 to 5 m.) high, simple or sparingly branched. The thick, concave, sharp-pointed leaves are bluish green with brown margins, and 35 to 50 inches (90 to 125 cm.) long and 1 to 2 inches (3 to 5 cm.) wide.

Palma pita grows in the States of Chihuahua, Durango, Coahuila, Nuevo León, and Tamaulipas, Mexico, chiefly in sandy soils, in a semiarid climate.

The coarse fiber is cleaned from the leaves by hand, chiefly by beating and scraping. Sometimes the leaves are steamed to soften the pulp so that it may be scraped away more easily. Most of the fiber produced is used locally in twines, cordage, and coarse sacking.

PALMA BARRETA

(LILY FAMILY)

Samuela carnerosana Trel.

In the States of Coahuila and Zacatecas, Mexico, the palma barreta is called also palma samandoca, or palma zamandoque. The name date yucca has been proposed because of its fleshy fruits. In Mexico the fiber is called istle, and in the fiber markets outside of Mexico it is usually called palma istle because of certain processes in its preparation, though it is unlike Tula istle or Jaumave istle.

The palma barreta first is a rosette of leaves arising from the ground and later develops a trunk 5 to 20 feet (1.5 to 6 m.) high, simple or rarely branched (fig. 39). The leaves are dark, dull green, 24 to 44 inches (60 to 110 cm.) long, 2¼ to 3 inches (6 to 8 cm.) wide, and ⅛ to ¼ inch (4 to 7 mm.) thick, concave, rigid, and rounded to a sharp point, with coarse brown curled fibers projecting out of the margins near the point. The flower stalk, about 3 feet (1 m.) long, bears many large cream-white flowers, followed by fleshy fruits 2 to 3 inches (5 to 8 cm.) long and 1½ inches (4 cm.) in diameter. The flowers and the sweet but somewhat bitter fruits are eaten by people as well as by wild and domestic animals.

Palma barreta grows abundantly, forming veritable forests in the high mountain valleys, 6,000 to 9,000 feet (2,000 to 3,000 m.) above sea level, around Saltillo and Monterrey, Mexico, where there are light frosts and snow almost every winter. The species has been reported from the States of Coahuila, Nuevo León, Zacatecas, and San Luis Potosí, Mexico.

Palma barreta is not cultivated. The leaves for fiber production are collected from plants growing wild. The pulp in the older, outer leaves is too firm and hard to be scraped away by hand; therefore most of the fiber is obtained from the young leaves, which form the central bud, or cogollo. A ring on a long handle is slipped over the spindle-shaped bud and given a sharp jerk, breaking out the cogollo in the same manner that the cogollos of lechuguilla are collected for the production of istle fiber. These palma barreta cogollos, resembling large ears of green corn in the husk, are steamed about 12 hours over crude vats to soften the pulp (fig. 40). They are then separated into their constituent leaves, and the pulp is scraped away by drawing each leaf, first one end and then the other, about five times under a knife pressed against

FIGURE 39.—Palma barreta; fiber is obtained from the young leaves forming the central bud, or cogollo. Carneros Pass, south of Saltillo, Mexico.

FIGURE 40.—Palma barreta fiber production; plants abundant on hills in background; trunks of palma barreta for burning in the crude stone furnace to steam the cogollos, at right, which are separated into fiber-yielding leaves, in center; these leaves are drawn under a knife by the man sitting on the ground. Carneros Pass, Mexico.

a block of wood. The fiber is dried in the sun, then tied into bundles to keep it straight, and packed into hand-made bales for shipment to market.

A machine that crushes the leaves and scrapes away the pulp of even the older, outer leaves, without the necessity of steaming them, has been used for preparing this fiber.

Some of the palma fiber is used in Mexico in hand-made twines, sacks, and brushes, and it is also exported to the United States and to Europe to be used in twines, especially unoiled twines for tying bundles of papers. Some of it is dressed and used in brushes. It is softer and much less resilient than Tula istle or Jaumave istle for brushes. It is quoted in the fiber market of New York at 3 to 5 cents a pound (about 6½ to 11 cents, United States currency, per kilo).

ZAMANDOQUE

(LILY FAMILY)

Hesperaloe funifera (Koch) Trel.

The Zamandoque plant is also called samandoca, and its fiber is called ixtli or Tampico fiber.

Zamandoque is different in appearance from most yuccas. Its leaves, 5 to 7 feet (1.5 and 2 m.) long and 1½ to 2¼ inches (4 to 6 cm.) wide, grow singly or two or three together, nearly erect, and scattered along creeping rootstocks.

Zamandoque grows wild in sandy plains in the States of Chihuahua, Nuevo León, and Tamaulipas, in northern Mexico, and is cultivated commercially in Nuevo León.

The leaves are collected and steamed to soften the pulp. Most of the leaves are so long that a tallador, or Mexican fiber cleaner, sitting on the ground, cannot pull the entire leaf under the scraping knife at one motion. It is the common practice, therefore, to cut the leaves in two. The pulp is scraped away by drawing the leaves by hand under a knife pressed against a block of wood. A fiber of better quality might be produced by crushing instead of steaming the leaves before scraping away the pulp. The pulp is so hard and firm that it could not be scraped away without being either steamed or crushed.

Zamandoque fiber is used chiefly in twine and coarse sacking.

CHAPARRAL YUCCA

(LILY FAMILY)

Hesperoyucca whipplei (Torr.) Baker.

Yucca whipplei Torr.

Chaparral yucca, the most beautiful of all the yuccas, grows in abundance in limited areas in the San Bernardino Mountains and Coast Range in southern California, and south into Baja California. It is often called flowering yucca because of the gorgeous cream-white, fragrant flowers, borne in great abundance on the erect flower stalks 12 to 20 feet (4 to 6 m.) high. The blue-green, straight, rigid, sharp-pointed leaves about 3 feet (1 m.) long, grow out from a trunk 8 to 20 inches (20 to 50 cm.) high, shaped like a large pineapple. The plant usually dies after flowering.

Fiber obtained from the leaves is white, nearly 3 feet (1 m.) long, similar in texture to henequen, and nearly as strong. This fiber has been produced on a small scale almost continuously since 1919. If this fiber production is expanded without efficient methods for propagating and cultivating the slow-growing plants, the species will soon be exterminated in its limited range. Its value as an ornamental plant is greater than the value of the fiber that might be obtained from it.

PITA FLOJA

(PINEAPPLE FAMILY)

Aechmea magdalenae André.

Chevalliera magdalenae André.
Ananas magdalenae (André) Standl.
Bromelia magdalenae (André) C. H. Wright.

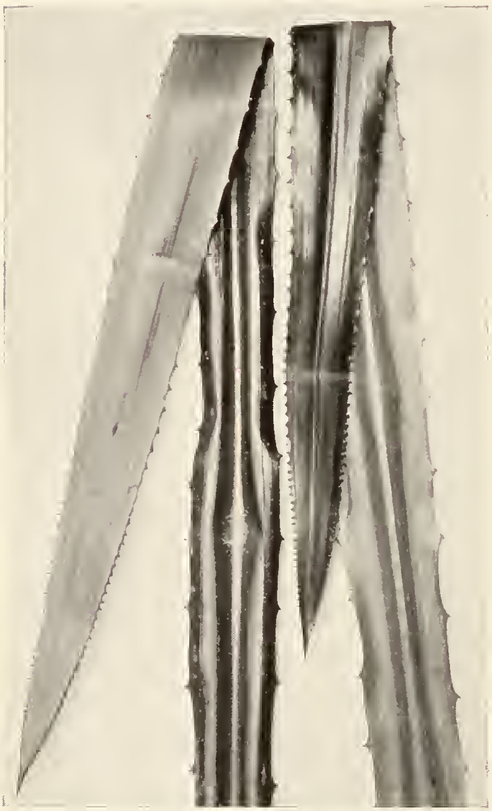

FIGURE 41.—Pita floja leaves showing prickles hooked downward on lower part of leaf and closer together and pointing outward or upward on the upper half. Leaves from Guatemala.

The pita floja plant, which is well known by local common names in many regions from southern Mexico to Ecuador, has been placed by botanists in four different genera within the past 40 years. It is now generally agreed that the correct botanical name is *Aechmea magdalenae*. In addition to the three other names, originally considered valid, the plant has been misidentified as *Ananas macrodontes* E. Morr., and *Karatas plumieri* E. Morr. Pita floja and more often simply pita are the names commonly used to designate the plant and its fiber, but pita alone is used to designate other fibers. The name arghan was adopted as a trade name by a London company that attempted to exploit this fiber without permitting its identity to be known. The plant has also been called wild pineapple, but this name is applied to other plants of the pineapple family. It is called silk grass in British Honduras.

The pita floja plant resembles a pineapple but is larger. The leaves, numbering 25 to 50 in a mature plant, are 7 to 10 feet (2 to 3 m.) long, 3 to 4¼ inches (8 to 11 cm.) wide, and 1/25 to 3/25 inch (1 to 3 mm.) thick, dark green and shining on the face, and silvery white on the back. The leaves are flat, even when dry, except at the channeled base. The margins of the leaves bear hooked prickles 1 to 2 inches (30 to 50 mm.) apart, hooked downward on the lower half of the leaf and closer together and pointing outward or upward on the upper half (fig. 41). The flowers are produced in heads like pineapples but not fleshy, sometimes borne singly but more often in groups of two to four on a stalk 8 to 12 inches (20 to 30 cm.) high (fig. 42). The flower clusters are surrounded by red or rose-colored bracts. Seeds are produced irregularly. Numerous suckers are produced from the creeping rootstocks, and these are the principal means of propagation, enabling the plant to occupy all the ground to the exclusion of other vegetation.

The pita floja plant grows generally in dry alluvial soils at low altitudes, from the coast region of Veracruz and Tabasco, in Mexico, through all of the countries of Central America, and from Colombia to Ecuador in South America. It grows sometimes in areas that are overflowed during brief periods of high water, but not in swamps or poorly drained soils. It is reported as growing in the open sunlight in the coast region of Costa Rica, but it generally forms a dense undergrowth in open forests where it is partly shaded. In Colombia these pita floja thickets, often many acres in extent, are called pitales. The plant grows so abundantly in the wild state that no attempt has been made to cultivate it in quantity in America. Efforts to cultivate the plant under unfavorable conditions in the Federated Malay States resulted in failure.

For many years, in places where the plants are abundant, the natives have prepared the fiber for local uses, especially for sewing leather, suggesting the name pita floja, or thread fiber. In some places the base of the leaf is beaten, exposing the ends of the fibers. These are picked out with the thumb and fingernail, and are then torn out entire and nearly clean from the back of the leaf, which is less firm and resistant than the face. In some places the full length of the leaf is beaten with a club to soften the pulp, which is

FIGURE 42.—Pita floja fruit from the Canal Zone.

afterward scraped away and the fiber washed. Sometimes the leaves are rotted in water to soften the pulp, which is then more easily scraped away; but this lazy-man's process results in a discolored and brittle fiber of inferior quality.

Since 1918 several companies have been organized to prepare pita floja on a commercial scale. Several kinds of machines have been tried. Although commercial success has not been fully attained, much progress has been made toward an efficient mechanical method for preparing the fiber. In order to produce fiber of good quality, the fiber must be extracted from the freshly cut green leaf.

Pita floja is very much like piña, which is produced from pineapple leaves in the Philippine Islands. When properly prepared, it is light-cream white, with good luster, and 5 to 8 feet (1.5 to 2.5 m.) long. It is finer and more flexible than any of the hard fibers now in general use. When tested on silk-testing scales, the strands of pita floja were found to have a breaking strain of 3 to 6.1 g. per denier and an elasticity of 1.8 to 2.5 percent. By another test the strands showed a breaking strain of 50 kilometers. This means that the breaking strain is equal to the weight of 50 kilometers of the fiber itself. This may be compared with 23 kilometers for cotton, or 31.8 for abacá. It contains 75 percent cellulose, which is more than that recorded for any other hard fiber.

The ultimate cells of which the pita floja strands are composed are $\frac{1}{16}$ to $\frac{1}{4}$ inch (1.7 to 6.1 mm.) in length, very slender, with long-pointed ends, narrow lumen, and relatively thick walls. These characters indicate that they are well adapted to the manufacture of strong tissue paper, and this has been further demonstrated by experiment.

Pita floja fiber is very resistant to deterioration in sea water and is used by the natives for fishlines and nets. It is used for sewing leather in saddles, belts, and especially fancy leather articles. It has been spun experimentally on flax-spinning machinery. When further supplies of the fiber are available for more extensive trials, many uses may be found for it in twines and fabrics requiring strength and durability.

Because of the peculiar characteristics of the pita floja fiber, especially its strength and its resistance to injury from sea water, and the abundance and rapid growth of the pita floja plants, this may be regarded as one of the most promising hard fibers not yet in general commercial use.

PHORMIUM

(LILY FAMILY)

Phormium tenax Forst.

The phormium plant and its fiber are generally known by the misleading English names "New Zealand flax" and "New Zealand hemp," but both plant and fiber are very unlike either flax or hemp. In South America, where the plant has been introduced, it is called formio. One of the common names for the plant in New Zealand is harakeke lily.

The plant is a perennial, growing from short rootstocks that send up fan-shaped clusters of leaves (fig. 43). The leaves are 5 to 13 feet (1.5 to 4 m.) long and $2\frac{1}{4}$ to 4 inches (6 to 10 cm.) wide, V-shaped at the base, but nearly flat above. Some varieties have leaves with a red midrib and red margins. These red marks on the leaves sometimes appear as scarlet threads in the fiber.

The harakeke lily is native to certain parts of New Zealand, where the temperature is remarkably uniform, rarely rising above 65° F. or falling much below freezing. It grows mostly in marshes or on reclaimed swamplands where water does not often stand on the surface but where the level of free water in the soil is not more than 3 feet below the surface and the soil is rich in nitrogen. Some varieties grow well on uplands, in soils well supplied with humus. A few fields of harakeke lily have been set out and cultivated in New Zealand, but most of the leaves for fiber production are cut from plants that are left when other vegetation is cleared out of the marshes. Harakeke plants have been introduced into the Azores and into the island of St. Helena. They have also been introduced on islands belonging to Argentina in the Rio de la Plata, and into the region of Valdivia, in Chile. Efforts have been made to grow the plant in the United States, but the winters are too cold and the summers too hot for it (fig. 44): in limited areas where the temperature is more equable, there is not sufficient moisture nor sufficient humus in the soil.

In New Zealand, where the fiber is produced commercially, it is prepared by rather tedious and laborious processes.

The outer leaves of each fan are cut separately by hand, leaving the younger middle leaves to continue growing. The long limp leaves, more difficult to handle than the shorter stiff leaves of

FIGURE 43.—Phormium or harakeke lily in flower; fiber is obtained from the leaves. Botanical garden, Berkeley, Calif.

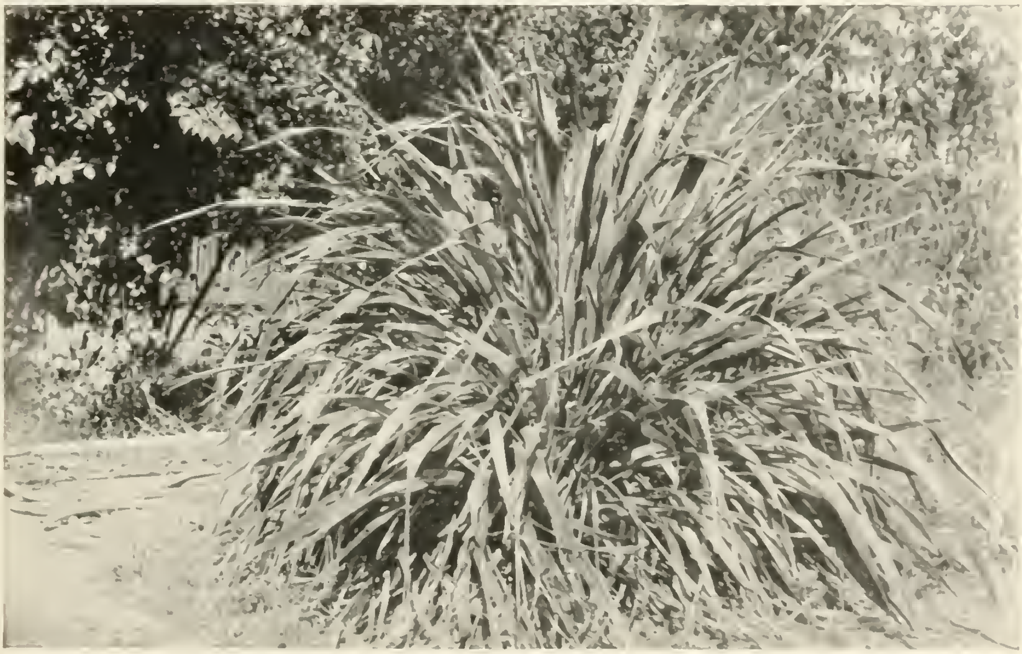

FIGURE 44.—Phormium plant with leaves thin and shriveled by hot weather, although it has been well supplied with moisture by spraying and irrigation. Chico, Calif.

henequen, are tied in bundles and taken to the "flax mills," where the fiber is cleaned. The leaves are put through a crushing machine, after which the fiber is washed in running water and spread on the grass to dry and bleach. After being taken back to the mill and scutched with revolving drums, it is inspected and the poorly cleaned portions are removed, and finally the finished fiber is baled for market.

The yield of clean dry fiber is 10 to 15 percent of the weight of the green leaves, which is much larger than the yield of other commercial fibers.

Phormium fiber is light tan to nearly white and 5 to 8 feet (1.5 to 2.5 m.), rarely as much as 10 feet (3 m.), long. It is longer than other commercial hard fibers except abacá ("manila hemp"). A test of phormium of good quality showed a breaking strain of 26,159 gm. per gram-meter, which may be compared with 20,021 for Yucatán henequen, or 32,773 for East African sisal. It is softer than sisal or henequen and lighter in weight per unit length of strand. It is composed chiefly of lignocellulose, with a cellulose content of about 63 percent, about the same as that of jute. It does not retain its strength as well as other hard fibers with a higher cellulose content.

Phormium fiber is used chiefly in twines and coarse cordage. In New Zealand fiber of the better quality is hackled and spun into fine hard-fiber yarns that are woven into fabrics.

Phormium fiber production has not become established on a commercial scale anywhere in America. There are no areas in North America where the climate is favorable for the growth of the plant. Conditions in limited areas in Argentina and Chile appear to be more promising, though not yet fully proved on a commercial scale.

ABACÁ

(BANANA FAMILY)

Musa textilis Nee.

"Manila hemp" is a name commonly used for both the plant and fiber of abacá, but the plant is not grown for fiber production near Manila, and the fiber is very different from true hemp. Abacá is a Malay name used to designate the plant and fiber before Europeans went to the Philippine Islands. Abacá is included in this publication because it is the most important hard fiber, and experiments have demonstrated that it may be produced in the American Tropics.

Abacá resembles the common cultivated banana plant, to which it is closely related. It is a perennial plant growing from short rootstocks. Numerous suckers grow up from the rootstocks, forming a cluster of stalks 10 to 20 feet (3 to 6 m.) high. These have green false trunks, 6 to 12 inches (15 to 30 cm.) in diameter, composed of broad overlapping leaf stems, which bear at the top spreading leaf blades 3 to 6 feet (1 to 2 m.) long and nearly 12 inches (30 cm.) wide (fig. 45). The oldest leaf stems are on the outside, and each successive younger one is pushed up on the inside. The point of growth is at the base. The fiber is near the outer surface of each successive leaf stem. Finally a flower stalk about 2 inches (5 cm.) in diameter is pushed up through the center, bearing at the top flowers, followed by green fruits similar to bananas but smaller and filled with black seeds instead of edible pulp. Abacá plants grown from

FIGURE 45.—Abacá plant growing well in fertile soil in the warm moist climate of western Panama, where it was introduced from the Philippine Islands in 1925.

seeds do not come true to type. The plants are propagated from suckers or from rootstocks in the same manner as bananas.

Abacá requires a continuous warm moist tropical climate. In the Philippine Islands as far north as Manila (about lat. 15° N.) the plants do not grow well. They have not grown well in northern Honduras or near the northern coast of Cuba; but in western Panama, where there is abundant moisture and warm weather throughout the year, they have made excellent growth. At the Plant Introduction Garden at Summit, in the Canal Zone, irrigation is required for the abacá plants. A small plot of less than 200 plants has grown well at the Federal Experiment Station at Mayagüez, P. R., in a ravine protected from drying winds, with a rainfall of about 45 inches (115 cm.). The plants require a fertile soil of rather loose texture affording good drainage. They will not endure either swampy conditions or drought. Strong winds are injurious, for the large leaves are easily whipped into shreds.

Abacá is native to the Philippine Islands. It is cultivated for fiber production in many places, from the southern part of the island of Luzon to the southern part of Mindanao. It has been introduced into Java, Sumatra, Celebes, Borneo, and the Andaman Islands. Since 1900 there have been at least a half dozen attempts to introduce it into the American Tropics. The largest and most successful introduction was made by the United States Department of Agriculture in 1925, resulting in an experimental plantation of 6 to 8 of the best varieties in the vicinity of Almirante, in western Panama. Abacá plants have been sent to the experiment station in Trinidad and also to Brazil, but thus far abacá fiber has not been produced in commercial quantities in America. Abacá fiber produced experimentally in Panama has been made into rope fully equal to rope made from abacá fiber from the Philippine Islands. It has been demonstrated that the plants grow well under suitable conditions in the American Tropics and that they yield fiber of excellent quality.

The first stalks for fiber production are harvested from the abacá plants about 2 years after the suckers are set out. Only the largest stalks are cut, leaving the others to continue growing. The entire trunk is cut down, and the leaf blades are cut off at the top. The trunks weigh from 35 to 120 pounds (15 to 50 kilos) or even more. They yield only about 2 to 3 percent of their weight in clean dry fiber; so it is not economical to transport them very far.

The fiber is prepared, usually by hand, from freshly cut green stalks. The fiber-bearing outer layer of each leaf stem is stripped off in ribbons, called tuxies, 2 to 3 inches (5 to 8 cm.) wide and $\frac{1}{12}$ to $\frac{1}{6}$ inch (2 to 4 mm.)

FIGURE 46.—Stripping abacá by pulling the tuxie under a serrated knife pressed against a block of wood by means of a spring pole. Province of Albay, P. I. Photograph from Philippine Bureau of Science.

thick. The tuxies from the outer leaf stems, yielding brownish fiber, and those from the inner leaf stems, yielding finer and whiter fiber, are kept separate. These tuxies are pulled by hand under a finely serrated knife pressed against a block of wood by means of a spring pole (fig. 46). This process usually scrapes away all of the pulp at one pulling. The fiber is dried in the sun, then made up into bundles and taken to a warehouse, where it is sorted into grades, inspected, and certified by fiber inspectors of the Philippine Government, and baled for market.

In some places a small machine is used. The workman using this machine places a tuxie under the knife, which is pressed down by weights or springs, and holding one end of the tuxie, gives it a turn around a revolving spindle and pulls it enough to make the loop cling to the spindle and draw the tuxie under the scraping knife. These machines, sometimes operated by water power, relieve the workman from the strenuous labor of pulling the tuxies under the knife.

On two or three large plantations in the Philippine Islands and in Sumatra, large machines, similar to those used for cleaning sisal, are used. In these machines sections of the abacá trunks are fed sidewise. The trunks are cut into pieces not more than 70 inches (180 cm.) in length, and these are split usually in quarters. The coarse brownish fiber from the outer-leaf stems is mixed with the finer white fiber from the interior unless the outer-leaf stems are taken off and kept separate, as is done in cleaning by hand or with the smaller machines. The fiber prepared by these large machines is classified separately, and in the Philippine Islands it is called deco.[4]

The total production of abacá fiber ranges from about 150,000 to 200,000 tons per annum. There are some 16 recognized grades, based chiefly on texture, cleaning, and color. The quotations in the New York fiber market for these various grades range from about 4 to 15 cents a pound (8.8 to 33 cents per kilo).

The principal consuming countries are Great Britain, Japan, and the United States. Abacá is used in 18 cordage mills in the United States and in many other mills in Canada, Cuba, Mexico, and South America. It is used more than all other fibers combined in marine cordage, well-drilling cables, hoisting ropes, transmission rope, tent cordage, and hay ropes and in all coarse cordage requiring strength, durability, and reliability.

In the Philippine Islands some of the best abacá is combed and the fibers are drawn out one by one and tied end to end, making a continuous long strand called knotted abacá. These strands are woven on hand looms into fabrics called sinamay and tinampipi that are used in clothing and especially in children's dresses. The knotted abacá is also braided into 13-strand braids about 1/8 inch (3 mm.) wide, which are exported to America to be sewed up into so-called "hemp hats" for women's wear.

Abacá is used extensively in Japan in making strong paper for the movable partitions in the homes. In recent years it has been used in increasing

[4] A large machine installed in Panama in 1942 is turning out clean dry abacá fiber at the rate of 1,000 pounds per hour.

quantities in the United States in the manufacture of fine strong tissue paper. Worn and discarded abacá rope (manila rope) is made into rope manila paper, a very strong paper used in sacks for flour, cement, lime, and similar materials.

Abacá is a multicellular long fiber consisting of cylindrical strands of fibro-vascular bundles. The strands are 7 to 14 feet (2 to 4 m.) long, or even up to 20 feet (6 m.) in special samples, and 1/125 to 1/25 inch (0.2 to 1 mm.) in diameter. The ultimate cells composing the strands are 1/8 to 1/2 inch (3 to 12 mm.) long and 16μ to 32μ in diameter, with a mean ratio of about 250.

Numerous tests indicate that abacá is the strongest fiber regularly used in the manufacture of cordage. In one series of tests the breaking strain per gram-meter of different samples of abacá ranged from 29,000 to 75,000 gm., with an average of 45,000 gm. This may be compared with 33,000 gm. for Hawaiian sisal and 20,000 gm. for Yucatán henequen. In another series the breaking strain per square millimeter of abacá was computed to be 91,430 gm., as compared with 31,458 gm. for cotton. Rope made of abacá lasts longer than rope made of other fibers. It absorbs water very slowly and is resistant to injury from salt water.

Palm and Palmlike Fibers

Most of the various kinds of fibers obtained from palm and palmlike trees are essentially hard fibers, but many of them differ from ordinary hard fibers in their development in the plant as well as in methods of preparation and characters, and in uses. They are therefore treated as a separate group.

Fibers or fibrous materials have been obtained from a great many different species of palms native to the American Tropics, but only a few are definitely recognized as yielding fiber in commercial quantities. The most important uses of palm fibers in America are in the manufacture of brushes and brooms, hats, baskets, and mats. The leaves of several species of palms are used locally for thatching houses and other buildings.

Most of the trees from which these fibers are obtained are readily recognized as either fan palms, like the palmettos, or pinnate palms, like the coconut palm. The terms "piassava" and "bass" are often used to designate general types of long coarse fibers obtained from leaf stems of various kinds of palms.

Included in the group is the fiber used in making the so-called "panama" hats, which is obtained from the toquilla plant, *Carlodurica palmata*, a palmlike species belonging to the screwpine family.

BAHIA PIASSAVA

(Palm family)

Attalea funifera Martius.

The name Bahia piassava is also spelled piassaba and piacaba. It is called chiquechique in Venezuela.

Bahia piassava is a pinnate or feather-leaved palm tree, attaining a height of 30 to 40 feet (10 to 12 m.). The young plants have leaves 10 to 17 feet (3 to 5 m.) long, growing up from the ground in a nearly erect cluster, and much of the fiber is obtained from these leaves before the trunk has developed. This palm is not regularly cultivated but grows abundantly in sandy soils or sandy ridges in the restinga region in southern Bahia and northern Espirito Santo in Brazil and in more limited areas in Venezuela.

The trees bear leaves suitable for fiber production at the age of 6 to 9 years. The fiber is obtained from the leafstalks, either by grasping one or more fibers at the base and tearing them out through the back of the leafstalk or by crushing the leafstalk and combing out the fibers. A workman can collect about 65 pounds (30 kilos) of crude piassava fiber in a day.

The fiber is stiff, of firm texture, does not absorb water readily, is light to dark chocolate in color, and $1/25$ to $1/5$ inch (1 to 5 mm.) in diameter at the angular base, tapering to a slender strand at the upper end. This fiber is very durable and retains its resiliency even when wet.

The thicker bases of the fiber are used in coarse brooms and street sweepers and the finer portions in house brooms and scrubbing brushes. The finer and more flexible strands are used for hand-made twines in the regions where the fiber is produced.

It is roughly estimated that about two-thirds of the piassava fiber produced is graded and packed into bundles of 100 to 130 pounds (50 to 60 kilos) each for export. The annual exports of this fiber from São Salvador, the principal port of Bahia, range from about 40,000 to 75,000 bundles, or from about 2,000 to 4,500 long tons (2,000,000 to 4,500,000 kilos). In quantity, this is the most important fiber, except cotton, exported from South America.

PARÁ PIASSAVA

(PALM FAMILY)

Leopoldinia piassaba Wall.

The Pará piassava is called monkey palm and piassaba or piassaba palm, and its fiber is called monkey bass. In the markets it is usually called Pará piassava because it has been exported through the port of Belém, formerly called Pará.

Pará piassava has pinnate leaves 10 to 16 feet (3 to 5 m.) long with broad leaf stems. These stems of the old leaves hang down, covering the trunk, and are frayed into fibrous ribbons by the wind and weather. This palm grows mostly in sandy soils, sometimes subject to overflow, but not in swampy lands, along the tributaries of the Amazon above Manáos in Brazil, and along the Orinoco in Venezuela.

The long fibrous strands of the old leaf stems are collected and combed by hand. The fibers are 3 to 6 feet (1 to 2 m.) long and $1/8$ to $1/4$ inch (3 to 6 mm.) thick at the base, tapering to fine strands above. These fibers are softer in texture than Bahia piassava. They absorb water and do not retain their resiliency when wet. They serve best in brushes and brooms for uses where they will be kept dry. The natives in the regions where the Pará piassava grows use the fiber in ropes, baskets, hats, and for tying materials.

CABBAGE PALMETTO

(PALM FAMILY)

Sabal palmetto Roem. and Schult.

Inodes palmetto (Roem. and Schult.) O. F. Cook.

The cabbage palmetto is so-called because of its edible bud. It is sometimes called Carolina palmetto because it is

FIGURE 47.—Cabbage palmetto; the best palmetto fiber is obtained from leaf stems in the bud inside of the upper part of the trunk. South Island, S. C.

the only native tall palm growing in the Carolinas. The Seminole Indians call this palm tah-lah-kul-kee.

The cabbage palmetto is a fan palm with a trunk 20 to 40 feet (6 to 12 m.) high. When young the trunk is covered with the broad bases of the leaf stems, called boots (fig. 47). Later the lower part of the trunk is smooth, but the leaf stem bases, or boots, persist on the upper part, the upper ones being still green and alive long after the large leaf blades have died and fallen. The leaves are 3 to 10 feet (1 to 3 m.) in length and nearly as wide, and are recurved at the apex. The leaves are borne on long stems and are pushed up through the interior of the trunk from the base of the bud nearly 6 feet (2 m.) below the top. New leaves are pushed up inside of the circle of older ones. The palmetto is propagated from seeds, which are produced in such abundance that with reasonable care the supply may be kept up when the old trees are cut down for fiber production.

The cabbage palmetto grows chiefly in the coast region and on the coastal islands, from Florida nearly to Wilmington in North Carolina, but very sparsely north of Charleston in South Carolina. It is often planted as a street tree or as an ornamental tree in parks.

Brush fiber of the best quality is obtained from the young leaf stems 3 feet (1 m.) or more in length that have not yet emerged from the top of the trunk. The tree is cut down and the trunk split open to obtain these young leaf stems. If the trunk is cut above the base of the bud, the tree may live and develop a new top. Coarser fibers are obtained from the stems of fully developed leaves, and even from the live green boots or bases of leaf stems from which the blades have fallen. These are all crushed, combed, and brushed by means of small machines.

The prepared fiber is red tan, straight, nearly cylindrical 8 to 20 inches (20 to 50 cm.) long, $^1/_{50}$ to $^1/_{25}$ inch (0.5 to 1 mm.) in diameter, and fairly uniform. It is resilient and resistant to injury from water.

In the brush-fiber market this material is known as palmetto fiber. It is used either alone or mixed with other fibers, chiefly in scrubbing brushes and horse brushes. Some of the finer fiber goes into clothes brushes.

The leaves of the cabbage palmetto are split into narrow strips and made into brooms called palmaswepa. As the basal ends of the strips are the tougher, the outer ends are fastened to the handle of the broom so that the tough basal ends are subjected to wear in sweeping. The leaves are used also in making hats, mats, baskets, and various novelties for the tourist trade.

SCRUB PALMETTO

(PALM FAMILY)

Sabal etonia Swingle.

The leaves of the scrub palmetto, *Sabal etonia*, a fan palm without an upright trunk, widely distributed in the southeastern United States, are also used in making hats, baskets, and fancy articles.

COROJO PALM

(PALM FAMILY)

Acrocomia crispa (H. B. K.) C. F. Baker.

Acrocomia fusiformis (Swartz) Sweet

A strong, slender, ribbonlike fiber called pita de corojo is obtained from the leaves of the corojo palm. This is a pinnate palm native to the West Indies. It grows most abundantly in the savannas of central Cuba, forming forests called corojales.

FIGURE 48.—Corojo palm, showing swollen trunk; fiber called pita de corojo is obtained from the leaves. Santiago de las Vegas, Cuba.

The trunk of the corojo palm is swollen and covered with horizontal rows of dark-colored spines (fig. 48). There are also numerous fine needlelike spines about $^5/_8$ inch (20 mm.) long on the rachis and leaflets. These are flattened on one side and are yellow, or nearly white, with very sharp, dark-colored tips. Some of these fine slender spines are often present on the ribbonlike fiber. The fiber in this stage is light straw

FIGURE 49.—Yaray, or Puerto Rican hat palm; coconut palms in background. Joyuda, P. R.

FIGURE 50.—Young yaray palm. Joyuda, P. R.

color in flat ribbons 1/12 inch (2 mm.) or less in width. Most of the strands are remarkably strong, but the lack of uniformity in strength is a serious handicap in their commercial use. The flat ribbonlike strands contain fine white fibers, nearly as fine and soft as the coarser types of flax fiber. These are sometimes extracted by hand and spun by hand into yarns that are woven into fabrics. The flat corojo fiber, which is the more common form, has been used extensively in fly brushes called plumeros de pita. The fiber is also used in hand-made twines, ropes, and halters.

YARAY

(PALM FAMILY)

Sabal causiarum (O. F. Cook) Becc.

Inodes causiarum O. F. Cook.

The palm known in Puerto Rico as yaray is also called by the English name Puerto Rican hat palm.

Yaray is a fan palm with shiny green curved leaves attaining a length of 3 feet (1 m.) or more, borne on a stout smooth trunk 10 to 16 feet (3 to 5 m.) high (fig. 49). This palm, together with coconut palms, grows in abundance in limited areas in sandy soils on the west coast of Puerto Rico and on the east coast of the Dominican Republic. It is not regularly cultivated, but the growth of seedlings and young plants is encouraged (fig. 50).

The young leaves are collected while they are still folded in plaits in the bud. They are dipped in boiling water and afterward dried in the sun. The thin tough segments of the leaves are split into narrow strips and these are woven into hats, mats, baskets, and many useful and fancy articles. The width of the strips determines the fineness of the hats. The strips are flat and rather

FIGURE 51.—Making hats from strips of yaray palm leaves, a household industry in Cabo Rojo, P. R.

firm in texture so that they are not woven so closely as to prevent ventilation. The finer hats are woven in the morning and evening or in rainy weather, but the cheaper hats may be woven at any time (fig. 51). Cheap, stiff, machine-made straw hats and still cheaper paper hats have reduced the market for good Puerto Rican hats.

TOQUILLA

(SCREWPINE FAMILY)

Carludovica palmata Ruiz and Pav.

The botanical name *Carludovica* commemorates Charles IV and Queen Louisa of Spain. The name toquilla (to-keél-lyah) is widely used to designate the plant and in many places the prepared fiber. The fiber is often called paja de toquilla. The name jipijapa, meaning straw and also designating a district in Ecuador where the hats are made, is used to designate the prepared fiber and also the hats. Manabí is another name for hats made in Ecuador, and Suaza is a name for one of the principal hat-making districts in Colombia. Other names used to designate the plant or its fiber are cogollo in Venezuela, junco in Honduras, palmichi in Colombia, and raicilla in Panama. The name "Panama hat palm" is misleading, for although the so-called "panama" hats were formerly exported through the city of Panama, they are not made in Panama, and the plant itself is not a palm.

The toquilla plant is much like a trunkless fan palm, with leaves often 3 feet (1 m.) or more in diameter, deeply cut into four or five divisions, and these again cut and borne on triangular stems 3 to 10 feet (1 to 3 m.) long (fig. 52). The flowers are borne in a spike at the base of the leafstalks. The leaves reach nearly their full length folded in plaits in the bud.

Toquilla grows in fertile, moist lowlands in partial shade. It is found from Guatemala and Honduras, through Central America to Colombia, Ecuador, and Peru, and east of the Andes in Venezuela and British Guiana. It has been introduced into Puerto Rico, Java, the Philippine Islands, and probably elsewhere in the Tropics. Some attempts have been made to cultivate toquilla by propagating it from seeds or from suckers, but most of the material used in making hats is obtained from wild plants. Toquilla grows most abundantly in fertile lowlands in western Ecuador and in the valleys of the upper Magdalena River in Colombia.

FIGURE 52.—Toquilla, from which the so-called "panama" hats are made, introduced at Mayagüez, P. R.

It is said that the first toquilla hat was made about 1630 in the Province of Manabí. Ecuador, by Francisco Delgado, an Ecuadorean. In recent years the most important centers of the industry have been in Jipijapa, Montecristi, Santa Rosa, Cuenca, and Guayaquil in Ecuador, and in Suaza, Antioquia, Zapatoca, and Bucaramanga in Colombia.

The young leaves attain their full length of 3 feet (1 m.) or more while still folded in the bud. They are collected in this condition with ½ to 1 inch (15 to 25 cm.) of the stem attached to be used as a handle, especially in the hot-water treatment. The coarse veins are removed, and the leaves, still folded in plaits, are dipped repeatedly in boiling water; in some places they are boiled in water a few minutes. Sometimes lemon juice is added to the water to bleach the segments. After boiling or dipping in hot water, the segments are shaken to remove water clinging to them. In some places they are exposed to the sun to bleach, but generally they are kept in the shade. In some places they are exposed to the night air. They are wrapped in cloth to retain moisture and to keep them clean, and they are handled as far as possible by the stems. The plaits are separated and split lengthwise by means of the thumb and little-finger nail or by a gage consisting of needle points in a wooden handle. The slender strips, still attached to the stem, are allowed to dry, or are first plunged into boiling water and then dried. As the strips dry slowly, they become involute, or inrolled, making fine cylindrical strands. These cylindrical strands, called jipijapa, are distributed or sold to the hat makers.

The hat weavers, mostly women and children, select uniform "straw," or jipijapa, for each hat. Beginning at the center of the crown with a design usually characteristic for each hat-making locality, they weave outward and downward. Long "straw" is selected for the crown, so that they will not have to be pieced. The "straw" used in the rim is often pieced, but the ends are tucked in so they do not show. In some places the hats are woven over wooden forms, and sometimes two or four women sitting opposite one another work together on the same hat. The "straw" must be kept moist throughout the process of weaving. In some places most of the work, especially on the finer hats, is done early in the morning or in rainy weather, but there is no authentic record that the hats are woven under water, as is often stated in fairy tales. The jipijapa is injured by being soaked. It must be moist but not too wet. Three to six months, in which the hat weaver works about 4 hours a day, is required to complete one of the finest and highest-priced hats, but a child can make two of the cheap hats from undressed "straw" in a day. The woven hat is finished by trimming the brim, edging the border, and fastening all projecting ends so they cannot be seen. The hat is washed in clean cold water, coated with a thin solution of gum, and polished with dry sulfur.

The qualities of a really fine toquilla hat are uniformity and fineness of the straw, durability, strength, elasticity, resistance to soaking with water, and the property of being easily washed

FIGURE 53.—Hemp sown broadcast for fiber production. Harvesting hemp by hand. Lexington, Ky.

when soiled. A good hat well cared for will last many years.

Toquilla hats, exclusive of the exceptionally fine ones that are not found in the ordinary markets, are sold at prices ranging from $2 to $40 a dozen. They are generally regarded as the best standard hats for summer wear. Hats woven from fine strips of palm leaves are sometimes called "panama" hats by retail dealers, but nearly all palm hats made in the Americas are heavier than the toquilla hats, and the strands are flat instead of cylindrical.

The coarser material from the toquilla plant, not suitable for good-quality hats, is made into baskets, mats, and fancy articles. Fibers extracted from the leaf stems are rather stiff and resilient, and they are sometimes used in brushes and brooms.

Soft or Bast Fibers

None of the important soft fibers of commerce are obtained from plants native to the Western Hemisphere. Fiber flax, hemp, jute, and ramie have been introduced into both North America and South America, but the production of their fibers has never attained importance in the Americas as compared with their production in the Old World.

All of the commercially important soft fibers are obtained from the inner barks of herbaceous plants. Some soft fibers have been obtained from the inner bark of trees or woody shrubs, such as the linden and willows in the Old World and majagua in the American Tropics, but these are not produced in sufficient quantities to be regarded as commercially important.

Flax fiber, the oldest and most valuable of the soft fibers, is obtained from the fiber flax plant, *Linum usitatissimum* L. Seed flax, which is cultivated extensively for the production of linseed in Argentina, northern United States, and northwestern Canada, belongs to the same botanical species, but is a different horticultural form, and its straw does not yield a fiber suitable for spinning.

HEMP

(MULBERRY FAMILY)

Cannabis sativa L.

The hemp plant has been cultivated, to some extent at least, in nearly all countries of the Temperate Zones and has received names in nearly all languages. Both the plant and its fiber are known by the names cáñamo in Spanish, cânhamo in Portuguese, chanvre in French, canapa in Italian, hanf in German, hennup in Dutch, and hemp in English.

Unfortunately, all of these names, which were first used to designate the true hemp and its fiber, have been applied to many other long fibers, both soft and hard, but never to flax fiber, which is most nearly like hemp. Confusion will be avoided if the term "hemp" is used to designate only the true hemp to which it was originally applied and if other fibers are called by their distinctive names.

Hemp is an annual herbaceous plant with a slender, erect stalk 3 to 10 feet (1 to 3 m.) high and $\frac{1}{6}$ to $\frac{5}{6}$ inch (4 to 20 mm.) in diameter, and without branches if crowded in broadcast culture as it is grown for the production of fiber (fig. 53). If grown in checks or drills and cultivated for seed production, the stalks often attain a height of 12 to 16 feet (4 to 5 m.) and a diameter of $\frac{2}{5}$ to 2 inches (10 to 50 mm.) and bear spreading branches (fig. 54). Ideal stalks for fiber production are about $\frac{1}{5}$ inch (5 mm.) in diameter and about 6 feet (2 m.) high. Larger and thicker stalks have more wood and less fiber and are difficult to handle. The leaves are palmately compound and have 7 to 11 leaflets. The plants are dioecious; that is, the staminate or pollen-bearing flowers and the pistillate or seed-bearing flowers are on separate plants. The two kinds of plants are alike except for the flowers and the seeds, and there is no apparent difference in the fiber, provided the crop is harvested at the proper time, when the staminate plants are in flower. The staminate plants die as soon as the pollen is shed, whereas the pistillate

FIGURE 54.—Hemp grown in checks for seed production; pistillate or seed-bearing plant (left) and staminate or pollen-bearing plant, which dies after shedding pollen. Arlington Experiment Farm, Arlington, Va.

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plants continue to live 20 to 40 days longer, until the seeds are ripe. Fiber from dead plants, whether staminate or pistillate, is of poor quality. In any one field or group counted, the proportion of staminate to pistillate plants may vary 40 to 60 percent either way, but the average ratio is about 50 to 50.

Next to flax, hemp was the earliest plant cultivated for fiber production of which we have a definite record. The Lu Shi, a Chinese work of the Sung Dynasty, about A. D. 500, contains a statement that the Emperor Shen Nung, in the twenty-eighth century B. C., first taught the people of China to cultivate "ma," a plant of two forms, male and female, for the production of fiber.

Hemp is now cultivated for fiber production in China, Japan, Iran, and Turkey in Asia; Russia, Italy, Poland, Rumania, Hungary, Yugoslavia, and Spain in Europe; and Chile, Argentine, and the United States in the Western Hemisphere. Russia and Italy produce more hemp fiber than all the rest of the world combined.

Hemp for fiber production requires a temperate climate and a rainfall of at least 27 inches (70 cm.) per annum, with abundant moisture during germination of the seeds and until the young seedlings are well established. Hemp crops grown broadcast for fiber production are rarely injured by windstorms and rainstorms that beat down corn, wheat, and oats. Storms sometimes beat down hemp grown in checks for seed production. Hailstorms often bruise the bark of young hemp plants, causing serious injury to the fiber. Light rains, heavy dews, or light snow melting on the stalks aid in retting the bark where dew-retting is practiced.

Fertile clay loam or silt loam soils, neutral or slightly alkaline, are best for hemp. It will not grow well in acid sandy soils, heavy clay or gumbo soils, or gravelly soils that dry out quickly. On peaty marshlands the plants may grow large, but the fiber will be small in quantity and poor in quality.

The land for growing hemp must be prepared by thorough plowing and repeated harrowing so as to make a fine mellow seedbed, as uniform as possible over the entire field. The seed is sown, at the rate of about 1 bushel or 44 pounds per acre (50 kilos per hectare), as early in the spring as the land can be worked to good advantage. The seed may be sown broadcast by hand and covered with a light harrow, or it may be sown with a grain drill. Most grain drills, adjusted for wheat or oats, cover the seed too deeply for hemp. The seeds of hemp ought not to be covered more than 1 inch (3 cm.) deep. Roller-disk drills often give better results with hemp than the more common tooth drills. Sometimes good results are obtained with the tooth drills by removing the teeth so that the seed will fall on the surface of the ground, to be covered with a light harrow following the drill. Rolling the land after seeding is often beneficial. Good hempseed should germinate at least 95 percent. It is always best to have samples of the seed tested for germination before sowing.

Hempseed selected and grown for at least three generations (3 successive years) in the country where it is to be grown for fiber gives the best results. Imported hempseed is less certain to produce satisfactory crops for fiber.

After the seed is sown, the crop requires no further attention until har-

Figure 55.—Harvesting hemp with a self-rake reaper. Kouts, Ind.

vesttime, about 4 months after seeding. Some early strains from Manchurian seed or other northern-grown seed may reach maturity in 3 months, but the yield of fiber will be smaller, as a longer time is required for the plants to lay down cellulose in the fibers.

The largest yield of fiber of the best quality is obtained if the hemp is harvested when the staminate flowers are beginning to open and shed pollen. In some regions it has been customary to permit the hemp to become fully ripe so as to obtain fiber and seed from the same crop. When this is done, however, the fiber is harsh and brittle and the seed lacks vitality.

Most of the hemp throughout the world is still harvested by slow and laborious hand methods. The stalks, 3 to 10 feet (1 to 3 m.) tall and growing thickly, are cut usually with hemp knives, somewhat like long-handled sickles, and spread on the ground to dry (fig. 53). In some places the crop is cut with self-rake reapers that place the stalks on the ground in unbound gavels (fig. 55). In other places self-binders used for harvesting wheat and other small grains are modified so as to harvest the hemp, but are not satisfactory if the hemp is more than 5 feet (1.5 m.) tall, especially if it is to be cut at the proper time, before it is too ripe and dry. Hemp harvesters, designed especially for harvesting hemp, cut the stalks and spread them on the ground for dew retting at one operation. These are used in limited areas.

A man cutting by hand may harvest and spread for drying about 1/8 acre (one-eighth of a hectare) in a day. A man with a self-rake reaper and span of good horses may harvest 5 acres (2 hectares), leaving the stalks in unbound gavels. Two men with a self-rake reaper and tractor may harvest and bind in bundles about 7½ acres (3 hectares) per day, and two men with a hemp harvester and tractor may harvest 10 acres (4 hectares), leaving the stalks spread on the ground for dew retting. Where hot sunshine at the time of harvest may sunburn the hemp stalks lying on the ground, they are left to dry only a short time and then are set up in shocks and spread for retting later.

The term "retting" is a technical form of the word "rotting." It designates the process of rotting or decomposition of the green coloring matter (chlorophyll) and the thin-walled tissues surrounding the fibers in the inner bark by means of which the bark and fibers become free from the inner woody shell of the stalk. Some of the gums and pectose elements cementing the fibers together are also dissolved and the strands of fiber are partly freed from each other. If the retting is continued too long, it causes too much of the cementing materials to be destroyed, and the fibers become weakened. A series of certain groups of bacteria that are always present are the active agents in the process of retting.

Most of the hemp is retted by spreading the stalks on the ground in thin uniform layers, or swaths, and leaving them exposed to the weather 3 to 8 weeks. Warm moist weather hastens retting, and cool dry weather retards it. Light snow melting on the stalks is favorable for retting, but if the stalks are buried under a heavy snow for a month or more they are likely to be overretted and the fiber ruined.

Water retting is practiced most extensively in Italy and in some parts of Russia, Hungary, and Yugoslavia. The stalks are tied in bundles and placed in slow-running streams or in shallow water near the shores of larger rivers. With water at a temperature of 60° to 70° F. hemp will ret in 10 to 15 days. Higher temperatures result in more rapid retting. When the bark, including the fiber, separates easily from the woody inner portion of the stalk the retting is completed and the bundles of stalks are taken out of the water and set up to dry.

In some parts of China and Japan hemp fiber is prepared by steaming the stalks, after which the bark, including the fiber, is peeled off by hand and then scraped to remove the thin outer skin, the coloring matter, and most of the thin-walled tissues surrounding the fibers. The fiber thus prepared is in flat ribbons with a parchmentlike stiffness, very strong but too stiff and ribbonlike to spin well in ordinary hemp-spinning machinery. Attempts to split it by hackling result in too much waste.

Chemical retting has received much attention in the press during the past 50 years. Numerous chemical treatments have been tried, but none of them can be regarded as satisfactory on a commercial scale.

Hemp fiber is separated from the retted stalks and prepared for market by two mechanical processes, breaking and scutching. The stalks are first dried, then the woody interior portion is broken into short pieces called hurds. This process, performed by various methods in different countries, is called breaking. The loosened fiber is separated from the hurds by various methods of beating and scraping, a

FIGURE 56.—Hand brake by means of which retted hemp stalks are crushed and the woody interior portion broken into small pieces that are removed by whipping the fiber across the top of the brake. Kouts, Ind.

process called scutching. Formerly much of the scutched hemp fiber was further cleaned and split into finer strands by being drawn by hand over hackles, or sets of upright steel pins. Most of the work of hackling is now done with machine hackles in the spinning mills.

In many hemp-producing regions the hand brake (fig. 56) is still used to crush and break the stalks. The loosened hurds are then removed by whipping handfuls of fiber across the top of the brake. This rarely removes all of the hurds, and most of the fiber thus prepared must be drawn over a coarse hackle before it is made up into hands (fig. 57) and baled for market. Some of it, without hackling, goes direct to the spinning mill, where it is carded, making a tow suitable for spinning into coarse yarns. Some goes through the more expensive processes of hackling and being kept straight for spinning into finer and better yarns.

Numerous machines have been devised for breaking and scutching hemp and similar fibers, but none have been found to be fully satisfactory in actual commercial work in the United States. One type of machine has been used in the hemp-scutching mills in Wisconsin and Illinois since about 1915. At these mills the bundles of dew-retted stalks brought from the farms are stored in stacks or large sheds to await the work of scutching. This work is carried on inside buildings in winter, when there is less demand for labor on the farms. The hemp stalks first pass through a steam-heated drier about 100 feet (30 m.) long; then endwise between 8 or 10 pairs of fluted breaking rollers, which crush and break into small pieces

FIGURE 57.—Hand of rough hemp ready to be baled for market. Kentucky.

the dry woody shells of the stalks. Most of the hurds drop out in this breaking process. The fiber coming from the rollers is turned sidewise and grasped near the middle by a pair of carrying chains or grooved belts, which carry it past large revolving drums with projecting bars that beat off the remaining hurds and most of the short and weaker fibers. After the fiber has passed the first scutching drums, a second pair of carrying belts grasps it at one side so that the center is scutched by the next scutching drum. The fiber comes from the machine straight and clean except that the ends are often tangled, and these are drawn by hand over a coarse hackle. Short hemp or tangled stalks are put through the breaking rollers, and, together with the short and tangled fiber beaten out by the scutching drums, they are put through a tow machine consisting of fluted rollers, beating cylinder, and shaker, a process that produces a clean soft tow. The hurds are carried by a blower to the furnace and are used as fuel to produce steam heat for the driers and power to operate the machinery. Twelve to fifteen men are required to operate each machine to full capacity. The machines have not been regularly manufactured but have been built to order in each scutching mill as needed.

A portable machine made at Bologna, Italy, is used extensively for breaking and scutching water-retted hemp in that country. This machine has fluted rollers for breaking and revolving cylinders for scutching. It does very good work with water-retted hemp, but has proved a complete failure with American dew-retted hemp. It requires 20 or more laborers to operate it to full capacity.

Other machines have been used, and new ones are brought out at frequent intervals, but thus far none of them has proved to be as efficient as the machines used for preparing sisal and henequen.

In the form of scutched fiber, hemp is composed of groups of strands in flat ribbons 1/50 to 1/5 inch (0.5 to 5 mm.) wide and 40 to 200 inches (100 to 250 cm.) long. It is split into finer strands by hackling. Dew-retted hemp is gray, and water-retted hemp is usually cream white. Fiber of good quality is lustrous and has a decided snap in breaking. The ultimate cells composing the strands of hemp are 1/5 to 2 1/5 inches (5 to 55 mm.) long by 16μ to 50μ in diameter, rather blunt-pointed but some with ends forked. They are composed of pectocellulose, with about 77 percent cellulose. Hemp is more nearly like flax than any other commercial fiber, and it may be hackled so as to be as fine as the coarser grades of flax. It is not linen, however, as is sometimes claimed. In a series of comparative tests for strength the ratios were as follows: Hemp 29, flax 36, jute 20. Hemp endures heat, moisture, and friction with less injury than any other soft fiber except flax.

The total world production of hemp fiber in recent years has ranged from 275,000 to 350,000 metric tons per annum. The largest quantity is produced in Russia, mostly for home consumption. Italy exports from 40,000 to 100,000 metric tons of hemp annually, chiefly to Great Britain and Germany. The importations into the United States, which is the principal hemp-consuming country in America, for 1930–39 were as follows:

Year	*Hemp (tons)*	*Year*	*Hemp (tons)*
1930	1,457	1935	927
1931	1,018	1936	735
1932	506	1937	782
1933	600	1938	157
1934	672	1939	678

Hemp fiber is used chiefly in the manufacture of twines, including tying twines, seine twine, sacking twine, mattress twine, upholstery twine, hat twine, bookbinder's twine, lashings for suspending telephone cables, soles for alpargatas (sandals), shrouds in standing rigging, houselines and marlines on shipboard, and ropes up to 1 inch in diameter, usually tarred. Hemp is still used in Europe for cordage, and until it was superseded by abacá ("manila hemp"), about the middle of the last century, hemp was used more than all other fibers in marine cordage. The so-called "hemp ropes" are no longer made of hemp but of hard fibers. Hemp tow is used extensively in oakum, for packing in pumps, engines, and pipe fittings, and for calking boats.

The prices quoted in the New York market for hemp fiber in recent years have ranged from 10 to 15 cents a pound for scutched fiber, from 6 to 9 cents a pound for tow of American dew-retted hemp, and from 12 to 18 cents a pound for scutched Italian water-retted hemp. There has been a tendency toward an increase in market quotations and a decrease in use.

CADILLO

(Mallow family)

Urena lobata L.

The cadillo plant, which is widely distributed in the Tropics and subtropics of both hemispheres, has many local names, some of which are as follows: aramina, carrapicho, and guaxima vermelha in Brazil; cadillo, guizazo, and malva blanca in Cuba; Caesar weed in Florida; cousin rouge and grand cousin in Guadeloupe; grand mahot cousin in Martinique; candillo in Venezuela; culut culutan in

FIGURE 58. — Cadillo (*Urena lobata*), left, guaxima rosa (*U. sinuata* L.), right. Both species yield fiber and both are called malva blanca in Cuba. Photograph from Sr. Gonzalo M. Fortún, Director of Experiment Station, Santiago de las Vegas, Cuba.

the Philippine Islands; paka in Madagascar; ake-ire, bolo-bolo, ototo grande, subive and toja in West Africa.

Cadillo is an annual herbaceous plant, 3 to 15 feet (1 to 5 m.) tall, branching if not crowded but with few or no branches if grown thickly in cultivation. The stalks sometimes attain a diameter of 1⅕ inches (30 mm.), but slender stalks yield more and better fiber. The leaves are ovate and three-lobed to nearly round and irregularly toothed. The seeds are borne in small burs (fig. 58). The plant is propagated from the seeds. The fiber is obtained from the inner bark of the main stalks. In some carefully conducted experiments in the Philippine Islands, it was found that 50 ordinary branching plants gave $1\frac{1}{10}$ pounds (0.522 kilo) of fiber and 50 of the less branched plants gave $2\frac{1}{2}$ pounds (1.127 kilos).

Cadillo grows best in fertile, well-drained soils and is sometimes a troublesome weed in cultivated crops in the Tropics. Many attempts have been made to cultivate cadillo for the production of fiber. From about 1900 to 1910 this plant was cultivated on a large scale near São Paulo, Brazil. The fiber produced was called aramina, meaning "little wire," and was used as a substitute for jute in the manufacture of sacks for shipping coffee. More recently the production of this fiber has been carried on in Cuba, where it is called malva blanca, and in Madagascar, where it is called paka. These efforts have not resulted in continued commercial success, because the methods for preparing the fiber have not been efficient enough for cadillo fiber to compete with jute imported from India.

The seed of cadillo is sowed in drills, the young plants are thinned, and the weeds are pulled or the land is hoed between the drills. The crop is harvested about 4 months after seeding, or when the plants are in flower. The stalks are retted in water 8 to 20 days; then the bark, including the fiber, is separated from the wet stalks or, in some places, from the dried stalks. Machines have been devised for this work, but they either wasted too much fiber or did not clean it well enough. Machines have also been devised to separate the fiber and bark from the green stalks as they are cut in the field to avoid the transportation of the entire stalks and shorten the retting process. Bark in strips, in which the retting bacteria are able to reach the tissues surrounding the fibers, rets more quickly than the unbroken bark on the stalks. The fiber has to be dried and cleaned after retting.

Cadillo fiber resembles jute in color, texture, and strength. It is light cream white, somewhat ribbony, and 3 to 8 feet (1 to 2.5 m.) long. The ultimate cells are 1/8 to 1/6 inch (3.5 to 4.5 mm.) long and about 19μ in diameter. Under the microscope the surface of the cells often shows roughness or minute transverse ridges. The pure fiber contains 74 to 75 percent cellulose, which may be compared with 63 percent in jute. In a series of tests at the Escola Polytechnica de São Paulo, Brazil, cadillo was found to have greater tensile and torsional strength than jute.

The native uses for cadillo have been chiefly in hand-made twines and occasionally in woven fabrics. Where the fiber has been produced in larger quantities it has been used chiefly as a substitute for jute in sacks and similar articles.

Samples of cadillo from various sources have been reported on by the Imperial Institute in London as being equal in value to India jute, provided the fiber is well cleaned. There seems to be no serious difficulty in growing the plants in suitable soils, but more efficient methods for scutching and preparing the fiber are needed if it is to be produced cheaply enough to compete with jute from India.

JUTE

(LINDEN FAMILY)

Corchorus capsularis L. and C. olitorius L.

Jute has been in commercial use only about 100 years, but because of its cheapness, ease of manufacture, and

FIGURE 59.—Round-pod jute, with rough, spherical seed pods.

availability in quantity and uniform quality, it is now used more than all other vegetable fibers combined, except cotton.

Jute is a soft, long, multicellular fiber, obtained from the bast or inner bark of two closely related plants, round-pod jute (*Corchorus capsularis*) (fig. 59), and long-pod jute (*C. olitorius*) (fig. 60). The two plants are so nearly alike that it is difficult to distinguish between them except by the seed pods and seeds. The names juta in Portuguese, jute in English, French, and German, and yute in Spanish are commonly used to designate the plants and fibers of both species.

Both species are herbaceous annual plants. They have slender cylindrical

FIGURE 60.—Long-pod jute, with smooth, elongated seed pods.

stalks 6 to 12 feet (2 to 4 m.) tall and $\frac{2}{5}$ to $\frac{4}{5}$ inch (10 to 20 mm.) in diameter. The stems and leaves are light green, and both plants have small yellow flowers. The round-pod jute has rough seed pods nearly spherical, $\frac{3}{5}$ to $\frac{4}{5}$ inch (15 to 20 mm.) in diameter, containing small brown seeds. The long-pod jute has nearly smooth, cylindrical, or five-angled seed pods about 2 inches (5 cm.) long containing much smaller bluish seeds.

The round-pod jute is grown more extensively than the long-pod jute. It endures inundation and is grown in broad river valleys where much of the land is subject to overflow. The long-pod jute does not endure inundation and is cultivated on higher ground. Both species require a very fertile sandy loam or silt loam soil and a warm wet climate. In Bengal and adjacent provinces in India, where practically all of the jute fiber of commerce is produced, the rainfall from the time of seeding jute, in March, to harvesttime, in August or September, ranges from 60 to 100 inches (150 to 250 cm.), and the mean daily temperatures from 75° to 90° F.

A requirement quite as important as soil or climate is an abundance of cheap labor willing to work under disagreeable conditions. It is said that a working population of at least 1,000 per square mile is required to produce jute as it is produced in India.

Both round-pod jute and long-pod jute are cultivated in the provinces of Bengal, Bihar and Orissa, and Assam in areas near the Ganges and Brahmaputra Rivers in northeastern India. They are also cultivated in Burma, French Indo-China, southern China, the southern islands of Japan, especially Taiwan, and French West Africa. However, no country except India produces the fiber in sufficient quantities for export on a large scale.

Many attempts have been made to cultivate jute in America, especially in Brazil, Cuba, Mexico, and the United States. The plants have grown fairly well in some places, but, without efficient mechanical methods for preparing the fiber, it cannot be produced cheaply enough to compete with that produced by hand labor in India. Many machines have been devised to prepare jute fiber, but they have not been efficient enough for practical work. The preparation of fiber by hand has not attained commercial success in any new locality within the past 100 years. The most promising conditions for jute-fiber production by hand methods in the Western Hemisphere may be in the Guianas, where there are many immigrants from India, some of whom are doubtless familiar with the work of preparing jute fiber in the Orient.

In India the land for growing jute is prepared very thoroughly, but generally with rather crude tools, such as wooden plows, wooden harrows, and mallets to break up clods of earth. The seed is sown broadcast by hand at the rate of about 18 to 22 pounds per acre (20 to 25 kilos per hectare) for the larger brown seeds of round-pod jute and about half as much for the smaller blue seeds of long-pod jute. The seeds are covered ⅖ inch (2 cm.) deep or less by drawing a bundle of twigs or a light bamboo harrow over the field. The plants are thinned and the weeds pulled by hand, usually twice before the jute plants are 40 inches high, and the growing stalks are left about 4 to 6 inches (10 to 15 cm.) apart.

When the stalks are 6 to 12 feet (2 to 4 m.) high and beginning to produce flowers, about 5 months after seeding, they are harvested (fig. 61). On dry land they are cut with a sickle, and on overflowed land they are pulled and the roots are cut off afterward. The stalks are tied in bundles with bands near the top and bottom, and the leafy tops are cut off.

All of the jute of both species is water-retted. In some districts the bundles of stalks are placed in water immediately after they are cut, and in other places the stalks are first dried in shocks and then placed in water. They are weighted down in the water to keep all of the stalks submerged. The temperature of the water in the shallow pools of the Ganges Valley is 75° to 80° F. at the time of jute retting

FIGURE 61.—Round pod jute ready for harvest. The plants here shown are growing in poor soil and consequently in a thin stand. They are less than 6 feet (2 m.) high and have leafy branches half way down from the top. Arlington Experiment Farm, Arlington, Va.

in September. After the stalks have been retted 10 to 20 days and the bark, together with the fiber, slips easily from the woody interior of the stalk, the workmen wade into the slimy, ill-smelling retting pools and work all day waist deep in the water, separating the fiber from the stalks and cleaning it by whipping it on the surface of the water. The fiber is dried on the bushes or any convenient support. Much of it is washed later in clean running water. An expert workman can clean 65 to 85 pounds (30 to 40 kilos) of dry jute fiber a day.

The average yield of jute fiber is about 1,300 pounds per acre (1,500 kilos per hectare). The green stalks yield nearly 5 percent of their weight in dry fiber. This is a larger yield per acre and also a larger percentage yield from green stalks than is obtained from other kinds of soft-fiber plants.

The flaggy lower ends of the fiber, which cannot be well cleaned, are cut off in pieces 6 to 12 inches (15 to 30 cm.) long, forming the jute butts of commerce. They are also called cuttings.

The long jute fiber after the butts are cut off is cream white to brownish gray, changing to a dingy brown in age. It is in slender strands 5 to 10 feet (1.5 to 3 m.) long, soft and flexible. The ultimate cells composing the fibers are $\frac{1}{25}$ to $\frac{1}{5}$ inch (1 to 5 mm.) long and 14μ to 20μ in diameter, with a mean ratio of diameter to length of about 125, which may be compared with 1,000 for hemp, 1,200 for flax, and 1,500 for cotton. The short, blunt-pointed ultimate cell is one of the weak characters of jute fiber. Another weak character is its chemical composition. Jute has a higher percentage of lignin than any other commercial soft fiber, even higher than that of most hard fibers. Fibers with a higher percentage of cellulose are generally stronger and more durable or longer lived. Jute fiber has only about 63 percent cellulose. This may be compared with 77 percent in hemp, 82 percent in flax, and 86 percent in cotton. The low percentage of cellulose and high percentage of lignin in jute result in a fiber lacking in strength and durability. The chief defect of jute is its lack of durability. Because the action of oxygen on lignocellulose has a tendency to disintegrate the constituents of the cell walls, oxidizing bleaching agents weaken the fiber.

Jute fiber has very little elasticity. According to Heerman and Herzog, German authorities on the properties of fibers, jute has a stretch of 0.8 percent as compared with 1.6 percent for hemp and flax and 6 to 7 percent for cotton.

Jute is used in the manufacture of burlaps, hessians, and various other kinds of sacking for sugar, coffee, grain, stock feed, potatoes, fertilizers, wool, and peanuts, sandbags for defenses against floods and against attack in wartime, and covering for bales of cotton and other fibers and of yarn and woven fabrics for shipment. Special types of burlap supply the backing for linoleum and oilcloth. Jute yarns are used in the manufacture of rugs and carpets. Narrow webbing to support the seats and backs of upholstered furniture is made of jute, and these soon rot out because of the short life of jute fiber. Jute is used also in cheap flat belting for machinery, but because of its lack of strength, lack of elasticity, and especially lack of durability, it is not adapted for this purpose. Jute is well adapted for uses where cheapness is more important than strength or durability, but owing to its lack of durability it ought not to be used for any purpose where this property is important.

RAMIE

(Nettle family)

Boehmeria nivea (L.) Gaud.

Urtica nivea L.

The name ramie, with slight variations in spelling, such as ramio in Spanish and rameh in Dutch, is used in nearly all countries to designate the plant and its fiber. In China, Japan, and India there are numerous local names for the plant and the fiber, but the name ramie is recognized at the ports where the fiber is exported. The term "ramie ribbons" designates the bark, including the fiber, as it is peeled off the stalk. When these ribbons are scraped, the product is "China grass." China grass is the hand-cleaned but not degummed fiber, rather stiff, and of a greenish or parchmentlike yellow, as it is exported from China. The name China grass is sometimes incorrectly used to designate the plant. Degummed ramie or ramie filasse is the fine, soft fiber prepared by degumming China grass. The terms "filasse" or "combed filasse" are sometimes used to designate the long straight fibers prepared by combing the degummed ramie, and ramie noils are short tangled fibers removed as waste in combing.

The ramie plant (fig. 62) has perennial rootstalks, which send up herbaceous canes 3 to 6 feet (1 to 2 m.) high and $\frac{2}{5}$ to $\frac{4}{5}$ inch (10 to 20 mm.) in diameter with few branches. The leaves are round or heart-shaped, 2 to 4 inches (5 to 10 cm.) in diameter, and woolly white on the undersurface. The specific name *nivea* (snow) refers to the white undersurface of the leaves. If the canes are cut during the growing season, new shoots grow up so that two or three crops, or under exceptionally favorable conditions four crops, may be harvested in 1 year. The crops are not equal, however, and three or four crops in one season do not produce three or four times as much as one crop. Small green or greenish-yellow flowers are borne in two clusters on the same stalk; the staminate, or pollen-bearing, flowers below, scattered in the axils of the leaf stem, and the pistillate, or seed-bearing, flowers above (fig. 63). The brownish-yellow ovate seeds are about $\frac{1}{25}$ inch (1 mm.) long and are often partly enclosed in the persistent calyx.

FIGURE 62.—Ramie, a dense growth of stalks. Arlington Experiment Farm, Arlington, Va.

As nearly as can be determined, the ramie plant originated in the mountain valleys in southwestern China. The fiber has been used many centuries in China and more recently but to a less extent in India. It was practically unknown outside of eastern Asia until after the middle of the last century. In 1869 the Government of British India offered a reward of £5,000 for a machine that would decorticate ramie successfully. The interest aroused by this offer resulted in the introduction of ramie plants in many places to try out machines. Many plans for machines were submitted, and some machines were actually built and tried, but none of them did the work in a satisfactory manner. The reward was not paid, and the offer was later withdrawn.

FIGURE 63.—Ramie branch bearing clusters of seeds. Arlington Experiment Farm, Arlington, Va.

Ramie has been introduced into nearly all warm-temperate countries. Numerous efforts have been made to develop ramie fiber production in Argentina, Cuba, Guatemala, Mexico, and the United States, as well as in Europe and Africa. Thus far, however, ramie fiber has never been produced in commercial quantities anywhere in the American hemisphere.

Ramie is not a tropical plant, but rather a plant of the warm-temperate regions. It grows better at Washington, D. C., where winter weather compels a resting period, than in Puerto Rico, where it continues to grow throughout the entire year. Where severe winter weather freezes the ground to a depth of 8 to 10 inches, the ramie rootstocks are likely to be killed, especially in poorly drained soils. In experimental plantings where the winters are cold, the rootstocks may be protected by heavy mulching, but this is not practical in commercial fields. Ramie grows best in a very fertile sandy loam soil not subject to drought. It will not endure prolonged inundation and does not grow well where free water in the soil is within 2 feet (60 cm.) of the surface. After the plants are well established they can survive rather severe droughts, but they require abundant moisture to yield good crops. Ramie requires more moisture than corn, cotton, or cowpeas, but not as much as sugarcane; and unlike cotton, a growth of stalk rather than fruiting bolls is desired. Rich bottom lands, rather than dry uplands, are better for ramie.

Fertilizer, in the form of either stable manure or commercial fertilizer, must be applied liberally if good crops of ramie are to continue and two or three crops are to be removed each year for 5 years or longer. Ramie requires more nitrogen and potash than wheat, but less phosphoric acid.

Ramie plants may be propagated by seeds, cuttings of the rootstocks, and cuttings of the stems. Rootstock cuttings are used most often because they give most certain results. They do not require as much careful attention as seedlings. If parts of entire crowns with the roots are transplanted, they will produce large canes most quickly. Small pieces of rootstocks may grow, and generally pieces 4 to 6 inches (10 to 15 cm.) long are used. They may be placed in a slanting position against the side of a shallow trench and covered so the upper end is about 2 inches (5 cm.) below the surface. The plants are usually grown about 20 inches (50 cm.) apart, in rows about 3 feet (1 m.) apart. Stem cuttings are rarely used except in experimental work. The plants may be increased most rapidly by growing them from seeds, but this method requires special care.

Seedlings are grown best in beds kept moist, but not too wet, by infiltration of water from furrows beside the beds. Usually not more than 70 percent of the seeds germinate. The young seedlings are very susceptible to attacks of a destructive fungus of the genus *Fusarium*. The young seedlings may be transplanted to the field when two or more buds appear near the base of the stem 60 to 90 days after sowing. The tops are cut off to reduce transpiration, and 6 to 8 inches (15 to 20 cm.) of the stems is left attached to the roots. Cuttings of rootstocks may be planted either in the fall or in early spring, but seedlings must be set out in early summer so that the roots may be well established before winter. The plants are killed down to the ground by frost, but the rootstocks send up new canes in the spring. Sometimes a small crop of canes is harvested the first summer after the plants are set out, but better results may be obtained if the plants are merely cut off in midsummer to induce a thicker growth and the first crop of canes for fiber production is not harvested until the second summer.

The land between the rows is cultivated about four times the first season and after that once after each harvest of stalks. Hand hoeing is necessary at least once a year to clear out weeds in the row. Fertilizer is applied after each harvest. The number of crops per year and the number of years that the plants continue to yield good crops depend largely on the original fertility of the soil and the care given to maintaining it.

In the principal ramie-producing regions in China the first crop is cut in May or June, the second in July or August, and the third in October. The stalks of the first crop are the tallest, producing the largest yield, but the fiber is coarser than that of succeeding crops. The second and third crops contain more gum. The fiber of the second crop is usually the finest.

Various methods of harvesting are practiced in different places in China. In some places the leaves are stripped off, and then the bark, including the fiber, is peeled off from the bottom up, leaving the stalks standing in the field. In other places the stalks are cut one at a time and the bark and fiber peeled off in ribbons. These ribbons are drawn by hand between a bone knife and a bamboo thimble worn on the thumb, and the thin outer bark, most of the green coloring matter, and some of the gum are thus scraped away. Sometimes the stalks or the ribbons are placed for a short while in running water to keep them fresh until the treatment can be completed, but ramie is not retted like other soft fibers. After the ribbons have been scraped and the fiber washed and dried, it is in the form known as China grass, and in this form it is placed on the market. In some parts of Japan the fiber is separated from the stalk and cleaned by decorticating machines. Improvements are being made in these machines, but thus far it has not been demonstrated that they are efficient enough to be operated profitably except where wages are very low. With either the hand methods in China or the machines in Japan, the fiber is separated from the freshly cut green stalks and cleaned as soon as possible after being cut and before the gums begin to solidify. The stalks and the leaves together contain about 80 percent moisture, and they dry slowly and ferment more quickly than other farm crops. No practical method has been devised for drying them in a humid climate. A practical method of decortication, including the separation of the fiber from the stalks and its preparation in the form of China grass, is the most important unsolved problem in the production of ramie fiber.

Degumming is the process of removing the gums binding the fibers together and freeing the fiber from the surrounding tissues. It corresponds to retting in the preparation of other bast fibers. In China the fiber is degummed and bleached by repeated washing and drying in the sun. Ramie fiber in the form of China grass is regularly imported into England, France, and Germany, where it is degummed by chemical processes in the ramie spinning mills in those countries. In America many tons of China grass have been degummed by chemical methods, but thus far this work has not been established as a permanent industry. Degumming ramie fiber is not a part of the work of the farmer who grows the plants, but is either a part of the work in ramie spinning mills or an intermediate step between the grower and the manufacturer.

Many claims about yields of ramie have been based on the yield of a few selected stalks, multiplied by the estimated number of stalks per acre. Very few estimates based on actual acre yields are available. At the Louisiana Agricultural Experiment Station an acre of good land produced in the second year 53,510 pounds of green ramie plants in four cuttings. Of this total, 47,800 pounds were suitable for fiber production and produced 1,231 pounds of ribbons (bone dry), or 535 pounds of pure fiber. Other estimates, based on actual weights, give the yield of degummed fiber as approximately 1 percent of the weight of the green plants.

Ramie fiber is a multiple-celled long fiber, but it differs from flax, hemp, and jute fibers in having only a few ultimate cells in a cross section of the strand. The ultimate cells are very much longer than those of other fibers, and the cell walls are thin. Ramie is often subdivided to its ultimate cells, especially when prepared in the form of combed filasse.

Ramie fiber in the form of China grass consists of flat fibers 2 to 5 feet (60 to 150 cm.) long and 1/50 to 3/25 inch (0.5 to 3 mm.) wide containing two or more strands. The ultimate cells are 3/4 to 20 inches (2 to 50 cm.) long, averaging about 6 inches (15 cm.) and 20μ to 70μ in diameter. They are three to five times larger in diameter than silk, cotton, or flax fiber. Degummed ramie filasse consists of nearly pure pectocellulose, with a cellulose content of about 78 percent. The cellulose elements are arranged in spirals in the cell wall, causing the fiber to turn clockwise when moistened and allowed to dry. All other textile fibers except flax turn counterclockwise.

Ramie fibers are remarkably strong. Single ramie cells have a tensile strength of 17 to 20 gm., whereas the average for cotton is about 7 gm. Ramie is less affected by moisture than most other fibers. It takes up and gives off moisture quickly, but with almost no shrinking or stretching. Ramie resists the action of chemicals more than most other fibers. It is resistant to injury from sea water, and for this reason it is used in Japan for making fish nets. The thin walls of this relatively nonelastic fiber do not endure rubbing under tension. It is not satisfactory for tire fabrics, belting for machinery, or similar fabrics.

In China ramie is used largely in summer clothing, and much of it is spun and woven by hand. Ramie grass cloth is woven by hand with strands that are not spun or twisted. In Europe ramie is spun by special machines, either alone or mixed with mohair, wool, or cotton. The yarns are used in upholstery fabrics, draperies, summer suitings, millinery, and trimmings. Ramie thread makes beautiful and very durable hand-made laces, and it is also used in embroidery and drawn work. The average annual production of ramie fiber in the form of China grass is estimated at about 100,000 metric tons. The exports from China to Europe range from 3,000 to 6,000 metric tons per annum. The total annual exports to all of the countries in the Western Hemisphere average less than 5 tons.

The market price of China grass in Europe ranges from £30 to £40 per metric ton, c. i. f. European ports.

SHORT OR ONE-CELLED FIBERS

The short fibers are 3/5 to 2 inches (15 to 50 mm.) long and most of them are one-celled. Unlike the long fibers, which are embedded in the tissues of the plant, the short fibers project out from the surfaces on which they grow. They are sometimes called plant hairs. One of the functions of long fibers in the living plant is to carry plant juices, and these fibers readily absorb water. Important functions of short fibers in the plant are insulation and buoyancy, and these fibers in their raw state do not readily absorb water. Nearly all of the short fibers are borne inside of seed pods, either on the seeds, as in the cottons and milkweeds (not included in this publication), or on the inner surfaces of the seed pods, as in kapok, samohu, and related species. The cottons are the most important plant fibers used in textiles; the other short fibers are not adapted for spinning.

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FIGURE 64.—Kapok tree. Central Juanita, Bayamón, P. R.

KAPOK

(BOMBAX FAMILY)

Ceiba pentandra (L.) Gaertn.

Bombax pentandra L.

Eriodendron anfractuosum DC.

The Spanish name ceiba is used in many places to designate the kapok tree and sometimes allied species. The misleading English names "silk-cotton tree" for the plant and "tree cotton" and "silk floss" for the fiber are often used in English publications. The name kapok is of Malay origin and is applied to both the tree and the downy fiber produced in its seed pods.

The kapok tree (fig. 64) is one of the largest trees in tropical forests, attaining a height of 100 feet (30 m.), with a trunk 6 to 10 feet (2 to 3 m.) in diameter and with mostly horizontal branches. The bark is smooth except for pyramidal spines ⅔ to 1 inch (2 to 3 cm.) in diameter and about the same height. The leaves are palmately compound, with 5 to 7 leaflets. The leaves come out just after the clusters of pinkish-white flowers and fall 8 to 10 months later, before the seed pods are fully developed. The seed pods (fig. 65) are spindle-shaped, 4 to 8 inches (10 to 20 cm.) long and about one-third as thick, with weak walls that may be easily crushed by hand. The white or sometimes tawny fluffy fiber filling the pods is produced along the five seed-bearing placentas extending lengthwise through the center of the pod. A very small proportion is produced on the seeds, but when the pods burst open at maturity both seeds and fiber are free from any attachment. The seeds are dull brown, irregularly pear-shaped, about ⅕ inch (5 mm.) long, and have a characteristic "monkey face" on one side.

The tree is propagated by either seeds or cuttings. Seeds are preferred because they develop a better root system, but cuttings about 3 feet (1 m.) long grow more rapidly at first and produce an earlier crop of seed pods.

Kapok trees grow best in a moist but well-drained soil of loose texture in a moist tropical climate. A dry season when the seed pods are mature is best for the work of preparing the fiber.

This species is native to southern Mexico and Central America. It was introduced into Malaysia by the early navigators, and now most of the kapok of commerce comes from Java. Kapok trees have been widely introduced in the Tropics of both hemispheres. Kapok fiber is produced in the Netherlands Indies, the Philippine Islands, Ecuador, and tropical West Africa. There are many areas in the American Tropics where the trees grow well, but the production of the fiber has not been developed on a large scale because it requires much hand labor to collect the seed pods and prepare the fiber.

Kapok trees in Java and most other oriental Tropics have branches in whorls and do not have large trusses at the base of the trunk as do most kapok trees in the American Tropics. The oriental variety is called *Ceiba pentandra indica* (DC.) Bakh. to distinguish it from the American form, called *C. pentandra caribbea* (DC.) Bakh.

FIGURE 65.—Kapok seed pods and seeds. Tahiti.

There are several large kapok plantations in Java where trees of selected strains are set out and cultivated like orchards of fruit trees, but more than 90 percent of the kapok produced in Java comes from trees growing along roadsides and borders of fields or around the houses of the natives.

The trees begin to produce seed pods 5 to 7 years after they are set out, and the crops increase for several years. The trees may live for a century or more, but it is difficult to collect the pods from very tall trees.

The seed pods are picked after they have attained full size but before they pop open. The fiber must not fall on the ground, where it may be soiled and discolored. The harvesters use ladders and long poles with hooks. They also climb up in the large trees, but such climbing is dangerous because the limbs are brittle.

The seed pods are taken to a central station where they are spread out on a clean floor like a floor for drying coffee. These floors are surrounded by walls of cotton cloth similar to tobacco cloth, to keep the fiber from being blown away. The drying floors are open to the sun, but many of them have covers that may be drawn over quickly in case of showers. The seed pods pop open as they dry in the warm sunshine. The fiber and seeds are picked out by hand and separated by means of simple machines in which the mass is stirred while a blast of air blows the light fiber out at the top and the heavier seeds fall to the bottom. In many places the seeds and fiber are separated by a three- or four-tined bamboo paddle operated by hand. Severe beating must be avoided, for if the fibers are broken or crushed their valuable properties of resiliency and buoyancy and their usefulness for insulation are destroyed.

After the fiber is separated and dried, it is graded and packed in bales of 110 pounds (50 kilos) each for shipment. Packing at the rate of more than 300 pounds (140 kilos) per cubic meter is likely to crush the fiber. The fiber is ruined also if packed while moist.

Kapok fibers are cylindrical cells pointed at the ends, 3/5 to 1 1/5 inches (15 to 30 mm.) long, or about the same length as cotton fibers. The walls are thin, nearly smooth, and impervious to water or air. The cells are filled with air, and until crushed or broken each hairlike fiber is a diminutive elongated gas bag. This construction is responsible for its valuable properties of buoyancy and resiliency and its usefulness in insulation for heat and sound. It is more buoyant than cork or other materials used in life preservers. It is more resilient than cotton or similar soft materials used in cushions and mattresses, and as it is a vegetable fiber like cotton, it is not eaten by moths, which eat wool and feathers. It breaks down under repeated beating or crushing and therefore is not as durable as cotton, feathers, or wool. Careful tests have demonstrated that it is one of the best insulators for heat and sound. Its value for any of these purposes is greatly decreased if the fibers are broken or crushed.

Because of its superior buoyancy combined with lightness, kapok is used in life preservers and life jackets. Because of its buoyancy combined with resiliency, it is used in mattresses and pillows on shipboard and cushions in pleasure craft, especially in canoes. Because of its resiliency and freedom from injury by moths, it is used in sofa pillows and also in bed pillows and mattresses, but for the latter purpose it is not as durable as is desired. Because of its insulating properties, it is used in the walls of refrigerators and ice-cream storage containers. As a filling in quilts and comfortables it is almost as warm and light as eiderdown, but it must be quilted rather than tied to be held in place. It is used in the walls of airplanes as an insulator for both sound and heat.

FIGURE 66.—Pochote tree, also called mosmote, bearing pods that yield fiber similar to kapok. Cercanías de Tepecoacuilco, Guerrero, Mexico.

Kapok fibers do not cling together and are not readily spun into yarns. These fibers have been spun by means of special treatment and special machinery, but the yarns and the woven fabrics made of the yarns are weaker and less durable than those made of cotton. Kapok fabrics may have a special value because of their superior insulating properties, but thus far they have not been produced in sufficient quantity to demonstrate their uses.

POCHOTE

(BOMBAX FAMILY)

Ceiba aesculifolia (H. B. K.) Britt. and Baker.

Bombax aesculifolia Humb., Bonpl., and Kunth.
Ceiba grandiflora Rose.
Ceiba schottii Britt. and Baker.

The name pochote or pochotl is used in Mexico to designate both the trees and the fiber of four or five fiber-producing species of the bombax family native to that country. It is doubtless applied most frequently to the species now known as *Ceiba aesculifolia* because this is more widely distributed and more abundant than the others.

In Yucatán it is also called by the Mayan names piim and yaxche. The name mosmote is used in Guerrero.

The pochote tree attains a height of 30 to 50 feet (10 to 15 m.), usually diffusely branching above the comparatively short trunk (fig. 66). The gray trunk and branches and even the young wood are armed with numerous short conical spines (fig. 67). The leaves are palmately compound, with five to seven leaflets, similar to those of a horsechestnut (*Aesculus*) and suggesting the specific name *aesculifolia*. The leaflets are smooth or have sparse simple hairs on the under side. The large showy

FIGURE 67.—Pochote tree trunk showing spines. Mérida, Yucatán, Mexico.

flowers with petals 6 to 6½ inches (15 to 17 cm.) long, white on the face and covered with yellow hairs on the brown backs, are produced just before the leaves in early spring. The seed pods, reaching maturity after the leaves have fallen in late autumn, are 4½ to 7 inches (12 to 18 cm.) long and 2 to 2¾ inches (5 to 7 cm.) in diameter, usually oblong, with blunt rounded ends (fig. 68). The walls of the seed pods are nearly ⅕ inch (5 mm.) thick and of a hard, brown, woody texture. The seeds are nearly spherical, dark brown or nearly black and usually shiny, and ¼ to ⅜ inch (7 to 10 mm.) in diameter. The fiber is white, tawny, or grayish, lustrous, and 1 to 1⅕ inches (25 to 30 mm.) long and is borne on the five seed-bearing ridges with the seeds, but at full maturity neither fiber nor seeds are attached.

This species grows in Mexico, from the State of Sinaloa to Oaxaca and Yucatán, and also in Guatemala. It is reported to be so abundant in some localities that, when the seed pods ripen, the ground is covered with the white flossy fibers to a depth of 4 to 8 inches (10 to 20 cm.). The trees are not cultivated.

The fiber has been collected and prepared for market to a limited extent, but the industry has not been sufficiently well developed to place the fiber on the market in good uniform quality. The large, spherical, smooth seeds may be separated from the fiber more easily than the small, rough seeds of kapok.

The fiber is slightly coarser and stiffer than kapok fiber. When well prepared, it is fully equal to kapok in buoyancy and resiliency. It is adapted to the same uses as kapok in cushions, pillows, mattresses, and life preservers, and for insulation.

NORTHERN POCHOTE

(BOMBAX FAMILY)

Ceiba acuminata (S. Wats.) Rose.

Eriodendron acuminatum S. Wats.
Ceiba tomentosa Britt. and Baker.

This tree and its fiber, like some related species, are known by the names pochote, ceiba, and silk cotton, but this species extends farther north than any of the other species, suggesting the name northern pochote.

The northern pochote tree, which attains a height of 15 to 30 feet (5 to 10 m.), has a widespreading top and a comparatively short greenish trunk 12 to 16 inches (30 to 40 cm.) in diameter, covered with broad conical spines, as are also the older branches, but the

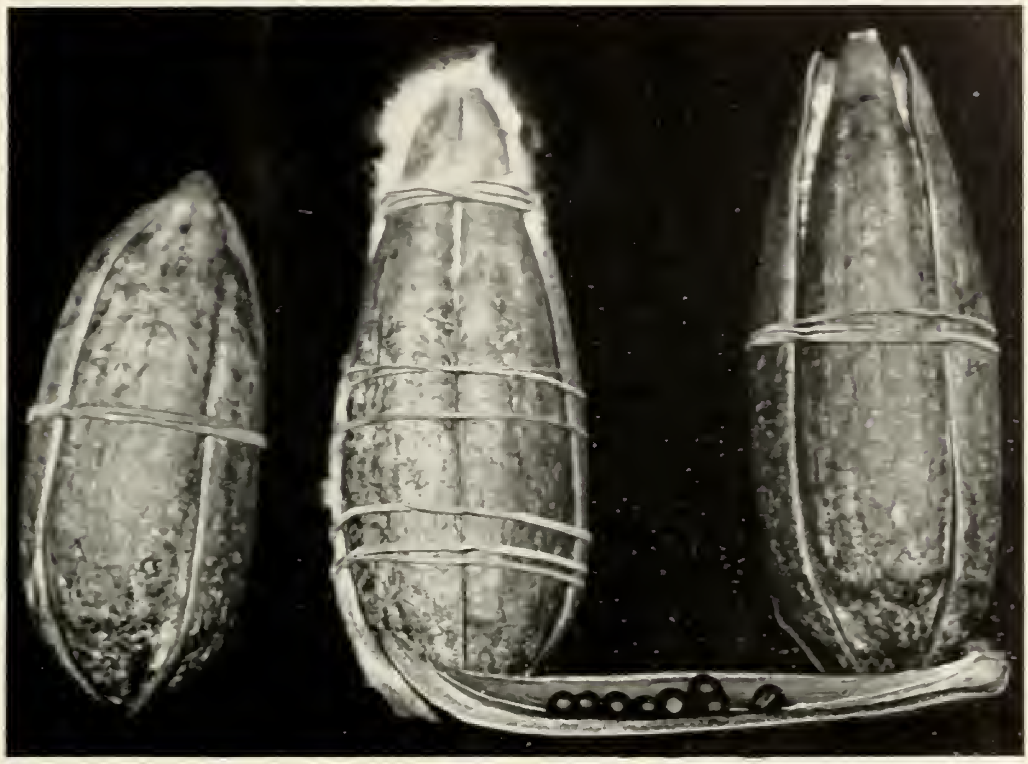

FIGURE 68.—Pochote seed pods, with section of pod and seeds. Guerrero, Mexico.

young wood is usually unarmed. The leaves are like those of the pochote tree, except that they are covered on the under surface with branching (stellate) hairs. The flowers are smaller, having petals 2½ to 4 inches (6 to 10 cm.) long, white on the face, and densely covered with yellow or brownish hairs on the back. The seed pods are 4 to 12 inches (10 to 30 cm.) long, generally blunt-pointed or narrowed toward the apex, but showing a wide variation in form. The five woody sections of the seed pod break away at maturity by well-defined sutures, leaving the fiber mass intact, but this soon puffs out (fig. 69). The fibers and seeds, borne on the five ridges of the paperlike central placenta, have no attachment at maturity. The seeds are nearly spherical, ¼ to ⅜ inch (7 to 10 mm.) in diameter, dark brown or black, and usually shiny. The seeds yield oil similar to cottonseed oil, amounting to nearly 20 percent of their weight.

The fiber is lustrous, white or slightly tawny, ¾ to 1⅜ inches (20 to 35 mm.) long, and usually longer and straighter than kapok from Java. The yield of fiber ranges from 7 to 15 percent of the weight of the seed pod. Oval pods thick in proportion to length yield the highest percentage of fiber.

Northern pochote grows in northern Mexico, from Baja California through Sonora, Chihuahua, and Zacatecas to

Tamaulipas. It is most abundant in well-drained gravelly soils in the foothills at altitudes of 500 to 1,300 feet (150 to 400 m.) above sea level. Throughout most of its range it is subject to frosts in winter. Under favorable conditions it grows rapidly and is sometimes planted as a roadside hedge. It may be propagated from either seeds or cuttings. The young trees begin to produce flowers and seed pods 3 to 5 years after they are set out.

The fiber is resilient and more buoyant than kapok. Ten grams of clean fiber from northern pochote, in a cheesecloth sack weighing 1 gm. and carrying a weight of 150 gm., when placed in a jar of fresh water sank at the end of 259 days (fig. 70). The weight was then removed and the sack of fiber, without extra weight, floated an additional period of 925 days, or 3 years 2 months and 29 days in all.

Figure 70.—Buoyancy test of northern pochote fiber. Ten grams of fiber, in a cheesecloth sack carrying a weight of 150 gm., beginning to sink at the end of 259 days. Fiber from Sonora, Mexico.

Figure 69.—Fiber masses from the acuminate pods of northern pochote beginning to puff out after the removal of the woody covering. Álamos, Sonora, Mexico.

The fiber from northern pochote is used locally for stuffing pillows, cushions, etc., but thus far it has not been produced regularly for export.

PALO BORRACHO

(Bombax family)

Chorisia insignis Humb., Bonp., and Kunth.

This tree is called palo borracho and yachan. The fiber, produced in seed pods, is called samohu or samuhú and paina, names that are used also to designate other species of *Chorisia*. The fibers of this group are often called kapok, which they closely resemble.

The palo borracho tree is 30 to 50 feet (10 to 15 m.) high. The leaves are palmately compound, with leaflets shiny on the upper surface and dull below. The showy white or partly yellow flowers, produced in great abundance, are followed by nearly spherical or pear-shaped seed pods 3¼ to 4 inches (8 to 10 cm.) in diameter.

The tree is native to dry lands in Peru, Ecuador, and the northern part of Argentina.

The fiber, like kapok, is produced chiefly along the seed-bearing placentas extending through the center of the seed pod. The fiber is white or slightly tawny, consisting of single hairlike cells about 1 inch (25 mm.) long. Being buoyant and resilient and a good insulator for heat and sound, it may be used for the same purposes as kapok.

The fiber is regularly collected from September to December from the palo borracho trees growing in the forests in Ecuador. It is prepared by freeing it from seeds, pieces of seed pods, and other trash, and is packed in bales for shipment. The amount of this fiber exported from Ecuador ranges from 200 to 900 tons per annum.

SAMOHU

(Bombax family)

Chorisia speciosa St. Hilaire.

This species is generally called by the Guaraná name samohu or zamohu, or sometimes palo borracho and arvore de paina.

The tree is 15 to 30 feet (5 to 10 m.) tall, of a round symmetrical form, with abundant dark-green foliage. The trunk and larger limbs bear abundant broad gray spines. Large purple or rose-colored flowers are borne in December or January or sometimes as late as March. The seed pods, 4 to 6 inches (10 to 15 cm.) in diameter, reach maturity in different areas from July to November, yielding large quantities of white flossy fiber.

This tree is native to humid areas in the La Plata valley. It is a very attractive tree in form, foliage, and flowers and is often planted along the streets and in parks in cities and towns.

The fiber is similar to kapok and is used for the same purposes. The fibers cling more firmly together than do the kapok fibers and are sometimes spun by hand into rather coarse yarns, which are woven into cloth. The fibers do not cling together firmly enough to be spun successfully on ordinary spinning machinery.

MISCELLANEOUS FIBERS

Some of the minor fibers, chiefly roots, stems, or entire leaves, are not readily classified in the groups of hard fibers, soft fibers, or short fibers; until there is a more complete classification, these may be grouped together as miscellaneous fibers.

BROOMROOT

(Grass family)

Muhlenbergia macroura (Benth.) Hitchc.

Epicampes macroura Benth.

In Mexico broomroot is called zacatón, elsewhere sometimes bunchgrass. Both names are commonly applied to other tall grasses, especially those growing in dense bunches. The fiber is called raiz de zacatón, corrupted into the English riceroot, and in the market is called Mexican broomroot, Mexican whisk, and riceroot.

FIGURE 71.—Broomroot. The stiff resilient roots of this grass are used in brushes. Specimen from Sayula, Jalisco, Mexico.

"Broomroot" is the name applied more particularly to the roots of this large bunchgrass. The plant grows to a height of 3 to 5 feet (1 to 1.5 m.) and has long slender leaves. The long wavy roots extend down into the soil in a mass about half as large as the bunch of leaves and stems above ground (fig. 71). The grass is propagated and distributed by its abundant seeds and grows year after year from the roots. It is found from southern Texas to Central America and is most abundant in sandy soils in open pine forests at altitudes of 1,000 to 1,600 feet (300 to 500 m.) above sea level in the region around Orizaba and Mexico City, where there is a fairly heavy rainfall, together with warm days and cool nights. It grows abundantly under similar conditions in Guatemala. It is not regularly cultivated, although attempts have been made to cultivate it in the State of Veracruz. The grass increases rapidly under favorable conditions, becoming a troublesome weed in cornfields. The roots of old plants are coarse and brittle and of little value for brushes. Cattle graze on the young leaves of the grass, but the older leaves are too tough and fibrous for even hungry cattle. It has been demonstrated experimentally that the leaves make excellent paper similar to that made from esparto.

The roots are collected from broomroot plants growing wild, often as a part of the work in clearing fields for cultivated crops. The ground is loosened around a clump of grass, then a pointed lever is pushed through the roots, and the entire bunch is pried out. The soil clinging to the roots is beaten off; then the roots are chopped off. The roots are washed in running water and rubbed on a rough stone to remove some of the barklike covering from the tougher inner part. Thus cleaned, the roots are dried in the sun and then taken to a receiving station, where they are weighed and the collectors are paid.

The small bundles from the receiving stations are taken to the factory, where they are piled loosely in a closed room and bleached by being subjected for about 24 hours to the fumes of burning sulfur. The roots are again washed, sorted according to size and quality, tied in small bundles, and bleached again in sulfur fumes 24 to 48 hours. They are then brought out, separated into four grades, made up into bundles of 110 pounds (50 kilos) each, and baled for shipment.

The prepared broomroot is light to deep canary yellow, 8 to 16 inches (20 to 40 cm.) long, and about 1/25 inch (1 mm.) in diameter, wavy or crimped, stiff, and resilient. It has the defect of becoming brittle when thoroughly dry.

Broomroot is used in stiff brushes, such as scrubbing brushes, and especially butchers' brushes to scrape off chopping blocks. It is also used in whisks that are stiffer than those made of broomcorn.

Germany and France were formerly the principal markets for broomroot, and the shipments to those countries ranged from 2,000 to 3,000 metric tons a year at prices ranging from 15 to 30 Mexican pesos per 50 kilos. The demand has fallen off, chiefly owing to the competition of palm fibers from India and West Africa.

TREEBEARD

(Pineapple family)

Tillandsia usneoides L.

Dendropogon usneoides (L.) Raf.

Treebeard is a gray fibrous plant hanging from trees and is called also southern moss, Spanish moss, Florida moss, Louisiana moss, black moss, hanging moss, barba de palo, musgo negro, and igan. In the upholstery market it is generally called just moss, but this name is also applied to other commercial products.

Treebeard is a flowering plant, not even distantly related to the true mosses. It belongs to the same family as the pita floja and pineapple. It is not a parasite but a true epiphyte, or air plant, obtaining its nourishment from the air, not from the trees on which it hangs (fig. 72).

Treebeard consists of slender, branching, gray stems 10 to 80 inches (25 to 200 cm.) long, bearing short, awl-shaped, recurved leaves and small yellow-green flowers in summer, followed about 10 months later by brownish seed pods 3/4 to 1 1/8 inches (2 to 3 cm.) long. The stems and leaves are covered by small gray scales capable of absorbing moisture. Through the action of these scales and the plant food dissolved from dust in the air and washed under them by rain, the plant receives its nourishment. The numerous seeds are covered with barbed hairs that may cling to birds and squirrels or to the bark of trees. The plant seems to be propagated chiefly by pieces of the stems that are blown from one tree to another. Treebeard is widely distributed, and in many places it is abundant. It is found in swamps or where there is much moisture in the air, from the Dismal Swamp, in southeastern Virginia, along the Atlantic coast to Florida and along the Gulf coast to Texas and Mexico.

It is not cultivated or propagated by man but reproduces itself rapidly. Severe hurricanes sometimes blow down so much of it that its growth is checked for a year or two.

FIGURE 72.—Treebeard, hanging from cypress trees. Photograph from J. C. T. Uphoff, Orlando, Fla.

Treebeard grows on many different kinds of trees, such as cypress, tupelo. live oak, and hickory, that grow either in the swamps or where there is abundant moisture in the air. It sometimes grows on dead trees or even on telegraph wires, but less vigorously than on living trees, where the foliage tends to conserve moisture and affords more surface from which the dust may be washed onto the treebeard. Although the treebeard does not take plant food from the trees, it sometimes becomes so abundant as to smother the trees and prevent the normal growth of foliage.

Treebeard is collected chiefly in late fall and winter, when the fiber is of the best quality. After severe windstorms it is picked up from the ground; in swamps it is often left in the water several weeks to rot off the outer covering. Most of it is collected directly from the trees by means of hooks on the ends of long poles. Some pickers sell the freshly collected raw material to the local dealer, but many of them cure it so as to obtain a higher price. The curing process rots off the outer gray covering.

In some places treebeard was formerly placed in pits and covered with water to simulate conditions in the swamps. The term "pitting" is still used, although the material is now generally piled in long heaps about 5 feet (1.5 m.) high and soaked with water (fig. 73). A fermentation is induced that rots off the gray outer covering so that it may be easily removed from the threadlike fibrous inner part of the stem. This process is commonly called curing. The fermentation produces heat in the interior of the pile, and if the temperature gets too high the fiber is injured. More water is thrown on to keep down the temperature or the heap is pitched over and repiled by placing the unrotted material from the

FIGURE 73.—Treebeard in long piles kept moist to cure, that is, to rot off the gray outer covering. Photograph from J. C. T. Uphoff, Orlando, Fla.

outside in the inside of the new pile, which is again soaked with water. The curing process requires about 3 weeks in summer or nearly 3 months in winter. The cured material is hung on poles or wires to dry (fig. 74). When dry, it is taken to the moss gin. It is there put through a machine consisting of fluted rollers and a beating cylinder or picker, and afterward shaken or raked to and fro over a screen to remove dirt. It is often put through the gin a second time and in some places through another gin with finer teeth closer together. It is then sorted into about three grades based on color, uniformity, and freedom from dirt. It is packed in bales of about 70 kilos each and covered with burlap to keep it clean. The final yield of the finished product is only 10 to 15 percent of the weight of the green treebeard.

The prepared fiber is brown to nearly black, and if well prepared it is lustrous and resilient. A lustrous dark seal-brown fiber is preferred. It is sometimes dyed with iron sulfate.

Treebeard is used most extensively in upholstering furniture. It is also used in cushions for automobiles, railway cars, and airplanes and in mattresses. It is one of the best substitutes for horsehair, which it resembles, the chief difference being that treebeard is branched and horsehair is not.

It is estimated that an average workman may gather 400 to 600 pounds of green treebeard in a day, and for this he is paid about 30 cents per 100 pounds; for well-cured material delivered at the gin he is paid about $3 per 100 pounds. The market price for the finished product fluctuates with supply and demand, and this depends to some extent on the changing fashions that create a demand sometimes for over-

FIGURE 74.—Treebeard "cured," hanging on wires to dry. Photograph from J. C. T. Uphoff, Orlando, Fla.

stuffed furniture and sometimes for carved-wood furniture. The average price for medium-grade treebeard is about 10 cents a pound.

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