Structural, or Leaf, Fibers

by CECILLE M. PROTZMAN

STRUCTURAL, or leaf, fibers (mostly known as hard fibers) include principally the cordage and brush fibers.

As a class, they are long, coarse, harsh, and strong.

Some (such as sisal, henequen, abaca, and some istles) are most suitable for twisting into coarse twines and cordage. They also are used extensively in floor coverings and locally in bags. Others (such as piassava, some istles, and magueys) are bulky, stiff, and suitable for brushes. A few are fine and soft (such as pineapple fiber) and are used locally in fabrics.

But all hard fibers have the same general characteristics of growth and methods for obtaining the fibers. Many of them originated in the Americas. The henequen of Yucatan was probably the earliest vegetable fiber used in the Western Hemisphere.

Hard fibers form the veins that carry water and food within the plant and furnish strength and support for the leaves and leaf stems of certain perennial plants.

They usually are obtained by a process of mechanically crushing the green leaves and scraping away the pulpy and other nonfibrous material.

Most of them grow best in tropical climates and are reproduced by vegetative propagation. A few are grown from seed. Harvest for many of them is a continuous process in a large field or plantation, as only the mature leaves or stalks are harvested and new growth continues from the same rootstock for some years.

Common names of fibers are often confusing, as one fiber may be known by different names in different countries. Indeed, the same name may be applied to several different fibers. *Phormium tenax*, for example, is known also by the common names of "New Zealand flax" or the "New Zealand hemp." Conversely, the name "hemp" is applied frequently to abaca, henequen, and sisal, as well as the true hemp (a soft fiber), with only the identifying country of origin as a clue to the type of fiber indicated. Pita and maguey are commonly used to designate several different fibers of Latin American origin.

Sisal and abaca are invaluable for their use in cordage. They were designated as strategic fibers during the Second World War and are stockpiled in countries of large consumption. The United Nations Committee on Commodity Problems endorsed in 1962 a Study Group for Hard Fibers (principally sisal, abaca, and henequen) to collect and exchange statistics and other information among all important producing and consuming countries in the hard fibers market.

SISAL (*Agave sisalana*) is most important of the hard fibers and is the principal cordage fiber.

It is used principally for manufacture into cables, ropes, binder and baler twines, and other tying twines for farms and industry. In some countries it also is used in bags for handling and storing agricultural, mineral, and industrial commodities. Sisal floor coverings and padding for upholstery also represent significant uses of sisal.

The manifold minor uses include novelty products and such items as pulp for papermaking, which uses mostly short fibers, tow, and waste fiber. Sisal is not the preferred fiber for ropes exposed to salt water, despite its durability in other uses.

Sisal originated in Central America and the Yucatan Peninsula, where Indians were using it along with henequen when the Spaniards discovered Mexico in 1509. It was named from the old seaport town of Sisal, Yucatan, from which most of the exports were shipped after the fiber entered commerce in 1839. Plants were taken to the Florida Peninsula about 1836 and from there to many other countries. They reached Tanganyika in 1893, and before 1939 that country had become the largest producer of sisal.

World sisal production was 1,445 million pounds in 1963, an increase of 185 percent over the 1934–1938 average of 507 million pounds.

The producers in 1963 were Tanganyika, 476 million pounds, or 33 percent of the world total; Brazil, 424 million pounds, or 29 percent; Angola, Kenya, Mozambique, and other African countries, with a combined total of 443 million pounds, or 31 percent; and Haiti, Taiwan, Indonesia, and Venezuela, with most of the remaining 7 percent.

Indonesia had ranked second, next to Tanganyika, in world production before 1940, and its fiber was of the highest quality, but wartime destruction and neglect followed by the breakdown of the plantation system of sisal production were factors in the decline of fiber output from 214 million pounds in 1941 to 9.2 million pounds in 1963.

Sisal is a tropical plant of the Amaryllis family. Each well-developed plant usually produces at least 200 long, stiff, fleshy, dark-green leaves, which grow in a rosette from the central bud at the base of the plant.

Older leaves are about 3 to 6 feet long, 4 to 6 inches wide, and nearly 1 inch thick at the center and thicker at the base. Each has a sharp, terminal spine nearly an inch long.

The plant requires temperatures above the frost level, moderate humidity, and annual rainfall of 30 to 70 inches. It is often grown in poor, dry, rocky soil, but grows faster and more luxuriantly in rich, well-drained, limestone soil.

Successful commercial production of sisal fiber requires a central cleaning machine within easy distance of the fields, plentiful water for washing the fiber, a place for waste disposal, sufficient labor supply, and means of transportation to market.

The growth habit of sisal lends itself most economically to large plantations of at least 2,500 acres and plantings of 1 thousand up to 2 thousand plants to the acre, according to the soil and climate.

Only the more mature, lower leaves are harvested at a time, but plants usually continue to produce new leaves for 10 or 15 years, according to local conditions, including the 6 or 7 years of peak production.

Leaves are harvested periodically as long as growth is economically sufficient. A pole, or flower spike, develops as the plant becomes older. It grows to a height of 15 to 20 feet and bears flowers and the bulbils or buds from which new plants are grown. After poling, the plant dies and is replaced.

Laborers cut the mature leaves from the plant with a heavy, curved, knife-type implement, remove the terminal spines, and tie the leaves in bundles that weigh about 90 pounds.

The bundles are hauled to the decorticating plant, where the fiber is extracted by machine, preferably within 48 hours after cutting. Workers lay the leaves parallel to each other and crosswise on a conveyor belt, which feeds them through revolving, corrugated crusher rollers to soften the leaf mass. Then in a cleaning process, during which the leaves are clamped firmly, revolving drums with beater blades scrape away the broken and softened epidermis and pulp surrounding the fiber, while water is sprayed over it to wash away the waste.

Leaves are sorted according to length and freedom from damage before being fed into the decorticator, and the fiber is graded as it comes from

the machine and further sorted with each handling. The clean, wet, greenish fiber from the decorticator is hung over lines to dry and bleach in the sun. The dried fiber is creamy white and ready for brushing and baling according to grade. It runs about 3 to 4 percent of the green-leaf weight.

Sisal is graded principally according to length, color, and cleanliness. Each country's fiber differs somewhat in quality for a specified grade. Consequently the purchasers buy not only according to grade but also according to origin.

Major producing countries have organizations of producers or exporters, or both, for handling and marketing the sisal and promoting the general welfare of the industry. Some major producing countries have organizations for hiring laborers and setting terms of contract between producers and laborers. Labor unions began to organize in British East Africa soon after 1950. Workers often have their families with them. The large plantations provide living quarters and facilities for community life and entertainment, such as schools, churches, and recreation centers.

The chief producing countries are also the chief exporting countries. Exports range from more than half to nearly all of the crop, according to the country.

Tanganyika has ranked first in both production and export of sisal. The fiber is the major commodity in the country's cash economy and is its most valuable export. The United Kingdom is the major buyer. The United States, Japan, Belgium, and the Netherlands are next. These five countries take two-thirds of Tanganyika's sisal exports.

Brazil, second in production, exported four-fifths of its 1962 crop, and shipped it principally to the United States and to the Netherlands, West Germany, and elsewhere in Europe.

Kenya sisal goes mostly to the United Kingdom, West Germany, Japan, Belgium, the United States, and other European and Asian countries. Angola ships more than a third of its sisal to Portugal and sizable amounts to Spain, the United States, and other European countries. Mozambique sends a third to the United States. The Malagasy Republic sends two-thirds of its sisal to France.

The exporting countries export their crop mainly as raw fiber, with 15 percent of the total destined for the United Kingdom in 1961, 55 percent to other European countries, 13 percent to the United States, and most of the other 17 percent to Asian countries and Australia. Products manufactured in industrial countries from imported sisal fiber are not only for domestic use but also for export to all parts of the world.

The price of sisal generally is determined more by fluctuation in demand than by fluctuation in production. The length of time between planting and the first harvest and the long producing period make sisal production fairly resistant to sudden large changes in production. Sudden demands for ropes for military emergencies or for twines to handle unusual grain crops, for example, may deplete stocks and force prices to levels that encourage the use of substitutes. This happened when prices reached an alltime peak average of 29.7 cents (for British East African No. 1, landed New York) in 1951, compared with a prewar average of 5.1 cents a pound in 1935–1938 and a postwar low of 9.4 cents in 1957. The level was 18.9 cents through the last 4 months of 1963.

Hecogenin is derived from sisal juice after dry decortication of fiber and is valuable in the partial synthesis of cortisone.

HENEQUEN (*Agave fourcroydes*) is second to sisal as a cordage fiber.

Its principal use is in binder and baler twines, but it can be substituted for sisal quite satisfactorily in many types of cordage up to about 1 inch in diameter. It is also softened, spun, and woven into sacking, other coarse cloth, floor coverings, and novelty items. It is

somewhat longer and coarser than sisal, but sisal has a greater average tensile strength.

Henequen originated in Mexico, where it has been used since prehistoric times and where more than 90 percent of the world total is now produced. Considerable confusion in names derives from lack of recognition in its early history of the difference between henequen and sisal. Sisal was the one that spread to the Eastern Hemisphere; henequen became the main hard fiber of Mexico and Cuba, but henequen is often erroneously called Mexican sisal or Cuban sisal.

World production of henequen was 330 million pounds in 1963—slightly less than the peak of 375 million pounds in 1960 and 34 percent more than the annual average of 247 million pounds during the prewar years.

Mexico has maintained its early position as principal producer, and the bulk of its henequen is grown in the dry, limestone soils of the Yucatan Peninsula. Mexican production was 340 million pounds (92 percent of the world total) in 1962. Cuba was second with an estimated 22 million pounds.

Henequen plants look much like sisal, except that the color is more nearly bluish-gray. The leaves have sharp, slightly hooked prickles along both edges and, like sisal, a dark terminal spine about an inch long. As with sisal, a leaf-scarred trunk develops as the lower leaves are cut in successive harvests and new leaves develop in the center. Leaves yield about 4 percent in fiber.

The large-plantation system, with all facilities for growing and processing the fiber and for care of the laborers, is the traditional system in the commercial henequen regions of Mexico, but a change began to develop about the middle of the 20th century. In the following 10 years, the Government took steps to restrict the acreage of large plantations and set up organizations to finance and establish workers on small, individual farms or on parts of larger, communal-type areas. Mexico has been purchasing decorticating plants from plantation owners and building new plants for the use of small and large producers.

The methods of cultivating, harvesting, extracting of fiber, and marketing of the baled product are essentially the same for henequen as for sisal. Henequen plants tend to grow a little slower and live a little longer than sisal plants. They may live for 20 to 25 years, but the useful life is barely more than half that time.

Henequen withstands a dry climate better than most plants, but prolonged drought adversely affects quantity and quality of production. The land in many of the Yucatan fields is so dry and stony that it is necessary to make planting holes with a pick and prop the young plants up with stones until they become well rooted. Weeding must be done by hand in such fields.

The first cutting is usually in the sixth or seventh year, as in Mexico, or the fourth year, as in Cuba, largely according to the amount of rainfall. Cutting continues at intervals of about 6 months for the next 10 to 12 years.

Dried fiber is 2 to 5 feet long and is reddish yellow to nearly white. Length, color, and cleanliness determine the grades. The standard bale is about 400 pounds, but the weights vary among processing plants.

The henequen industry—production, manufacture, and export—is the chief factor in the economy of the Yucatan Peninsula. Yucatan factories consumed about 80 percent of the domestic henequen fiber in 1962. Increased demand for cordage to handle unusually large grain and other crops meant a 7-percent increase in mill consumption of fiber in 1961. Another 3-percent increase in 1962 raised consumption to 266 million pounds. The cordage factories of Yucatan were consolidated into one corporation in 1961.

Mexico exports 88 to 90 percent of its henequen products. The United States receives 95 to 98 percent of Mexican exports of raw fiber and about 90 percent of the exported man-

ufactured products. Baler twine is by far the largest item. The balance of raw fiber is shipped principally to Japan and Europe, but the other manufactured goods go chiefly to Central America and South America.

Henequen prices are normally a little below those of sisal. Grade A Mexican henequen, landed New York, was 11.4 cents a pound at the beginning of 1963. Its postwar peak was the annual average of 24.5 cents in 1951.

ABACA (*Musa textilis*), of the banana family, provides the strongest and best of the cordage fibers. It is one of the few hard fiber plants that is not native to the Western Hemisphere.

Spanish and Portuguese explorers of the 16th and 17th centuries found Filipino natives wearing clothing made of abaca fiber. In modern times it is considered primarily as a cordage fiber, and it is the preferred vegetable fiber for the best grades of commercial ropes and cables and for marine cordage because of its resistance to salt water and small amount of swelling when wet. Some of the finer fibers are woven into cloth. Large quantities are made into pulp for strong, high-quality paper and specialty items, tea bags, and mimeograph mats.

Abaca is indigenous to the Philippines, where more than 95 percent of it is grown.

The fiber is often called by the trade name, Manila hemp, even though it is not a hemp and very little is grown as far north as Manila. It received the unrepresentative common name from Europeans who found it in the market of Manila when they first went to the Philippines in 1697.

True hemp had been the recognized cordage fiber before that time. It was understandable that the newly found fiber that was so suitable for cordage should be called hemp and differentiated from the familiar true hemp by using the name of the port city—Manila—where it was first discovered.

It soon became recognized in England as an important fiber for good cordage. Production spread to Indonesia, North Borneo, Malaya, and smaller islands of the Pacific, but met with little continuing success outside the Philippines and Indonesia.

Most early attempts to grow it in the Americas were unsuccessful. It was introduced into Central America in 1925 through efforts of the United States Department of Agriculture and the United Fruit Co. These experimental plantings were developed into a source of emergency supply to the United States while Philippine supplies were cut off during the Second World War. The plantations were abandoned later for economic reasons.

World production of abaca was 260 million pounds in 1963. This represented 13 percent of the combined production of sisal, henequen, and abaca, the three principal cordage fibers. Peak production of abaca was 428 million pounds in 1935. Peak production in postwar years was 318 million pounds in 1951.

Philippine production was 416 million pounds in 1935. Wartime damage to Philippine plantations in 1941-1945, the removal of Japanese producers, and some migration of the native population who were not familiar with abaca cultivation from other parts of the islands to the abaca regions during the war and in early postwar years all worked together to reduce production. Also, infestation by mosaic disease and the rising cost of production continued to keep abaca from regaining its prewar eminence. Philippine production in 1963 totaled only 247 million pounds.

The principal fiber obtained from the abaca leaf is 7 to 14 feet long. The fiber from the outer leaf sheaths of the stems is strong, coarse, and brownish in color. Fiber from inside leaf sheaths is finer and white, but has lower strength.

Some of the best Philippine fiber is combed, carefully drawn out in single fibers, and knotted to make a long, continuous strand, called knotted abaca. This is woven by hand into a

cloth, called sinamay, that is used for clothing in the Philippines.

Abaca of good quality can be grown most economically as a plantation crop in a consistently warm, humid climate with well-drained, fertile soil.

A mature abaca plant resembles a banana plant and consists of 10 to 30 stalks growing in a cluster. Each stalk grows to a height of 10 to 20 feet.

Its leaves, about 12 inches wide and 3 to 6 feet long, extend from long, sheathlike stems that grow out of a central base and overlap to form a false trunk 6 to 15 inches in diameter. The broad, green leaves appear to grow from the top of this false trunk, although the leaf sheaths form it.

Harvest begins about 2 years after the suckers are set out. The entire trunk of the tallest stalks is cut down for fiber. Shorter stalks are left to continue growing.

After a field is established, it can be harvested two or three times a year for 10 to 15 years. A trunk weighs 35 up to 120 pounds, but only 2 to 3 percent of its weight is usually recovered as fiber.

The worker separates the leaf sheaths from each other and with his knife pulls off the outside layer of the leaf in tuxies, or ribbons, that are 2 to 3 inches wide and the length of the leaf. This is done in the field.

All pulp is scraped away in a stripping shed. The fiber is extracted from the tuxies by pulling them under knifelike scrapers, operated by hand or by crude or semiautomatic machines.

The work is heavy, and a laborer using the hand method can handle only about 500 strips a day and obtains about 25 pounds of clean fiber. The fiber is dried on long lines in the sun.

A few plantations use large machines, like sisal decorticators, which can extract up to 1 thousand pounds an hour and recover a larger portion of fiber. The decorticated fiber, classed as deco, lacks sheen, but is becoming acceptable in the trade as equivalent to hand-cleaned fiber. Deco fiber is dried in automatic dryers.

All fiber for export is graded under government supervision and pressed into bales that may weigh about 279 pounds. The domestic industry of the Philippines uses mostly loose bales of noninspected, or unbaled, fiber, which was 14 percent of the crop in 1962.

Cleaned abaca fiber is mostly cream colored, glossy, stiff, and tenacious. It is 3 to 14 feet long. All the fibers grow in the outer layer of the leaf sheaths, but those near the margins are shorter. Those from leaf sheaths near the outside are stiffer and darker colored.

The basis for standard grading of Philippine fiber was set up with help from the United States Department of Agriculture and became effective in 1915. Abaca is classified into many grades. It is designated according to the island where it was grown, and fiber of each origin is classified as to degree of cleanliness, color, uniformity, and strength.

Exports of Philippine abaca fiber fell from an annual average of 370 million pounds in 1935–1939 to 208 million pounds in 1962. It goes principally to the United States (29 percent in 1962), Japan (26 percent), the United Kingdom (15 percent), and the other European countries (19 percent).

The Philippines produced 35 million pounds of unbaled or noninspected fiber in 1962 for domestic manufacture into cordage, and factories also used 2.5 million pounds of inspected fiber.

A large share of the cordage was exported, and it was shipped chiefly to the United States, other North American and South American countries, and Asia.

Abaca ordinarily commands a better price than other cordage fibers because of its superior strength, appearance, and stability in salt water. Abaca (Davao I) was being quoted in the New York market at 23.2 cents a pound in 1962 when Mexican henequen (grade A) was selling at 9.4 cents and British East African sisal (No. 1) at 12.7 cents.

The three principal cordage fibers—abaca, sisal, and henequen—each has

its own normal place in use preferences. Abaca (the highest priced) is used in cordage of the best quality.

Henequen (priced the lowest) is used in ropes of lesser value and twines.

Sisal is used for the great range of cordage of various grades and sizes in between.

The lower grades of abaca and the better grades of sisal, however, are readily interchanged in most rope uses and are often thus substituted when any change of supply or price relationship may warrant. Likewise, lower grades of sisal and better grades of henequen may be interchanged.

Cotton, jute, hemp, and paper twines compete with the cordage fibers.

Lesser known native fibers compete in every category of use when price relationship, ready availability, or government policies of self-sufficiency favor the substitution. Wire and steel straps and steel cables have gained importance in such fields as binding bales and reinforcing packages.

Nylon entered the cordage field about 1940 and polypropylene somewhat later. They seem established in certain uses where their higher initial price is justified by their properties, such as endurance and light weight.

THE ISTLE FIBERS include principally certain fibers of the Amaryllis and Lily families.

They are used in bags of various kinds, other protective coverings, brushes (especially scrubbing brushes), wrapping twines, small ropes, novelty items, and many twine and fabric items for use about the home or farm.

Mexican Indians have long used the istle plants for food, clothing, beverage, and means of livelihood.

Istle (pronounced *issel*) is the anglicized name for "ixtle," the name used in Mexico, where most of the world supply originates. Some istles receive their common or trade names from place names of the region where they are found in greatest abundance. But common names are not applied consistently and often overlap.

The most important istles are lechuguilla, Jaumave, and palma. Lechuguilla (*Agave lophantha* var. *poselgaeri*, formerly known as *Agave lecheguilla*) belongs to the Amaryllis family and is the most important istle. It is known also in trade channels as Tula istle or Tampico fiber, but the latter designation includes also zamandoque (*Hesperaloe funifera*) and some other similar fibers of the same region.

The plant of lechuguilla istle resembles a small sisal but does not form a trunk. It grows wild on the arid, limestone mesas of northern Mexico, and in parts of southern Mexico, but the fiber of commerce is obtained from the northern growths. Lechuguilla grows best at 3 thousand to 6 thousand feet, where the climate is temperate.

Lechuguilla istle fiber, in general, is the coarsest and stiffest of the commercial agaves and is especially suited to use in scrubbing brushes, but the grades range from fine and soft to hard and stiff. It is round, tapered, creamy to green in color, and 7 to 20 inches long.

The tallador, or gatherer of istle, gathers cogollos (central stalks) about once a year after the plants are 6 to 10 years old. The cogollo is composed of 6 to 15 new, tender leaves wrapped closely together in an elongated ball, and the fibers are extracted from them. The leaves are up to 20 inches long and somewhat less than 2 inches wide.

The worker uses a stick with an attached iron ring to hook over the cogollo and pull it off. He can gather 65 to 90 pounds a week, from which he can extract 6 to 8 percent as fiber. He obtains the fiber by scraping the leaves with a heavy knife against a block of wood. He takes the results of his week's work to a central collection station, where fiber is collected, bought, sorted, graded according to length and color, and pressed into bales of about 110 pounds. Both collecting and marketing of istle is controlled by government through cooperative societies.

The tallador uses some of the istle he collects to make his rope basket to

carry the cogollos and also ropes to tether cattle, bags for many purposes, rugs for his hut, saddle blankets, and brushes for his family's use. He receives barely a living from his sale of fiber, and the work is difficult and the living hard in the hot, semiarid regions of the istles. Consequently, less istle is collected in years when rainfall favors other crops.

Mexico produces 25 to 30 million pounds of commercial lechuguilla istle annually and uses about 15 to 20 percent of it in domestic manufacture of cordage. The other 80 to 85 percent is exported—principally to the United States, the Netherlands, and other European countries.

The short fibers are curled by twisting before being baled and used in upholstery and pads for under carpets and car mats. Exported brush fiber is sold almost entirely on order; each lot is cut, dyed, and bunched according to the buyer's specifications.

Lechuguilla has to compete with palm or palm-type fibers for use in stiff brushes, but it has greater competition from nylon and other man-made fibers.

Jaumave istle (*Agave heterocantha*), formerly known as *Agave funkiana*, of the Amaryllis family, is third in commercial importance among the istles, but the fiber is superior in quality and brings the highest price.

Production, though small, is entirely for export, mostly to the United States, where it is used in high-quality brushes.

The plants grow only in the semiarid, limestone soil on the sides of mountains in Tamaulipas, Mexico. They differ from lechuguilla in that the leaves are straighter and longer.

MAURITIUS FIBER or Mauritius hemp (*Furcraea gigantea* or *Furcraea foetida*) is a member of the Amaryllis family.

It is another hard fiber for cordage and bags that has a common misnomer. It is quite different from the true hemp and is not native to Mauritius, where it was introduced about 1790. It is used for sugar bags in Mauritius and ranks next to the sugar industry in importance to the island.

It originated in eastern Brazil, where it is known as piteria; from there it spread to Mauritius, St. Helena, Madagascar, Australia, the West Indies, southern Asia, and Africa.

The fiber is known in Mauritius and in the trade as aloe fiber, although it only slightly resembles the true aloe of Africa. Production of Mauritius and similar fibers is relatively small—only 2 million or 3 million pounds annually—but is important to each producing country as a source of fiber for domestic use in cordage, bags, and various other local uses.

SOME LEAF, or structural, fibers have many characteristics of stem fibers and are relatively pliable. These include phormium, caroa, banana, and pineapple fibers and the sansevierias, or bowstring hemps.

Phormium (*Phormium tenax*), from the *harakeke* lily plant of the Lily family, is often known as New Zealand flax or New Zealand hemp because of its softness, even though it is a leaf fiber and differs considerably from both flax and hemp, which are stem fibers.

Captain Cook, when he visited New Zealand in the late 1700's, found the New Zealanders using the leaves for making their baskets and the fiber for clothing and cordage. They used phormium as the first article of barter with the Europeans.

Cultivation spread from New Zealand to St. Helena, Chile, the Azores, and Argentina. Phormium is the only commercial hard fiber found outside the Tropics. Attempts to introduce it into western Europe, some African and other South American countries, and California have met with small success commercially.

Production has been fairly steady since 1957 in the main producing countries. All of the New Zealand production of 9 million pounds and most of Argentina's 9 to 10 million pounds are consumed domestically. The crop

of 2 million pounds in St. Helena is exported.

New Zealand began to export phormium in the 19th century, mostly to the United States, Australia, and the United Kingdom. Competition from sisal caused exports to decline to negligible quantities during the next half century.

The fiber is tan or creamy white, soft, quite flexible, and lustrous. It is stronger than henequen but not so strong as sisal. At 4 to 8 feet it is next in length to abaca.

Its use is restricted because it deteriorates rapidly in color and strength when wet.

Fiber is obtained from wild and cultivated plants, but the latter yield the finer fiber.

The principal use of phormium in New Zealand is for manufacture into bags and wool packs, but in other countries it is used chiefly for rope and binder twine, alone or mixed with sisal or abaca. Some is made into floor coverings. It has stiff competition in the world market from other natural fibers, especially sisal.

The African or Guinea bowstring (*Sansevieria metalaea* or *guineensis*) is probably best known of the sansevierias. The common house plant, Spanish bayonet, is one of this group.

Fibers of this group are soft, long, strong, fine, and silky white, but somewhat brittle, and are used especially in cordage, fish nets, native bowstrings, mats, and coarse cloth.

All species grow in Africa, southeastern Asia, and Latin America, mostly where the climate is warm and moist and the soil is sweet.

Extraction of fiber is similar to that for sisal, and is from leaves of either wild or cultivated stands. Production is relatively small, and use is insignificant beyond the areas of origin.

Caroa (*Neoglaziovia variegata, Mez. Bromeliaceae*) has long been used in Brazil, where it grows wild on millions of acres in the hot, dry, northeastern section of the country. Only a small part is harvested.

Caroa leaves are thorny and are 3 feet or more in length. They are cut from the wild plants by hand with stout knives and tied into bundles of 90 to 110 pounds for transport by burro to the nearest processing station.

The fiber is similar to pineapple fiber, long, silky, white or light tan, finer than sisal or abaca, and stronger but somewhat harsher than jute.

It is manufactured into cordage, threads, nets, fish lines, and bags, or mixed with other fibers for use in cloth. It is a satisfactory source of pulp for manufacture into lightweight paper for airmail or cigarette papers. Large quantities are used in bags for coffee and other Brazilian commodities, especially when jute prices are relatively high, but its tendency to deteriorate hampers more widespread use.

Production was 8.6 million pounds in 1961. Peak production averaged about 25 million pounds during the war years, when jute was hard to obtain. Brazil now grows its own jute and is dependent on neither imported jute nor domestic caroa for bags, but the population of the caroa region continues to use the local product and export some fiber and manufactures.

Pineapple fiber (*Ananas comosus*) is obtained from leaves of the plant that produces the pineapple fruit. The plant is indigenous to Brazil and Paraguay, but it has spread to many other parts of the tropical world, including the Philippines, Hawaii, Indonesia, Puerto Rico, and Cuba.

The fiber is not produced in significant quantities for export.

Banana fibers can be obtained from several varieties of the banana or plantain plants. Unlike their relative, abaca, most of them lack sufficient strength for satisfactory commercial use in competition with other fibers. Their use is quite limited.

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