ABACA

A CORDAGE FIBER

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SCOPE OF THE STUDY

In the history of fibers war has brought sudden and lasting changes. By shutting off the supplies of Russian hemp, the Napoleonic wars (1796-1815) brought sunn fiber into prominence. Soon after the close of that conflict an officer of the American Navy, Lieutenant John White, returning from the Philippines, demonstrated the superiority of a "new" fiber, abaca, for marine use. Nevertheless, it was not until the Crimean war (1854-56) again deprived this country of Russian hemp,[1] that abaca finally displaced hemp as the premier cordage fiber.

In the years immediately following the Spanish-American War (1898) Americans entered the Philippine abaca industry.[2] While the Filipino planters continued to grow the fiber as their ancestors had grown it and to clean it in the same primitive way that Magellan's companions might have observed when they visited the Islands four centuries ago, the Americans introduced modern methods of culture and invented a machine for stripping the fiber that took some of the burden of the work from the man. In the early part of this century Japanese brought in to do the work on the plantations became more numerous, and at the close of World War I, having the "know-how" of the Americans and with plenty of capital, they were able to take over and develop the most progressive and most profitable part of the abaca industry, that in Davao in the southern part of the island of Mindanao. Now after World War II the Japanese are gone, and the Philippine Government is endeavoring to rehabilitate the industry. A new abaca industry, however, has arisen in the Western Hemisphere. What the future of this industry will be it is still too early to say. Meantime there are many fibers growing in the Western Hemisphere that are potential substitutes for other fibers that might not be available to the United States should imports from the Far East again be cut off.

This monograph discusses the physical and chemical characteristics of abaca as compared with other cordage fibers or their products, as well as the economic and agricultural problems connected with abaca production. Some of these "alternate" cordage fibers that are named are practically unknown in international trade, but potentially a few have great value, and their presence in the Western Hemisphere is of strategic interest to the United States.

In addition to published technical information on the subject of cordage fibers, records of various organizations have been made available to the writers for inclusion in this monograph. These include principally the records of the Division of Cotton and Other Fiber Crops and Diseases of the Bureau of Plant Industry, Soils, and Agricultural Engineering, United States Department of Agriculture; manufactured rope tests performed at the Boston Navy Yard and reported to the Bureau of Ships, Navy Department; and certain records of the Office of Technical Services, which have been declassified. Various individuals and organizations have contributed also, as will be indicated in the text. Special mention should be made, however, of the cooperation accorded the writers by the Cordage Institute, which represents the primary cordage manufacturers of the United States.

GENERAL SURVEY

During the period between the two world wars production of the major hard fibers--abaca, sisal, and henequen--bordered upon chronic surplus, and at one time or another in almost every producing country measures were taken to control their production.

With the fall of the Netherlands East Indies and the Philippine Islands to the Japanese forces in 1942 the picture changed radically. All the world's commercial abaca-producing areas were in Japanese hands, and the Western Allies found themselves cut off from the sources of half the total world supply of hard fibers. At the same time the war increased the demand for fibers for marine cordage and for military, industrial, and agricultural uses. An urgent and far-reaching program was instituted by the United States Government to overcome these shortages. From experimental plantings of abaca begun by the United States Department of Agriculture in Panama in 1925 in anticipation of interference with importations in case of war, propagating stocks were available for increasing production in the Western Hemisphere. Plantings in Central America were rapidly expanded, and by 1945, when accumulated stocks of

[1] BALMACEDA, C., and BARTOLOME, V. C. A STUDY OF THE PHILIPPINE ABACA INDUSTRY. 27 pp. Sept. 3, 1935. [Unpublished report submitted to the Technical Trade Committee.]

[2] PHILIPPINES: MARCH 1950 ABACA AND OTHER FIBERS SITUATION. 12 pp. Report 238 of Mar. 1, 1950, from American Embassy, Manila, P. I. [Unpublished.]

abaca from the Pacific Islands were exhausted, the rate of Central American production had increased to approximately 20,000 tons per year, or nearly half the pre-war importation of about 43,000 tons a year from the Western Pacific (195).*

With sisal, the next most important of the three major hard fibers, the story of expanded production was the same. Haiti in 1926 had begun the planting of sisal; in 1932, 12,500 acres were under cultivation and by the end of 1945 the acreage planted to sisal had increased to almost 50,000 (18). Exports increased from 350 long tons in the fiscal year 1929-30 to 16,521 long tons in 1945-46 (18). The growing of sisal had likewise expanded in Brazil and Venezuela.

Cuban henequen beginning about 1885 totaled 29,100,000 pounds in 1945,[3] an increase of 8,100,000 pounds above the 1930-35 average figure.

Stimulated by the war demand, other hard fiber plants were grown more extensively in Latin America. Phormium production was increased in Brazil, Chile, and Argentina and greater facilities were made available for collecting and cleaning caroa in Brazil.

Such was the picture in September 1945 when the war came to a close. Yet so acute was the need for fibers during the war and so great the dislocations following it, that after five years of peace the world need for fibers was far from satisfied.

The decline in abaca production in the Philippine Republic after the war and its failure to recover have far exceeded expectations. For 1949 production was estimated at 176 million pounds as compared with 181 million pounds in 1948, 241 million pounds in 1947, and 400 million pounds before the outbreak of the war (1935-38 average) (103). Production in Central America on the whole increased steadily until 1948, but the production of fiber for 1948 was only 146,477 bales (300-lb. bale), and, for 1949, less than 100,000.[4]

In the United States true hemp (Cannabis sativa), which more than a century ago was the chief fiber used in the manufacture of rope, regained some of its former importance during the war, when it became a valuable extender of sisal in the making of rope. Under Government sponsorship the supply produced in the United States rose from less than 600 long tons in 1937-39 to almost 60,000 long tons in 1943, the year of peak production (185). At the close of 1944 the need for a Government hemp program was less, and the 1945 production dropped to an estimated 3,420 long tons (185). Of the 42 Government-constructed hemp-scutching mills in operation during the war most were disposed of and none was used by 1949 for processing hemp. Three privately owned mills were still operating in 1952.

The shortage of jute and hard fibers has forced the hemp-producing countries to use more of this fiber for domestic needs and so has restricted the quantity available for export.

The production of flax in the United States, which averaged less than 400 long tons in the thirties, rose to about 3,000 long tons (185) during World War II, but in this product, too, there has been a substantial reduction since the Government price-support program was discontinued. Flax, like hemp, is now produced chiefly in the Soviet Union and countries associated with her.

The world looks to India and Pakistan for its requirements of jute. Before partition most of the jute was grown in what is now Pakistan. From there it was shipped to Calcutta, where part of it was processed and the rest, together with the manufactured goods, was exported. Partition left India with most of the mills and Pakistan with most of the raw jute. India is trying to grow sufficient jute to feed her mills, and Pakistan is attempting to build mills to meet her own requirements for manufactured products.

Prices of abaca, sisal, and henequen while fluctuating, have been very much higher than before the war. In July 1948 representative grades were selling at over three times the 1934-38 averages (71). The rise in the price of jute has been even greater; in February 1950 the price of raw jute was 383 percent higher than in 1940 (158). The countries that can pay in hard currency get the bulk of the fiber offerings when supplies were scarce though the trade press in the United States in the late forties reported considerable resistance to the high prices of abaca and sisal on the part of the cordage industry, whose sales are said to have declined.

In quantity of plant fiber consumed in commercial use, jute has been second only to cotton. This position of eminence is not due to its strength, however, but to its cheapness. What effect the rapidly disappearing price differential in favor of jute will have on the jute economy of India and Pakistan cannot as yet be gaged, but attention will undoubtedly be focused on lesser known fibers that may serve as substitutes.

New purchasers have been competing for the fibers in short supply. In the latter part of 1948 Japan, traditionally one of the heaviest buyers of low grades of Philippine abaca, entered the market through SCAP (Supreme Council of Allied Powers). These purchases by SCAP were

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[3] CUBAN FIBER INDUSTRY IN 1945. 16 pp. Report 88 of Mar. 5, 1946 from American Embassy, Habana, Cuba. [Unpublished.]

[4] UNITED FRUIT COMPANY, and U. S. RECONSTRUCTION FINANCE CORPORATION, GOOD HOPE, MONTE VERDE, COSTA RICA, GUATEMALA, HONDURAS, AND PANAMA DEVELOPMENT PROGRAM. STATEMENT OF PRODUCTION, SHIPMENTS, AND QUANTITY ON HAND JANUARY 29, 1949. 5 pp. 1949. [Processed.]

*Italic figures in parentheses refer to Literature cited, p. 122.

made primarily to help rehabilitate the fishing industry of Japan on which she depended so heavily for food in the pre-war years. In 1949 Japan also bought 25,000 tons of East African sisal,[5] and according to a statement made by the chairman of the Tanganyika Sisal Marketing Association, Japan represents "an entirely new and secure future market for East African sisal."[6] In 1949 Germany also reentered the hard fibers market by placing orders in Indonesia.[7] Dollars released through the European Recovery Plan have made it possible for still other countries to purchase fibers which previously were unable to satisfy their needs because of dollar shortage.

All in all, it may be said that in a world short of industrial fibers the United States has been able to meet her normal needs, but for building against future needs the supply is still inadequate.

PRINCIPAL CORDAGE FIBERS

DEFINITION OF TERMS

History and sentiment play a large part in an understanding of the term "cordage." The word cordage is used loosely by many people and even by many specialists in the field. Frequently this has led to confusion and it would be well if the term could be specifically defined.

The American Society of Testing Materials, Textile Committee D-13, in an article entitled "Definition of Terms, Designation D 123-48" does not define cordage although it does define cord, twine, thread, and yarn, as are cited later. As generally understood, the term "cordage" includes all threads, yarns, twines, cords, ropes, and cables; "textiles" includes all fabrics. If a manufacturing firm was producing jute yarns for the carpet trade where the yarns would be used on a loom, the production of such yarns would be a textile business, whereas if the yarns were to be twisted into twines or cords and used as such, the designation would be a cordage business. While manufacturers use cordage in a comprehensive sense to include all sizes and varieties of the article from a harvester twine to the largest cable, the term is generally considered more applicable to a rope that is greater than one-half inch in diameter.[8]

Some authors have attempted to separate threads and twines from the heavier type cordage such as ropes and cables by selecting an arbitrary figure and classifying all products having a diameter smaller than the chosen figure as thread or twine and all having a larger diameter as rope.

An extensive search of the literature has not been made to obtain the history of the arbitrary selection of a measurement of bulk to separate ropes from small twines and threads. The United States Tariff Act of 1930, U. S. Public Law 361, Washington 1930, paragraph 1004 (c) defines material that shall not be included in that paragraph but shall be listed as cordage under paragraph 1005 (a) as "twines or cords composed of three or more strands, each strand composed of two or more yarns, if such twines or cords are 3/16 of an inch or more in diameter." This figure, 3/16 of an inch or more in diameter, apparently has some precedence through usage, for in 1940 Evans and Cheatham (69) stated that "cordage is defined as 'ropes and cords in general' and is distinguished from twine, according to the usual acceptance, in that it is three-sixteenths of an inch in diameter or greater." Three years later the United States War Production Board in Conservation Order M-84, February 2, 1943, defined agave cordage as "cables and ropes 3/16 inch in diameter and larger." However, the terms used in fiber nomenclature must not be construed too narrowly. For example, if a product is of rope construction but is only 5/32 of an inch in diameter, there will be particular instances when it cannot be said that it is not a rope. The precedent which has been established, however, of using the diameter 3/16 might well be continued to separate general statistics in reference to the production of twines and ropes. Possibly some similar figure of lower denomination might be arrived at for distinguishing threads in a broad sense from twines.

In order to clarify the usage of a number of cordage terms that will be employed throughout the discussion, the following definitions are given. These definitions are taken from the American Society of Testing Materials, Committee D-13, Definition of Terms (D123-48), October 1948.

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[5] RECENT DEVELOPMENTS IN THE TANGANYIKA SISAL EXPORT MARKET. 8 pp. Report 84 of Nov. 23, 1949 from American Consulate, Dar-es-Salaam, Tanganyika. [Unpublished.]

[6] See Footnote No. 5.

[7] HARD FIBER PRODUCTION AND EXPORTS, CALENDAR YEAR 1949. 5 pp. Report 190 of March 15, 1950 from American Embassy, Djakarta, Indonesia. [Unpublished.]

[8] WATERBURY ROPE COMPANY, NEW YORK. Catalog. 1901.

Yarn. --A generic term for an assemblage of fibers or filaments, either natural or manufactured, twisted or laid together to form a continuous strand suitable for use in weaving, knitting, or otherwise intertwining to form textile fabrics. Note. --Varieties include single yarn, ply yarn, cord, twine, sewing thread, etc.

Thread, Sewing. --A variety of yarn, normally plied, characterized by a combination of twisting and finishing with solid or semi-solid, waxlike materials to secure a smooth, compact strand which is quite flexible but presents no loose fibers.

Twine, 1. General. --A ply yarn made from medium twist single yarn with ply twist in the opposite direction.

2. Binder. --A single strand yarn usually 3 or 4 mm. in diameter made of hard fibers, such as henequen, sisal, abaca, or phormium, and sufficiently stiff to perform satisfactorily on a mechanical grain binder.

Cord. --The product formed by twisting together two or more ply yarns.

Braid. --A narrow tubular or flat fabric produced by intertwining a single set of yarns, according to a definite pattern (Maypole process).

Twist, Cable. --A twine, cord or rope construction in which each successive twist is in the opposite direction to the preceding twist, an S/Z/S or Z/S/Z construction.

Twist, Hawser. --A twine, cord, or rope construction in which the single and first ply twist are in the same direction, and the second ply twist is in the opposite direction, an S/S/Z or Z/Z/S construction.

To the above terms two additional ones not defined by the American Society of Testing Materials should be added:

Strand. --A term employed to describe a number of yarns twisted together to form one of the component parts of the finished rope. In reality, strand is synonymous with twine in respect to mechanical construction, but strand is an intermediate, not a final product.

Laid (or Lay). --This term is synonymous with twist and applies to the method of laying together strands to form the rope. Rope can be supplied in either right or left lay.

The construction of yarns, twines, cords, and ropes is illustrated in figure 1, which shows in surface view different types of twist construction. The twists as viewed in vertical position are designated by the letter "Z" for a right twist and "S" for a left twist. These letters are more commonly used by the trade and in published articles than the letters "R" and "L". The question might be asked how the twist can be reversed in assembling yarns into twines, or cords or twines into cables or hawsers. The explanation is that in general the reverse twist is not as great as the original twist, hence the article is not completely unwound.

CONFUSION IN USE OF FIBER TERMS

Unfortunately there exists a great deal of confusion in the use of various fiber terms. This is particularly true of the term "hemp." To many people hemp applies to any ropelike fiber, but to the botanist the true hemp plant is *Cannabis sativa*. Even in a large manufacturing plant the term "hemp" may be used differently in different departments. Thus in a department employing soft fiber machinery the term "hemp" is understood as the true hemp *Cannabis sativa*, while in the hard fiber department of the same concern the term "hemp" might apply to abaca, *Musa textilis*. The term "hemp" is so loosely used that even the trained fiber specialist sometimes has difficulty in interpreting it. To many this might seem of minor consequence, but when it involves trade statistics and customs duties, it is an item of considerable importance. Many trade journals have not followed a nomenclature that would clarify this confusion. The Linen Trade Circular, February 5, 1949, in an article on the raw materials imported into the British Isles, is quoted as follows: "Total imports of hemp during the year 1948 amounted to 92,848 tons, valued at £ 8,488,630. Soft hemps included 7,319 tons from India and Pakistan, etc., 1,866 tons from Italy and 763 tons from Chile. Hard hemps imported included 71,822 tons from British East Africa, and 9,268 tons from the Philippine Islands." A well-informed fiber specialist reading this article will readily understand that the "hemp" from the Philippine Islands is likely to be abaca, though some cantala might be included. The "hemp" from British East Africa is probably sisal, that from Italy and Chile is true hemp, while that from India and Pakistan is likely to be all jute, though it might include some sunn (*Crotalaria juncea*) or mesta (*Hibiscus cannabinus*), or even other fibers.

The trade statistics of China are frequently very confusing because of the use of the general Chinese word Ma, which apparently is the root of numerous fiber terms and may account for the lack of clarity in statistics relating to the production of the different Chinese fibers.

A

B

C

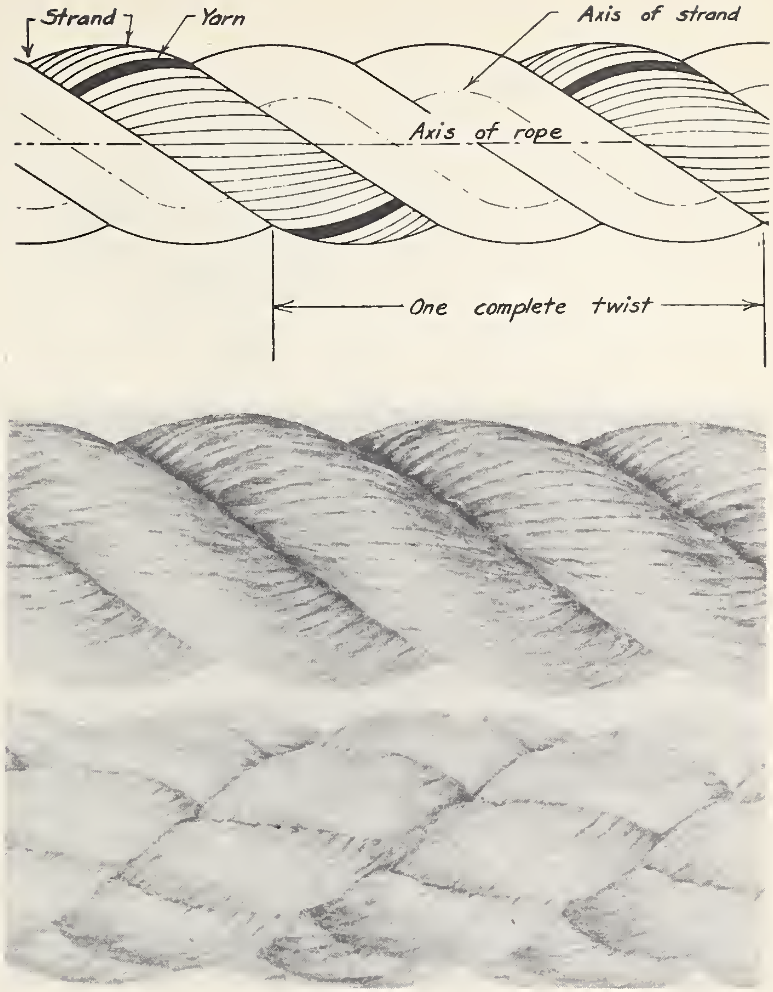

Figure 1.--Different types of twist construction illustrating the position in a rope of the fiber in the yarn ond the yarn in the strond (A), the stronds in o rope (B), and the ploin-loid ropes in a coble (C).

FIBERS USED IN THE CORDAGE WORLD

The cordage fibers are (1) soft, bast or stem fibers, such as flax, hemp, ramie, etc.; (2) hard or leaf fibers, such as abaca, sisal, henequen, etc.; (3) seed hairs, such as cotton; and (4) other fibers of special structural origin, such as coir. Thus cordage fibers may include almost any known plant fiber that can be spun or twisted into yarns.

Because of the structural characteristics of some fibers their value for textiles is low. Hence such coarse fibers as abaca, sisal, and henequen are normally used in cordage products. This does not necessarily mean that they cannot be used in textiles, for abaca fabrics in the Philippine Islands have been tourist articles in recent years and earlier formed household fabrics. In Latin America large tonnages of henequen and closely related sisal-like agave fibers such as Agave letonae in El Salvador and Furcraea cabuya in Ecuador are used in the manufacture of sacks for packaging native products. Hence these so-called hard fibers normally associated with cordage can be classed as textile fibers even though their use in that field is relatively minor from the standpoint of world utilization.

Evolution in fiber utilization is constantly taking place. While many people are familiar with the recent introduction of artificial fibers, i.e., rayons and nylon, and many may remember from their early history studies the rise in importance of cotton in textiles and twines after the invention of the cotton gin in 1793, few realize how relatively new in international trade are abaca, sisal, henequen, and jute. These four fibers have taken the place of true hemp in many products.

Abaca is native to the Philippine Islands. The exports from these islands in 1818 were only 41 tons, and in 1850, 8,561 tons (60). Compared with the exports in 1935 of over 180,000 tons the rise in importance of this fiber is evident. Sisal and henequen, two closely related agave fibers, are both indigenous to the American Tropics. The earliest effort to introduce these fibers into commerce was made in Mexico in 1839 (99), but it was not until the invention of a machine called the "raspador" reduced the labor required to prepare them and aided in the production and mill consumption of these fibers. The 1934-38 annual world production of sisal and henequen fibers amounted to 351,000 metric tons. Experimental shipments of jute fiber were made to Europe from India as early as 1791.[9] The first commercial shipments to Dundee, Scotland, are usually stated to have been made in 1828, but there was no great progress in the manufacture of jute until 1838 and thereafter. Thus it may be seen that the use of abaca, sisal, henequen, and jute, which make up a large percentage of the tonnage annually prepared into cordage, is of relatively recent origin. In fact, these four fibers, together with cotton, play such an important part in our domestic utilization that we are inclined to overlook the importance of hemp and flax as cordage fibers. This results partly from the fact that these fibers are not used to any great extent for cordage in the United States. In Europe, the U.S.S.R., and China, however, they are important cordage fibers as well as textile fibers.

Ernst Schilling, in his monograph "Die Faserstoffe der Pflanzenreiches," published in 1924, listed 1,926 different plant species utilized for fiber. However, the number of fibers that enter international trade and are of importance in the principal industrial countries of the world are: Cotton, hemp, sisal, henequen, abaca, jute, and flax. To these might be added possibly 10 more that play a minor role in international trade, namely: Urena lobata, coir, Mauritius, cantala, ramie, phormium, caroá, sunn, kenaf, and palma istle. These 17 fibers are for most practical purposes the only ones used in cordage at present that enter international trade. There are, however, many other fibers used in native industries in countries where industrial development has not progressed far that offer possibilities of an increase in production. Among these are many which from time to time have been produced in limited quantities experimentally and samples have been shipped to cordage manufacturers for tests. Due to many factors such fibers have not so far been used to any great extent. However, there are many which might assume an important role if their physical and chemical properties were better understood or if some change occurred in the standards of living and economics of production in the countries where they are produced.

Table 1 lists the more important cordage fibers utilized five years after World War II, together with some of the principal plant fibers that will be discussed because of their potential value as cordage fibers. In addition, table 1 gives the principal countries of production or the native habitat of the plant, together with the reported or estimated amount of the fiber that enters international trade.

Although this text does not plan to discuss fibers other than those of vegetable origin and in their natural condition, the extent to which nylon, paper, and metallic wires are used to substitute for plant cordage fibers should not be overlooked in visualizing the future of this industry.

The potential cordage fibers listed in the third section of table 1 are primarily ones selected by the authors. The more common fibers utilized in primitive industries for fabrics and cordage are included. Most of these fibers are so-called jute substitutes and only a few, such as sansevieria and pita floja, are suitable for utilization in large size cordage.

Small quantities of cordage of a fourth group of fibers, in most cases amounting to no more than a few hundred tons, are prepared under various conditions for local use. Some of the fibers so employed are fique (Furcraea macrophylla) and cabuya (F. cabuya) in South America; bamboo in the Canton delta region of China; esparto (Stipa tenacissima) in southern Spain; Agave lecheguilla, A. tequilana, and A. zapupe in Mexico; and even palms, as Bactris spp. in Brazil, Acrocomia spp. in Latin America, and Chamaerops spp. in the Mediterranean area. To this list might be added many additional fiber plants. These have been omitted because in the authors' opinion it is extremely doubtful if they would be cultivated and prepared on such a scale that the fibers could compete in international trade with the more common ones.

In some cases only the commonest or type species of a genus is given in the third section of table 1. Frequently there are many other closely related species of the same genus which are potentially valuable fiber plants. This is particularly true of the wild species of many genera of the Malvaceae.

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[9] SURVEY OF THE INDIAN JUTE INDUSTRY. Report of Aug. 24, 1937 from American Consulate General, Calcutta, India. [Unpublished.]

TABLE 1.--Relative importance of different cordage fibers, source of origin, world production, quantity consumed as cordage in the United States, and purposes for which used

Fiber	Scientific name	Principal source of origin	World production	Approximate quantity consumed in U.S.[a]	Uses in United States
A. Primary fibers in international trade:			*Lbs.*	*Lbs.*	
Cotton	Gossypium spp.	U.S.A., India, China	[b] 12,199,180,000	[a] 118,000,000	Threads, twines
Henequen	Agave fourcroydes	Mexico, Cuba	[c] 277,956,000	[a] 119,000,000	Twines
Sisal	Agave sisalana	Br. E. Africa, Indonesia	[c] 452,230,000	[a] 82,000,000	Twines, ropes
Abaca	Musa textilis	Philippines, Central America	[c] 260,308,000	[a] 84,000,000	Marine ropes
Jute	Corchorus spp.	Pakistan, India	[b] 3,199,180,000	[a] 40,000,000	Twines
Hemp	Cannabis sativa	U.S.S.R, Italy, Balkans	[b] 661,800,000	[a] 3,000,000	"
Flax	Linum usitatissimum	U.S.S.R., Western Europe	[b] 860,340,000	[a] 3,000,000	"
B. Secondary fibers in international trade:					
Cantala	Agave cantala	Philippines, Indonesia	[d] 7,756,000	Minor	Twines
Phormium	Phormium tenax	New Zealand	[e] 17,067,822	"	"
Coir	Cocos nucifera	India	[f] 110,961,000	[g] 4,619,000	Mats, cords
Mauritius	Furcraea gigantea	Mauritius Islands	[h] 716,800	Minor	Wire-rope cores
Palma istle	Yucca carnerosana	Mexico	[i] 66,180,000	[a] 10,000,000	Twines
Urena lobata	Urena lobata	Congo, Madagascar, Brazil	[j] 49,855,600	Minor	"
Caroá	Neoglaziovia variegata	Brazil	[k] 29,781,000	"	"
Sunn	Crotalaria juncea	India	[l] 179,200,000	"	Oakum, paper
Ramie	Boehmeria nivea	China, Brazil	[m] 20,130,000	"	Threads
Kenaf	Hibiscus cannabinus	India, Brazil	Minor	"	Twine
C. Potential cordage fibers of minor importance in international trade:					
Sansevieria	Sansevieria spp.	Mexico	[n] 29,220	[n] 29,220	Lariats
Pita floja	Aechmea magdalenae	Colombia	Minor	0	
Chingma	Abutilon theophrosti	China	"	0	
Mescal	Agave pseudotequilana	Mexico	"	0	
Letona	Agave letonae	El Salvador	[o] 8,089,494	0	
Anabo	Abroma augusta	Philippine Islands, Africa	Minor	0	
Kendyr	Apocynum venetum	U.S.S.R.	"	0	
Roselle	Hibiscus sabdariffa	Indonesia	"	0	
Malva	Malva spp.	Brazil	"	0	
Malachra	Malachra capitata	World tropics	"	0	

TABLE 1.--Relative importance of different cordage fibers, source of origin, world production, quantity consumed as cordage in the United States, and purposes for which used--Continued

Fiber	Scientific name	Principal source of origin	World production	Approximate quantity consumed in U.S.[a]	Uses in United States
Uacima	*Pavonia* spp.	Brazil	Minor	0	
Malva	*Sida* spp.	Brazil	"	0	
Polompom	*Thespesia* spp.	Indo-China	"	0	
Triumfetta	*Triumfetta rhomboidea*	Brazil	"	0	
Cattail	*Typha latifolia*	Temperate and tropical regions	"	0	
Nettle	*Urtica* spp.	" " " "			
Malva	*Wissadula* spp.	Brazil			
Kenab	*Kosteletzkya pentacarpa*	U.S.S.R.	"	0	
Olona	*Touchardia latifolia*	Hawaii	"	0	
Punga	*Cephalonema polyandrum*	Congo	"	0	
Sparmannia	*Sparmannia africana*	South Africa	"	0	

[a] 1937 data (69). [b] 1947-48 data (71). [c] 1947 data (71). [d] 1948 P. I. data (103). [e] 1947 data [10] and [11]. [f] 1939 Ceylon exports [12]. [g] Imports 1939 (11). [h] 1939 data (111). [i] 1945 data [13]. [j] Estimated 12,000 metric tons Congo 1948 [14] Brazil 1943 [15] and Madagascar 1,000 metric tons 1937 crop (70). [k] 1947 data [16]. [l] See (49). [m] Estimate, 1947 [17]. [n] Average 1942-47 Mexican exports to U. S. [18]. [o] Average 1940-41, 1944-45 [19]

[10] American Embassy. Wellington, New Zealand. [11] INTER-AMERICAN ECONOMIC AND SOCIAL COUNCIL. STATUS OF THE FIBER PLANT INDUSTRY IN LATIN AMERICA. 225 pp. Washington, D. C. 1947. [Mimeographed.] [12] AMERICAN CONSULATE. 1939 CEYLON EXPORTS. Colombo.
[13] See Footnote No. 11. [14] American Consulate. Leopold, Congo. 1948. [15] See Footnote No. 11. [16] See Footnote No. 11.
[17] Estimate, 1947: Japan 1,000,000 lbs.; Brazil 3,970,000 lbs.; United States 800,000 lbs.; China 14,330,000 lbs.
[18] See Footnote No. 11. [19] See Footnote No. 11.

As mentioned earlier, the first section of table 1 lists the seven common fibers that enter international trade. Actually, the list would be increased if the two species of jute and two or more of cotton were counted separately. This fact is mentioned because the production of the several different agave species--sisal, henequen, and cantala--have been recorded separately.

DISTRIBUTION OF ABACA

EASTERN HEMISPHERE

The recorded history of abaca goes back to the days of the early Spanish and Portuguese explorers. On the first circumnavigation, 1519-22, of the globe, Pigafetta, a companion of Magellan, noted that the natives of the island of Cebu in the Philippines wore clothing made from the fiber of the abaca plant (59). In 1697 another navigator, Dampier, an Englishman, reported that a "plantain," apparently abaca, was cultivated on the island of Mindanao, and from it fiber was obtained.

Though abaca is indigenous to the Philippine Islands, it is not cultivated throughout the archipelago. Its northern limit of cultivation is central southern Luzon, comprising the Provinces of Cavite, Laguna, and Batangas (156). The three areas in which most of the commercial fiber is produced are (1) the Bicol Peninsula of southern Luzon, comprising the provinces of Albay, Camarines Sur, Camarines Norte, and Sorsogon (fig. 2) (127); (2) Leyte and Samar in the Visayan Islands; and (3) the province of Davao on the island of Mindanao. Attempts to introduce the plant into other countries have been made, but with so little success that until recent years the belief was generally held that the plant could not be grown commercially outside of the Philippine Islands.

Abaca was introduced into Guam in the early 1880's. The plant grew well, but skilled labor for working the fiber was not available and the planting was discontinued. In 1903 the natives of Botel Tobago Island, off the coast of Formosa, were said to grow abaca for the manufacture of cord and cloth. Attempts have been made to introduce abaca into India (as early as 1822), the Solomon and Andaman Islands, Formosa, Ceylon, Burma, Indo-China, Celebes, Java, Sumatra, Borneo, Fiji, the Federated Malay States, New Caledonia, Queensland, New Guinea, Hawaii, German East Africa, Madagascar, and Réunion (47, 59, 73, 105, 106, 171, 183).

For various reasons the production of abaca in most of these countries was unsuccessful. In some instances the fiber obtained was of inferior quality, in others the cost of production exceeded the value of the product, and in still others there was no demand for the fiber after it was produced. In the Netherlands East Indies, however, the industry was successfully established. About 1925 abaca began to be produced in Sumatra from suckers obtained from the Philippines. The Dutch, who had great financial resources, highly skilled technicians, and long experience in tropical agriculture, as well as an abundance of land with favorable soil and climate, lacked only the skilled labor for stripping and cleaning the fiber to develop an important abaca industry. A satisfactory machine was eventually developed and the Dutch, though they never became a leading producer of abaca, were able to sell their product at lower prices than the Filipinos could sell fiber of comparable grades. In 1931 the Philippine Secretary of Agriculture, comparing the selling price of the Philippine fiber with that of Sumatra, stated, "It is plain that Sumatra abacá would eliminate the Manila abacá in the world's market if she could fully supply the demand" (140). The war put an end to this promising industry. Production in 1949 was from old plantings which were nearing exhaustion. In 1950, however, some postwar plantings reached maturity, and if economic and political conditions stabilize, Indonesia might again recover its prewar production of high-grade abaca fiber.

The output of abaca from British North Borneo was reported to be 2,100 tons in 1939, an insignificant output when compared with that of the Philippines, but interesting because the production was almost wholly a Japanese enterprise. A postwar development in North Borneo included the formation of a company, called Borneo Abaca Limited, which bought 16,000 acres of Japanese estates for replanting to abaca.[20] The company in 1949 was clearing 4,000 acres and had 3,500 acres under cultivation. The plan was to have the entire acreage planted by 1952.

The British are also stepping up plantings in Malaya. These plantings, however, are hardly beyond the experimental stage, though the fiber produced is said to be comparable in color, texture, and strength to good quality abaca from the Philippines.

The failures that have attended the numerous attempts to introduce abaca into various countries are not to be regarded as proof that it cannot be successfully grown in these countries.

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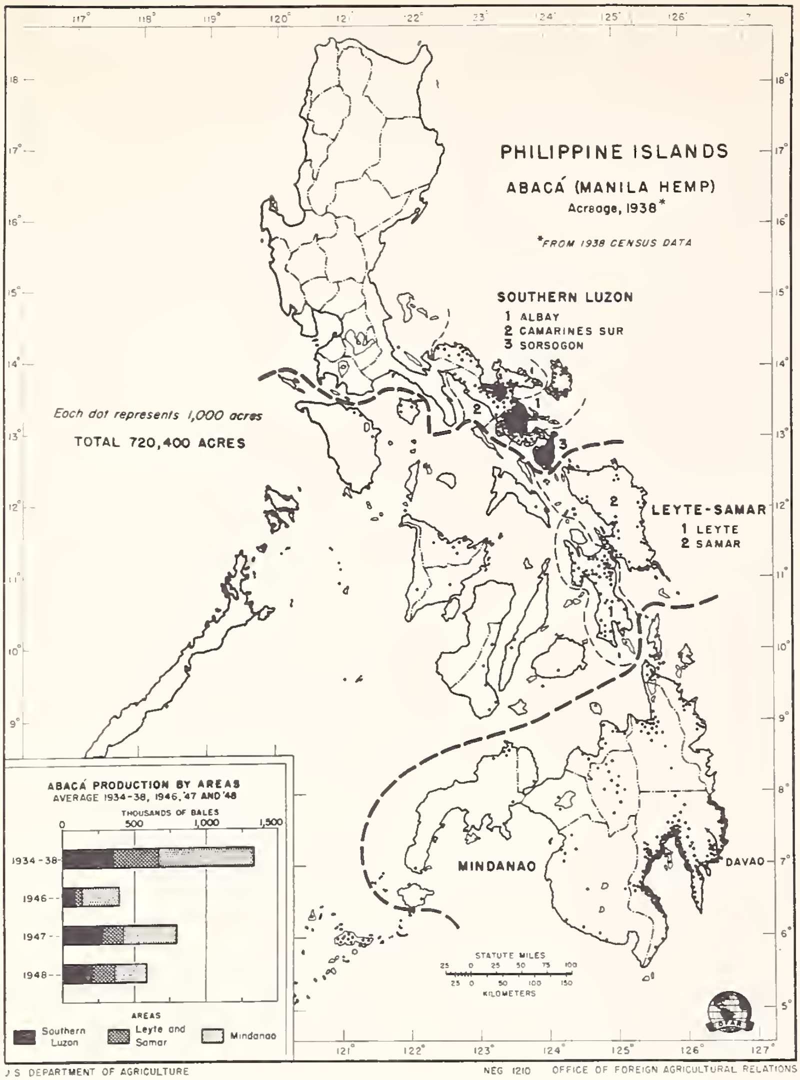
[20] PROSPECTS FOR THE DEVELOPMENT OF HARD FIBERS IN NORTH BORNEO, SARAWAK, and BRUNEI. 2 pp. Report 34 of Apr. 11, 1949 from American Consulate General, Singapore. [Unpublished.]



U S DEPARTMENT OF AGRICULTURE NEG 1210 OFFICE OF FOREIGN AGRICULTURAL RELATIONS

Figure 2.--The three principal abaca-producing areas in the Philippine Islands: the Bicol Peninsula of southern Luzon, Leyte-Samar, and Mindanao. (Courtesy of Foreign Agriculture.)

It is entirely possible that with present facilities for rapid transportation of planting stock and with a better knowledge of the cultural requirements of the plant and the economics of its production, it may be grown in many places where it has been tried unsuccessfully.

WESTERN HEMISPHERE

In 1922, the Philippine Islands constituted the sole source of the world's supply of abaca. To a nation such as the United States recently emerged from war, the disadvantage inherent in the concentration of this vitally important product in a limited area thousands of miles from the continental United States was obvious, and plans were drawn to study the possibility of introducing abaca into the Western Hemisphere. In February of that year, the United States Department of Agriculture made a survey of areas in the Canal Zone to determine whether conditions there would be suitable for growing abaca (58). The result of the survey showed neither sufficient available land nor soil or climatic conditions favorable for its growth. The survey was then extended to the Almirante region in northwestern Panama, near the Caribbean seacoast and the Costa Rican border.

In the first third of the present century, Almirante, in the valley of the Changuinola River, was one of the richest banana plantations of the United Fruit Company, but the "Panama" and Sigatoka diseases destroyed the bananas and the plantation was practically abandoned. Here the soil and climatic conditions seemed ideal for the growth of abaca. In 1923 abaca rhizomes were shipped from the Philippines, but these failed to survive the long voyage. When the plants were examined at the Plant Introduction Gardens in the Canal Zone, they were found to contain large numbers of active nematodes and possibly borers as well. The United Fruit Company then refused to receive any more abaca plant material from the Philippines and stated that they would conduct no further experiments with abaca.

In 1924 some abaca plants were shipped to Washington D. C., but these soon died. Undeterred by these setbacks, Edwards and Dewey, of the United States Department of Agriculture, whose project this was, made still another attempt to introduce abaca into Panama. In 1925 the United Fruit Company, which was sending a plant pathologist to the Philippines to collect banana plants for shipment to Panama, agreed to permit him to supervise the collection and preparation of abaca material also for shipment to Panama. The plants were obtained in Davao, which grew the best varieties and at that time was relatively free of abaca diseases. Meantime strong opposition developed in Manila to the shipment of material which might eventually build an industry in the Western Hemisphere that would challenge the monopolistic position of the Philippines. So strong was the pressure on the Government that the Philippine Legislature passed in 1925 a law prohibiting the export to foreign countries of abaca seeds or plant material. But the law came three months too late to stop the first successful shipment of abaca to the western world. The collections by Edwards were not made without difficulty, however, and it was only because of the cooperation of the two leading American producers that the collections were possible. Twenty years later, as Edwards (59) recounts, these men died in Japanese prison camps "at a time when millions of pounds of marine rope, made possible because of their patriotism, were being used in the war with Japan."

The last shipment (1925) consisted of more than 1,400 items of plant material, representing 6 different varieties of abaca. On arrival at the plant quarantine station, Panama Canal Zone, after 42 days at sea, less than three-fourths of the plants were alive, but within 3 months after the first planting about 500 strong plants were growing in a nursery near Almirante, Panama.

In 1928 the nurseries were expanded to 50 acres of experimental field plantings. The plants flourished in the rich soil, and in 1929 a hagotan fiber cleaning machine brought from the Philippines was used to strip the fiber. Manufacturing tests in the United States showed the tensile strength of the rope made from this fiber to compare favorably with that manufactured from Philippine abaca. Consideration was then given to enlarging the plantings, but the low price of abaca and the uncertainties that accompanied the industrial depression of the early thirties caused the project to become dormant. In 1936, however, the improvement in economic conditions in the United States and the increasing control of the abaca industry by the Japanese in the Philippines again stimulated interest in the expansion of plantings in Central America. In 1937 about 1,000 acres of abaca were planted at Almirante, Panama, and in 1939 a second planting of 1,000 acres was made. With the coming of war no time was lost in expanding the plantings, and by the autumn of 1943, 11,472 acres had been planted in Costa Rica, 5,716 in Guatemala, 5,012 in Honduras, and 4,415 in Panama, a total of 26,615 acres (58). By April 1945 five large semiautomatic fiber-cleaning mills were in operation on the Central American acreage and more than 20,000,000 pounds of fiber had been produced. All of the Central American plantations have been operated by the United Fruit Company under contract with the United States Government.

Another development in the abaca industry in the Western Hemisphere is the apparently successful introduction of abaca into Ecuador. There exists in Ecuador what is known as the "Garua" belt--"garua" meaning drizzle--where the air is always moist. Three of the four plantations are situated in this belt on land reclaimed from the jungle. The original planting stock consisted of six rhizomes obtained from the early introductions into the Canal Zone. From these six, planted in 1929, has come the seed stock for approximately five hundred acres. (See fig. 3.)

Hand stripping in Ecuador was first attempted but with little success, partly due to the low production of the unskilled help. Later a few hagotan machines were introduced, and there were various ups and downs with these before they were successfully utilized. The work in 1950 was still in the experimental stage with only sample trial runs of fiber being attempted. In 1949 these sample tests resulted in 29,773 pounds of fiber valued at less than $3,000.[21] Production could be increased materially, however, if the owner believed that his methods were advanced

[21] FIBERS, ECUADOR, 1949. 3 pp. Report 37 of Feb. 24, 1950 from American Consulate General, Guayaquil, Ecuador. [Unpublished.]

Figure 3.--A flourishing 20-month-old abaca plantation in Ecuador.

enough to be economically feasible. The fiber prepared has been considered of high quality. While only one grower is engaged in producing abaca in Ecuador, it would appear that, in view of the relatively large area of high quality soils that exist between Quevedo, where the present production is located, and Santo Domingo de los Colorados, an opportunity for large-scale operations in abaca exists.

Abaca was introduced into the Dominican Republic (47) about 1908 and the Department of Agriculture has conducted trial plots in six different areas of the island from the original stock and from plant material more recently introduced from Trinidad. Samples of fiber prepared in 1947 were analyzed and evaluated at the Imperial Institute in London, where the report showed a slight inferiority to commercial grades but on the whole the fiber was found to be of good marketable quality.

Experimental introductions have been made into Brazil, British and French Guiana, Cuba, Jamaica, Puerto Rico, Martinique, Guadeloupe, Dominica, Trinidad, Mexico, St. Vincent, and Florida, but without any reported developments except in Martinique and Brazil, where some increase has occurred. In 1949 planting material was sent by the United States Department of Agriculture to Bolivia, Peru, Nicaragua, and El Salvador From the foregoing review it will be seen that abaca has now been widely distributed in the Western Hemisphere.

HISTORY

For nearly a century the production of abaca fiber has been one of the leading agricultural industries of the Philippine Islands, and from 1901 to 1905 abaca constituted more than two-thirds in value of the total export trade of the Islands.[22]

[22] EDWARDS, H. T. REPORT ON FIBER INVESTIGATIONS IN THE PHILIPPINE ISLANDS FROM NOVEMBER 26, 1926 to APRIL 2, 1927. Washington, D. C. (U. S. Bur. Plant Indus., Div. Cotton and Other Fiber Crops and Dis.) [Unpublished report.]

To the Filipinos until very recent years abaca has been a noncompetitive crop, and this very lack of competition has been responsible for many of the ills that have beset producer and consumer alike. From 1909 to 1913 a few firms held a monopoly of the export business, each local merchant graded his fiber to suit himself, and no premium was put on the production of a superior product (72). Under these conditions the quality of the fiber went down. It was then that sisal began to replace abaca in the manufacture of binder twine, and other substitutes for abaca were sought by American manufacturers. So bad did the situation become that the Philippine Government in 1915 established a fiber inspection service whose duty it was to fix official standards and see that fibers were correctly graded according to those standards.

During and immediately following the first World War there was a strong demand for all hard fibers, with accompanying high prices. As a result, fortunes were made in Manila and there was more than the usual amount of speculation in the fiber market. Large loans were made by the different Manila banks to the fiber dealers, and there appeared to be no general realization of the fact that these conditions could not continue indefinitely.

In the latter part of 1920 the crash came. One of the large exporters in Manila failed, with liabilities of several million pesos, and other large commercial houses were seriously involved. It was only by prompt and concerted action of the banking interests that a general business panic was averted.[23]

One of the direct results of these conditions was to discourage the abaca planter and to still further lessen production, which was already on the decline. The planting of coconuts and food crops steadily and rapidly increased in the abaca provinces and many of the fiber strippers sought employment in other lines of work.

At that time also complaints from London concerning the quality and condition of the fiber were numerous and bitter. In some cases it was stated that the product received was so inferior that deductions up to 50 percent of the value of the abaca were made. This influenced the British ropemakers to turn more to African sisal, and the cultivation of sisal was extended.

In the Philippines before World War II there were two systems of culture in the abaca industry--that of the planters in the old-producing regions, where the production of abaca was essentially a "native" industry, and the large, modern plantations in Davao.

The story of the plow that broke the plains contains no more thrilling chapter than that of the Americans who cleared the jungles of Davao and developed a primitive pursuit into the leading industry of the Philippine Islands. In 1899, when the first American troops arrived in Davao, three-fourths of the population were pagan, half-savage hill tribes (113). Lieutenant Bolton, the first civil governor of Davao, brought peace to the warring tribes and induced them to settle down and grow abaca for a livelihood. Though he, like Magellan, met his death through the treachery of a native chief, the state of peace that he had brought to Davao continued. Another officer, Captain Burchfield, became the first American to develop an abaca plantation. In 1904 General Leonard Wood, and later Brigadier General Pershing, both governors of the Moro Province, of which Davao formed a part, gave their active assistance in bringing American settlers to Davao.

These settlers found abundant land but little available labor and practically no means of transportation. The labor problem they surmounted by importing Filipinos from the Visayan Islands. The native and the Spanish planters, who cultivated with hoes and bolos, warned the Americans against trying to clear where cogon and other pernicious grasses grew, but the Americans, relying on their machines, soon had the land plowed, fenced, and planted. By 1908 some of the plantations had been in production for four years, and the secretary of the Davao Planters' Association (113) wrote enthusiastically: "Davao district offers to the newcomer a just and stable government, conditions of peace and order, unoccupied Government land rich with the accumulated fertility of the ages, fair transportation facilities, American neighbors (the benefit of whose experience in plantation work may be had for the asking), a climate free from many of the annoyances found in other parts of the Philippines, a section in which cholera, surra, and rinderpest have never made their appearance, and a community whose intelligent cooperation will tend to perpetuate existing favorable conditions, thus insuring a high quality of product and a good market price."

In spite of all these advantages, however, the arduous labor required to clear a tropical jungle, the lonely life of the pioneer far from neighbors or friends, the difficulty of getting labor to care for the crop, and the long wait for the harvest--these things called for self-sacrifice and self-discipline. An early observer (4), describing the hardships of these men wrote, "This work has been no exception to the rule that great results can not be obtained without great

[23] EDWARDS, H. T. Letter. Washington, D. C. January 18, 1921. (U. S. Bur. Plant Indus., Div. Cotton and Other Fiber Crops and Dis.) [Unpublished.]

sacrifice. For those who have laid down their lives the most enduring monument will be the 'new Davao' which they have helped to create."

As the plantations expanded and more laborers were needed, Japanese workers were brought in. These in time were followed by other Japanese with capital, who obtained leases in Davao, and gradually the control of the industry passed out of American hands. At the beginning of World War II the number of Japanese living in Davao numbered about 23,000 (187). They controlled from 100,000 to 150,000 acres of land and 65 percent of the total abaca production of the Province (187).

The Japanese adopted the improved methods of culture introduced by the Americans and raised the industry to a high level of efficiency. Well-equipped Philippine experiment stations were established, a limited number of superior varieties of abaca were selected for planting, legumes were introduced to replace the sweet potato that had formerly been used almost exclusively as a cover crop, and a double-row system of planting was instituted.[24]

In Davao a tenant system was followed both by the Japanese and the Americans. Under this system the owner of the plantation leased his land in small parcels to individual tenants, usually for a term of 15 years.[25] The tenant planted the crop, cultivated it, and stripped the fiber. In the final division about 15 to 20 percent of the crop would usually go to the landlord and 80 to 85 percent to the tenant.

The Japanese also developed a marketing system that assured the producer a fair return for his product and the buyer a product of reliable quality. Under this system there was a central warehouse to which the growers of the surrounding districts brought their fiber, and once a week an auction was held. Exporters and fiber merchants in Davao sent their buyers to these auctions and the fiber was sold to the highest bidder. The local association of Japanese abaca planters guaranteed both the weight and the quality of the fiber. Any deficiency in respect to either was made good by these associations and the producer responsible was severely penalized. Adulteration in packing the fiber was punished by a fine of 50 pesos for the first offense; confiscation of the fiber for the second; and banishment from the island for the third (126). Thus the Davao producers established a reputation for quality that resulted in their receiving top prices for their product.

By 1937 Davao had become the main source of supply of the medium grades of abaca, particularly grades I, G, and J1.[26] The Bicol provinces, including Albay, South Camarines, and Sorsogon, traditionally heavy-producing abaca areas, in 1937 still furnished the greater part of the high-grade fiber and fairly large quantities of fiber of the medium grades. In fact, in the years immediately preceding World War II, although abaca was produced in more than 30 provinces in the Philippine Islands, Davao and the Bicol Provinces were the only abaca-producing regions of the Philippines of particular interest to the American consumer of abaca fiber.[27]

Among other improvements made by the Japanese was the substitution of a small spindle machine for the wasteful and laborious hand-stripping method of cleaning fiber that was common in the Islands. Numerous efforts to establish the use of these "hagotan" machines in the northern provinces never met with much success. Practically all of the abaca produced in provinces other than Davao continued to be cleaned by the old hand-stripping process, whereas almost all of the plantation abaca in Davao was cleaned with these small machines. In addition to the spindle machines, two large semiautomatic machines were operated in Davao yielding so-called "Deco" (decorticated) fiber.

The relative production of the different grades of fiber tended to fluctuate according to market demand. Local conditions, and particularly typhoon damage, might have a marked effect on the relative production of high-grade and low-grade hand-cleaned fiber. The abaca strippers would rather clean low-grade than high-grade fiber because the work was much less difficult. During periods of high prices the strippers could make a living producing any of the grades, and for this reason when prices were high the production of low-grade fiber increased. In Davao, however, these factors were not important because the greater part of the fiber was cleaned with the spindle machines and the production was largely under the control of competent plantation management.

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[24] EDWARDS, H. T., SALEEBY, M. M., and YOUNGBERG, S. REPORT ON SURVEY OF THE PHILIPPINE ABACA INDUSTRY. 49 pp. May 23, 1947. [Processed.]

[25] EDWARDS, H. T. FIBER INVESTIGATIONS IN THE PHILIPPINE ISLANDS, 1927 TO 1928. 57 pp. illus. [n. d.] (U. S. Bur. Plant Indus., Div. Cotton and Other Fiber Crops and Dis.) [Unpublished report.]

[26] EDWARDS, H. T. REPORT ON FIBER INVESTIGATIONS IN THE PHILIPPINE ISLANDS, THE FEDERATED MALAY STATES AND CEYLON, FEBRUARY 15, 1937 TO JUNE 16, 1937. 55 pp. [n. d.] (U. S. Bur. Plant Indus., Div. Cotton and Other Fiber Crops and Dis.) [Unpublished report.]

[27] See Footnote No. 26.

The result of the improvements introduced by the Davao planters was that whereas in 1915 Davao produced only 34,000 bales or 3.4 percent of the total output of abaca, in 1940 it produced 693,000 bales or 53.3 percent of the total output (108). In the old-producing areas, on the other hand, the yearly production from 1915 to 1929 remained almost stationary at 1,000,000 bales; then it went down gradually until 1940, when only 606,700 bales were produced, or 46.7 percent of the total output (108).

At the same time that the Davao fiber was going up in quantity it was also rising in quality, whereas fiber from most of the old-producing regions was dropping both in quantity and quality. The net result was a marked increase in the use of Davao fiber in the cordage mills of the United States and a market price higher than for fiber of the same grade produced in most of the other provinces. This was a matter of deep concern to the Filipinos, who foresaw a day rapidly approaching when the Japanese producers in Davao would displace the Filipinos in the world market. Then came the second World War. The former Japanese plantations, or what is left of them, still exist, but the Japanese abaca industry in that region no longer exists. Large areas once planted to abaca are now in food crops, and until the supplies of rice and corn are again adequate or the price of these foods drops to the point where it is more profitable to grow abaca, it is hardly to be expected that the land will be used for this crop. Even before the war the American abaca plantations had largely been replanted to coconuts, and in the northern provinces a large part of the coastal areas that were formerly in abaca were covered with coconut groves.[28]

In many areas rice, coconut, and abaca compete for an inadequate labor supply, and if occasion permits, the laborer will leave the arduous work of hand stripping fiber for the lighter task of harvesting rice or preparing copra.

Just before the last war ramie captured the imagination of many abaca planters, and in 1940 and 1941 this crop became very popular with planters in Davao, and many old abaca fields were planted with it. This, of course, had a tendency to restrict the output of abaca. After occupation, the Japanese ordered many abaca fields to be dug up and food crops planted in them and they forbade maintenance work on others that were left. Nevertheless, at liberation about 75 percent of the Japanese plantations could have been rehabilitated without much difficulty.[29] Then the inevitable happened. Squatters--ex-guerrillas, former employees of the Japanese, and others--finding the former owners dispossessed and the Government not yet in control, moved in, cut and stripped the plants mercilessly, leaving the fields to grow up in weeds and brush.

A committee of experts,[30] who made a survey of the Philippine abaca industry in 1947, reached the conclusion that--

"The restoration of pre-war conditions in the Davao abacá industry, however desirable this might be, is not within the range of possibility. It may be possible to build up in Davao a new abacá industry as stable, as prosperous, and as productive as that which existed before the war, but the conditions under which the Japanese operated no longer exist, and this new abacá industry in Davao will be materially different from that of the period from 1920 to 1941. An industry organized and directed by the Government will have both advantages and disadvantages that were not a factor in the business organization of the Japanese abacá planters in Davao. With the facilities that are furnished by the Government, it may be possible to develop in this province a stable and prosperous abacá industry, but this can only be accomplished with an organization and with management equal, if not superior, in efficiency to that of the former Japanese abacá planters."

The Philippine Government is making an effort to rehabilitate the abaca industry. To this end in February 1947, a body known as the National Abaca and Other Fibers Corporation (NAFCO) was placed in control of the former Japanese holdings in Davao, and later other properties were transferred to its jurisdiction. This body drew up a five-year plan which includes: (1) development of new plantations consisting of 25,000 acres in Davao out of the Government reservation; (2) rehabilitation of about 50,000 acres of former Japanese plantations in Davao; and (3) rehabilitation of some 175,000 acres of private plantations in the non-Davao regions (42). This program called for a large outlay of money. Faced with many problems urgently needing solution, the Philippine Government in early 1950 had not yet seen its way clear to provide the funds necessary for this project. To carry to a successful conclusion so comprehensive a program it will be necessary to secure trained personnel to replace the former Japanese management, the ownership of land now in litigation will have to be settled, new roads will have to be built and old ones rebuilt, machines will have to be purchased, and skilled labor will have to be found to care for the plantations and strip the fiber.

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[28] See Footnote No. 24.
[29] See Footnote No. 24.
[30] See Footnote No. 24.

The 1950 outlook for the Philippine abaca industry was confused. Even in 1947 it was estimated that at least half of the prewar plantings in the Davao area, or about 87,500 acres were passing out of cultivation, and some planters believed that only about 62,500 acres of the former 175,000 could be returned profitably to an annual production basis (26). Three years after these estimates were made there seemed little to justify the hope that the Davao abaca industry would soon return to its prewar position as the largest producer of high-grade abaca. The following figures tell the story:

Balings for:[31]

	Davao	Non-Davao	Total
1946	256,962 (66%)	134,292 (34%)	391,254 (49,000 tons)
1947	352,822 (45%)	433,943 (55%)	786,765 (98,000 tons)
1948			586,608
1949			524,586

A new pattern of farming is developing in postwar Davao. In contrast to the great estates of the Japanese, most of the new farms are small, each containing from 12 to 25 acres; those allocated to settlers on the former Japanese estates contain only 12.4 acres (144). As might be expected, on these small, family-size farms, the planting of food crops, especially rice and corn, has increased.

There has been a large influx of immigrants into Davao since the war, especially from the Visayan Islands, and many of these settlers are opening up new land for planting. Official reports from Manila[32] in 1950 indicated that as the settlement of lands continues in Mindanao and farmers obtain title to the land they work, greater progress may be expected. There is a general belief that there will be a steady but slow increase in abaca production in the Davao area, but there is little to base estimates as to the probable date when the prewar rate of balings will again be achieved.

THE PLANT

Musa textilis, from which abaca fiber is derived, is a member of the banana family, and so closely does it resemble the banana that a casual observer might easily mistake the one for the other. However, the stalks of abaca are usually slenderer and the leaves are smaller, narrower, and more pointed than those of the banana. The leaves of abaca and banana are so rolled in the sheath than when the plants develop and the leaves unroll, a dark line is left on the right-hand side of the undersurface of each (fig. 4). This mark is much more pronounced in abaca than in banana and is an aid in distinguishing the two.[33] It cannot, however, be considered an entirely dependable diagnostic character. The abaca leaf is somewhat lighter and firmer in texture than the banana leaf. Consequently, under similar conditions, the abaca leaf will dry and become shredded by the wind more quickly than the banana. Because of the great difference in both abaca and banana arising from differences in variety, in soil, exposure to sun, and other environmental conditions, the foregoing distinguishing characters can only be regarded as approximate.

The genus Musa to which both abaca and banana (M. paradisiaca var. sapientum) belong is a large genus comprising many species of commerical value, a few of which are illustrated in figure 5.

The fruits of abaca (fig. 6), though somewhat resembling those of the banana, are much smaller (about three inches in length), inedible, green when ripe but later maturing yellow and contain numerous large black seeds which are approximately 3/32 inch in diameter. The fiber of the two are somewhat alike in appearance, but that of the banana lacks strength and is poorer in other desirable cordage properties.

The stalk of the abaca plant rises from a fleshy, perennial rootstock. New shoots emerge in more or less whorls or rings so that there is soon a cluster of stalks at each "hill." When mature, the plant consists of a group of 12 to 30 or more stalks in different stages of development.

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31. Figures for 1946 and 1947 from Wigglesworth & Co., Ltd., London. Report for March 1948. Figures for 1948 and 1949 from U. S. Foreign Serv. Report. (See Footnote No. 2.)

32 See Footnote No. 2.

33 EDWARDS, H. T. Unpublished notes. Mar. 17, 1923. (U. S. Dept. Agr.)

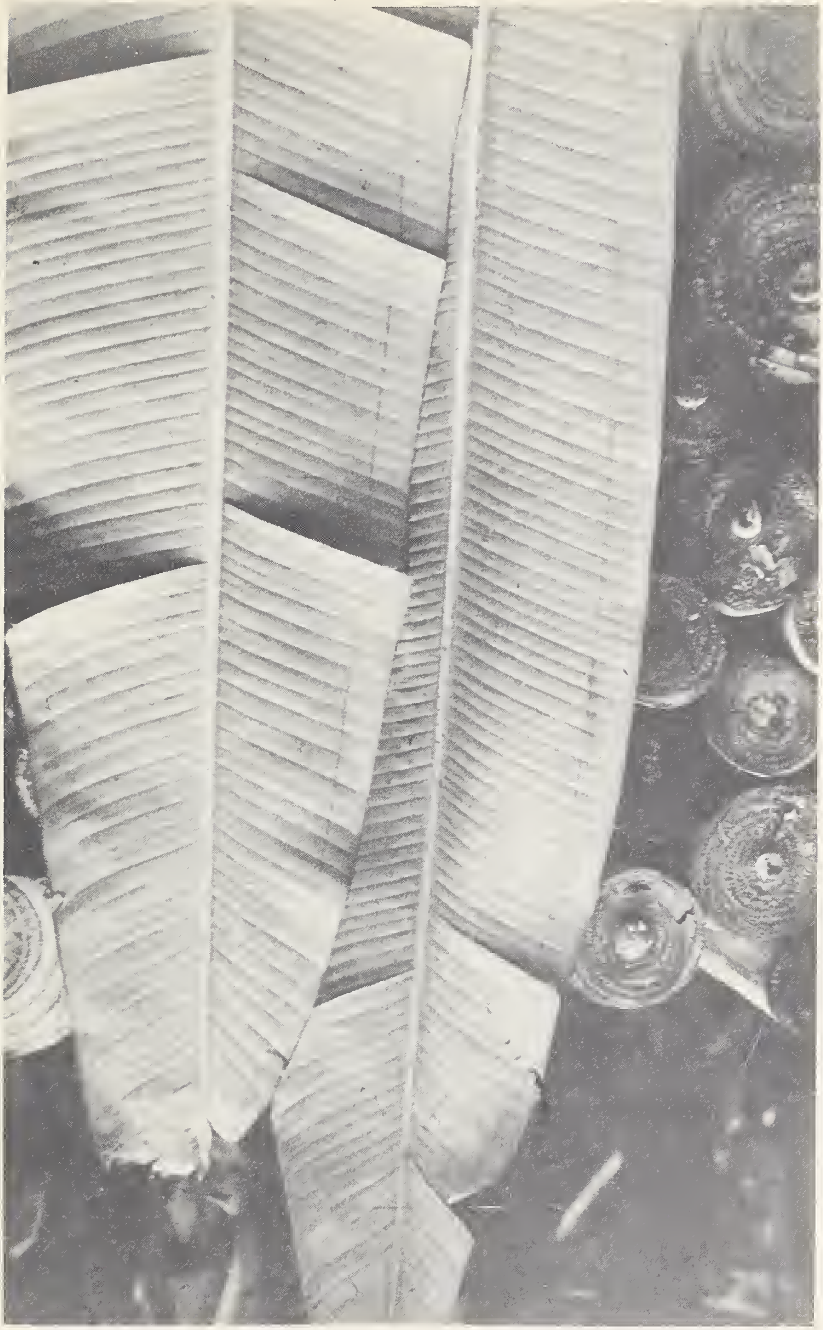


Figure 4.--Abaco leaves showing characteristic black marginal line on the under surfoce. This line is more pronaunced in abaca thon in banona. The leaves of abaca are mare pointed and stand more erect than thase af banana. Cross sections of abaca stolk ot right.

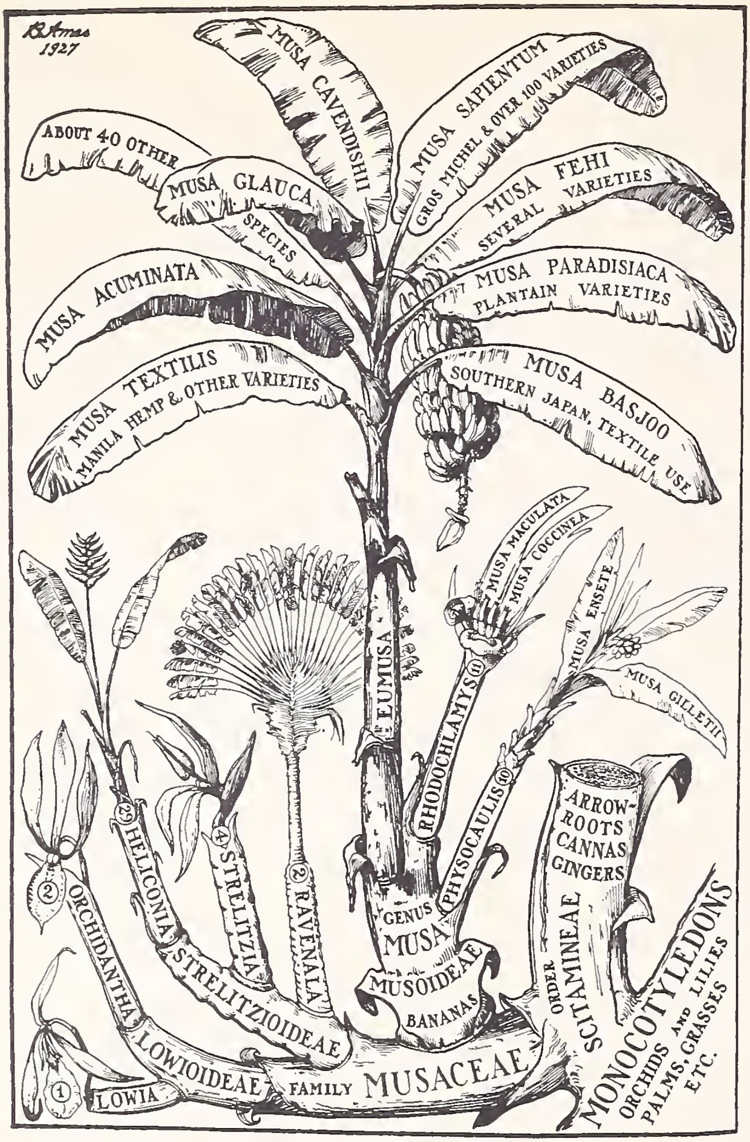


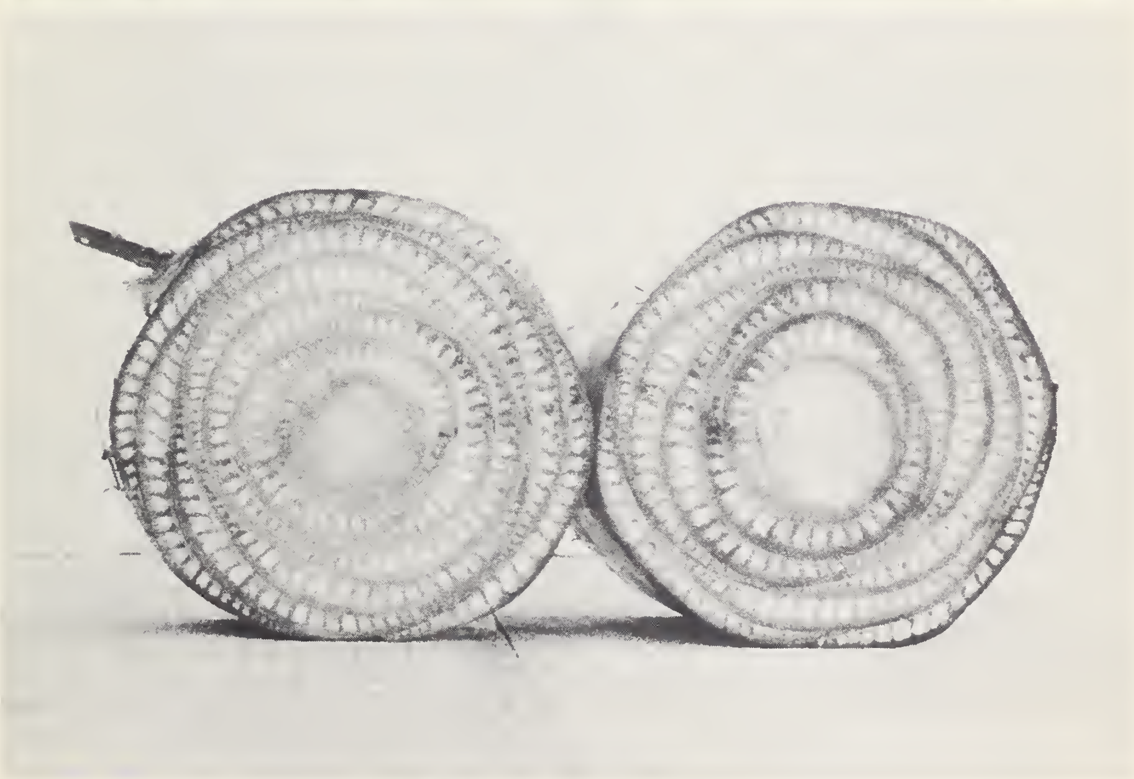
Figure 5.--Sketch showing botanical relations of the family Musaceae. Figures in circles indicate approximate number of species in each genus. (From Reynolds: "The Banana." Courtesy Houghton Mifflin Company.)

The stalk of the abaca plant is composed of a fleshy, fiberless central core--the true stem--surrounded by overlapping leaf sheaths, which arise at or near the base and extend nearly to the top (fig. 6). The outer leaf sheaths are the shorter and older; the younger ones push up through the center, each new one higher than the preceding. When sheath formation is complete the flower bud develops and produces a cluster of flowers similar to those of the banana. The flowers are first enclosed in a cone, each cluster of flowers being covered by a reddish brownish to green bract. The first bracts that open contain the female flowers from which the fruits develop; the outer bracts only contain male flowers. (25)

The plant grows more slowly than the banana to a height of 15 to 25 feet, bearing open leaves, or blades 4 to 8 feet long at the top. The stalk may attain a diameter of 5 to 12 inches. It consists of 12 to 25 sheaths, which vary in thickness and width depending on their position in the stalk. Those on the outside rise from the base of the core but do not extend to the top, whereas those on the inside rise at varying points slightly above the base and reach the top. Only the central sheaths are exactly the same length as the stalk.

A

B



a b

Figure 6.--A, Fruit and flower bud of abaca. The fruits grow in clusters like the "hands" in banana. Normally the mature fruits are about the size of a man's thumb. B, Cross sections from (a) mature and (b) immature stalks cut high up on the stalk. Central core of mature stalk is fleshy and fiberless; central core of immature stalk is composed of unfolded leaves.

Figure 7.--Cross section of abaca leaf sheath. The sheath consists of three layers, but the fiber of commerce is obtained only from the outer one.

Each sheath is composed of three layers: an outer, from which most of the fiber is obtained; a middle, which is the source of some fine white fiber of lower tensile strength than that of the outer layer; and an inner, which contains no fiber (fig. 7).

Apparently few, if any, comprehensive studies of the physiology and development of the abaca root have been made; yet in view of the "tip over" plants found so frequently in the Central American plantations, root studies would seem to be worth while.

Sherman (168) reported that the roots penetrate but a relatively short distance into the surrounding soil, and Espino and Novero (65) stated that abaca is a surface feeder, most of its roots lying between 15 and 25 cm. below the surface of the ground and deep cultivation may injure the roots. An illustration of root development in abaca is shown in figure 8.

In 1911 Copeland (45) reported the results of some experiments on the physiology of the root and measurements of its growth. The root cap, he states, ranges in length from 0.5 to 1.5 mm. and the growing region, measured from the extreme tip, is usually less than 5 mm. in length. Thus the greater part of the elongating region lies outside the root cap. This fact, together with the absence of a hard hypodermis and the presence of root hairs, leaves the roots exposed to all the possible hazards of their environment.

Copeland reported that the general average daily absorption of water per root is intimately related to the rate of transpiration, the hours of most rapid absorption following closely upon those in which water is given off most rapidly. He gives the transpiration or daily loss of weight of plants growing in cans as varying from 630 grams daily by a plant with a leaf area of 1,750 sq. cm. to 1,350 grams daily by a plant with a leaf area of 7,100 sq. cm. Copeland's leaf area figures would apply to relatively small stalks as a medium size mature stalk would have a leaf area of possibly 40,000 sq. cm., and would transpire a relatively larger amount of water.

The root measurements showed an average rate of growth of somewhat more than 6 mm. per day. Copeland stated that in a good moist soil the roots of neighboring plants as ordinarily planted will begin to overlap before the plants are a year old and that there is active competition between the roots of mature plants.

TECHNICAL DESCRIPTION

Musa textilis Née, 1801
Musa sylvestris Colla, 1820
Musa abaca Perr. 1825
Musa troglodytarum textoria Blanco, 1837
Musa mindanensis "Rumph." Miquel, 1855 (46)

Trunk cylindrical; stoloniferous; leaves narrow-oblong, deltoid at base, round or acute at apex, bright green above, glaucous beneath (150). Length of mature blade from 162 to 200 cm., width from 25 to 30 cm., petiole from 60 to 70 cm. (175). Inflorescence small drooping spike,

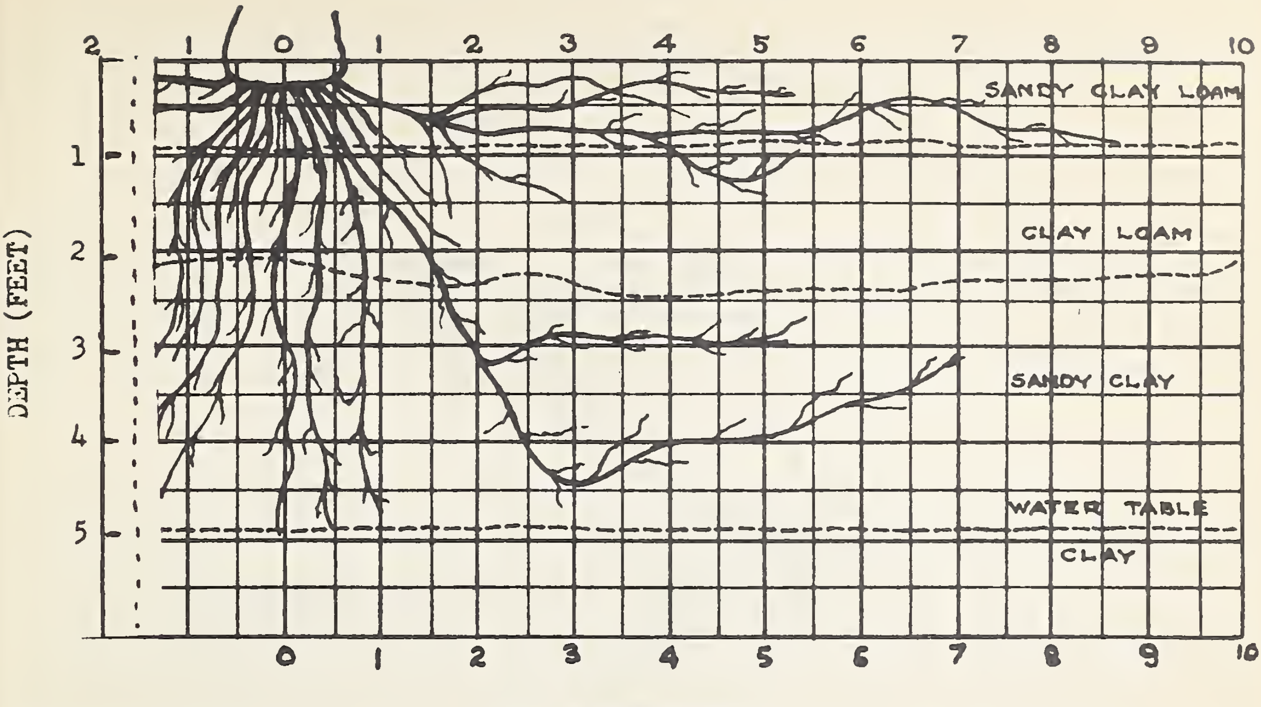


Figure 8.--Root development of a six year, seven months old abaca plant of the Bungulanan variety grown in Honduras. Courtesy Tela Railroad Co., La Lima, Honduras.

fertile flowers toward base, sterile staminate flowers toward apex; flowers small, arranged in dense, two-rowed fascicles, in three-ranked spirals; 9 to 10 fertile flowers in a fascicle and from 3 to 6 hands in an inflorescence (175); male flowers deciduous; calyx five-lobed. Mature fruits very small, 5 to 7 cm. long, 2 to 5 cm. thick, green, three-angled, curved, thick-skinned, and filled with black seeds; pulp white; bitter to the taste.

CLIMATIC REQUIREMENTS

Abaca is a strictly tropical plant, and it cannot be grown successfully except under tropical conditions. Even in the Philippines it is not cultivated as far north as Manila, except on a small plantation near Laguna de Bay, and it is doubtful if it would grow satisfactorily in regions with an average temperature of less than 72° F. (74). Although abaca is produced in the Philippines at altitudes as high as 3,000 feet above sea level, the yields at these altitudes are not high; in fact, the temperature is too low for the perfect development of the plant at elevations of more than 1,000 to 1,600 feet (74).

Abaca grows best where the atmosphere is warm and humid and the rainfall is abundant and evenly distributed. Even a few weeks of dry weather will check the growth of the plants, and abaca cannot be grown successfully even in tropical regions where rainy seasons are followed by long dry seasons. Perhaps the exacting climatic together with exacting soil requirements more than any other factors gave the Philippines its monopoly of this valuable product of international trade for more than a century.

Dewey (52) mentioned an evenly distributed rainfall of 60 inches or more, together with a continuously warm temperature, as essential to the successful growth of abaca.

In the great abaca-producing regions of the Philippines--Albay, Ambos Camarines, Mindanao, and the eastern coasts of Samar and Leyte--the best abaca is grown in the sections characterized by a total annual rainfall of 108.9 inches, heaviest in November-February and lightest in March-June, with no dry season; a humidity range of 78 to 88 percent, and an average temperature of less than 80.6° F. (151).

Table 2 shows the annual rainfall and temperature for some of the abaca-producing regions of the Philippines.

TABLE 2.--Annual temperature and rainfall data for some abaca-producing regions in the Philippine Islands (73)

	Number of years averaged	Temperature	Days rain	Rainfall
		°C.		Inches
Albay	6	26.05	218.5	118.42
La Carlota (Negros)	10	26.5	154.3	103.65
Mamburao (Mindoro)	2	....	147.3	124.65
Iloilo	4	....	152.6	71.84
Cebu	6	....	161	58.88
Tamontaca (South Mindanao)	2	....	121.3	76.38
Davao	2	....	187	79.82

Typhoons, which are common in the Islands, take a heavy toll of the abaca crop. In Davao, however, typhoons are practically unknown, and it is this fact, together with the fertile soil and the abundant and evenly distributed rainfall, as well as the competent management, that made Davao the most important abaca-producing province.

In Central America all the abaca plantations are on flat to gently sloping land,[34] which in its natural state is poorly drained and subject to flooding from the sudden rise of the tropical rivers. Expensive drainage systems have been installed to prevent the drowning of the crops. In Panama and Costa Rica heavy rains are sometimes accompanied by tropical winds which result in "blowdowns." These have been estimated to affect about 10% of the acreage in bad years. Most of the stalk material from such blowdowns can be salvaged by immediately harvesting if the areas are not too big but it results in some disrupture of the regular farm management program.

The following observations on rainfall and temperature in the Central American plantations were made by Saleeby[35] on an inspection tour in 1946.

Panama.--At Almirante the average annual rainfall during the years 1936-46 was 90.54 inches. It was as evenly distributed throughout the year as in the best abaca-producing districts of the Philippines. The least rainfall in any one year during this period was 52.70 inches, the heaviest 142.36. Usually the heaviest rains occurred in November and December and again in June and July.

Costa Rica.--The two projects, one at Monte Verde and the other at Good Hope, are only about 9 miles apart and have much the same climate. The temperature seldom rises above 90° F. or falls below 62°. The average annual rainfall at Monte Verde during the years 1936-46 was about 135 inches. Rainfall is heaviest from October to January and again in June and July. The amount and distribution of rainfall are usually favorable for the growth of abaca, but every few years there are destructive floods at Monte Verde following exceptionally heavy rains.

Honduras.--The Honduran project, located in the Guaymas district of northern Honduras, has a temperature range of 55° to 95° F., a range which would not be considered favorable for abaca in the Philippines. However, Saleeby states that the minimum of 55° is not considered low enough to affect adversely either the growth of the plant or the quality of the fiber. Rainfall for 1943-45 varied from 70 to 80 inches. It was not evenly distributed, for there was a distinct dry season in February, March, and April, when there was little or no precipitation.

Rainfall records for the Guaymas district for 1927 to 1931, as reported by the Tela Railroad Company,[36] were:

1927	88.40 inches
1928	107.81 "
1929	84.01 "
1930	84.22 "
1931	83.12 "

[34] SALEEBY, M. M. REPORT COVERING INSPECTION OF THE FIVE CENTRAL AMERICAN ABACA PROJECTS, SUBMITTED TO THE UNITED STATES OFFICE OF DEFENSE. 26 pp. Washington, D. C. June 28, 1946. [Processed.]

[35] See Footnote No. 34.

[36] TELA RAILROAD COMPANY. RESEARCH DEPARTMENT ANNUAL REPORT FOR 1942. La Limas, Honduras. [Unpublished manuscript.]

Guatemala.--The abaca plantation in Guatemala is situated on the north bank of the Motagua River, near Puerto Barrios. The temperature range, as in Honduras, is 55° - 95° F. The rainfall for the years 1942-1945, which was fairly evenly distributed, follows:

1942....................	143.65 inches
1943....................	137.91 "
1944....................	107.35 "
1945....................	112.97 "

The retarding influence of drought on abaca is strikingly illustrated by the plantings in Honduras and Ecuador. As previously stated, three of the four plantations in Ecuador are situated in a belt where there is practically continuous moisture either as actual rain or as a fine mist or fog. The fourth plantation at San José lies outside of this belt, and from the beginning of June through October practically no rain falls. During these months the plants almost cease to grow, and, despite the greater fertility of the soil, the plants at San José require many months more to mature than those on the other plantations.

SOIL REQUIREMENTS

While abaca will grow on a fairly wide range of soils of different textures, there is a marked difference in its productivity over such a range of textured soils. It is rather difficult to record specific soil requirements that apply generally to abaca. Abaca is very sensitive to favorable soil conditions and soil management, and to the climate to which the soils are subjected. This degree of sensitiveness is much more pronounced for the successful culture of abaca than for many plants. It is much more important and economical to select a good soil than to try to improve a poor soil by management. It is considered that a slightly higher initial cost for good land may be better than additional costs each year after planting to improve a poor soil.

In the first place abaca must have a fertile soil for economic production. Tropical soils of recent volcanic or alluvial origin are in general the most productive and the first choice for abaca. The texture and structure of the soils, together with their slope, permeability, and elevation, influence materially the production of the crop. Abaca should be grown on friable loam, very fine sandy loam, or silty clay loam soils which have permeability, slope, or elevation that insures good natural drainage, but such soils must possess the structure to insure good retention of moisture. Experience has shown at Guaymas, Honduras, that soils with light subsoils must be avoided because they are too droughty in the dry season experienced there. On the other hand, because of the poorer natural drainage and heavier more uniform rainfall conditions experienced on abaca plantations in eastern Costa Rica, the heavier soils with somewhat lighter subsoils are more productive as they insure drainage. Good drainage is essential to successful abaca culture, for abaca will not tolerate a water-logged soil. Except for short periods after heavy rains, the water table should always be more than 3 feet below surface.

Sandy soils or soils with underlying strata of gravel that permit a rapid percolation may dry out too quickly to meet the demands of the plant for a large and continuous supply of moisture, and should be avoided. Likewise, stiff clays that break or crack during the dry weather and become wet and pasty in the wet season, and a soil underlain by a hardpan which impedes root penetration and interferes with the free movement of water and aeration in the soil, should also be avoided.

Since abaca can stand neither too dry nor too wet a soil, Hernais and Espino (91) made a study to determine the optimum soil moisture requirement of the young plant. The results of the study showed that abaca seedlings could not be grown even in a fertile soil if it had less than about 50 percent saturation and that the optimum moisture requirement of the young plant lies somewhere between 60 and 80 percent, probably about 70 percent, of saturation.

Abaca will make its best growth on proper soil types following the removal of a virgin forest, because the crop benefits from the accumulation of humus and the physical soil factors common to newly cleared land. Large blocks of such soils for modern plantation installation are difficult to find. Hence it is usually necessary to select land that may have been earlier cleared and cropped and then abandoned and grown up to bush, or to select areas of somewhat less desirable soil factors.

PHILIPPINE ISLANDS

The Philippine Government has published reports on soil surveys of eleven provinces in the Islands. These include the provinces of Bulacan, Rizal, Cavite, Batangas, Pampanga, Tarlac, Pangasinan, Nueva Ecija, Iloilo, Laguna, and Bataan (14). Of these only Cavite has ever ranked as a leading abaca-producing province, and the bunchy top disease practically wiped out the industry there many years ago.

The three types of soil on which best results with abaca are obtained in the Philippines are (1) moist, mellow loams of volcanic origin; (2) alluvial plains subject to some overflow by streams or rivers; and (3) moist and well-drained loams (60).

In Albay, once the leading abaca-producing province of the Philippines, and in the Camarines and Sorsogon, provinces noted for the quality of their fiber, the finest abaca is grown on the lower slopes of old volcanoes where the soil, derived from the disintegration of volcanic rock and the deposit of volcanic ash, is a rich, mellow loam. In Leyte some of the best fiber is grown on the lowlands where the soil is a heavy silt loam of alluvial origin.

A scientific study of the soils of Davao has recently been made by Mariano (114). He reports that the premier abaca-producing soil of Davao is Tugbok clay loam, which occupies an area of 217, 286 acres, or 4. 5 percent of the area of the province. It lies southwest of Davao City at the foot of Mount Apo in gently rolling country. The soil, of volcanic origin, is reddish in color, deep, and well drained. It was on this soil that the Japanese had most of their plantations.

Kidapawan clay loam, which comprises 13, 205 acres, is not inferior to Tugbok clay loam as an abaca soil, but the topography is rougher. Miral clay loam, comprising 85, 012 acres on the lower slopes of Mount Apo, is also a good abaca soil. At present most of it is covered with second-growth forests. San Manuel silt loam (333, 092 acres), Cabangan silt loam (271, 149 acres), and Matina clay (23, 500 acres) are also recommended for abaca.

From this survey it is obvious that there is no lack of land suitable for successful abaca production in Davao province. In the great island of Mindanao, larger than the State of Maine, only about ten percent of the land is cultivated, and parts of Davao, which is one of its largest provinces, are still practically unexplored (124).

Since abaca is grown on the same land for ten to fifteen years without rotation, replanting, or the application of fertilizer, the soil chosen for the plantation as indicated earlier must have a high degree of natural fertility. On many of the "lates" or plantations of the Philippines the same soil has produced abaca for more than fifty years practically without cultivation and with no fertilization other than the humus returned to the soil from the abaca waste left to ferment on the ground after the plants are harvested. In the harvesting process the entire plants are cut down, and because of their size and weight and the consequent expense of transportation, they are stripped (tuxied) in the field. In harvesting and stripping only about 10 to 15 percent of the material of the entire crop, which represents mainly fiber, is removed; the rest is left on the ground (168). The 85 to 90 percent so left decays rapidly in the warm, humid atmosphere of the Tropics and becomes incorporated in the soil as humus. Some of the acid produced by the decaying waste reacts chemically with the soil minerals, becomes neutralized and forms salts that may be absorbed by the plants; some of it leaches out; but some of it is directly absorbed by the plant with--according to Sherman (168)--deleterious effects on both its growth and the quality of its fiber. This contention of Sherman that abaca waste left on the field produces an acid condition of the soil that injures the growth of the plant and reduces the quality of the fiber is by no means shared by all investigators.

Tirona and Argüelles (178), in a comparison of renovated and virgin abaca soils, found that virgin soil and soils recently planted for the first time are acidic and that the reaction of the soils tends to become more alkaline as the fields grow older. For example, the soil of a field on recently cleared ground was more acidic than that of an adjoining field 10 years old, and two fields, aged, respectively, 20 and 25 years, were less acidic than a neighboring field 7 years old. This decrease in acidity of old fields is, in the opinion of Tirona and Argüelles, due to the incorporation in the soil of the decomposed waste left on the ground after harvesting.

From these two opposing points of view, it is apparent that the role of the waste returned to the soil is a matter that might well be the subject of further study. Over the long term, the results obtained on soil in Central America, where little of the waste plant material is left in the field, may offer some interesting data for comparison. In these non-limestone soils, there is frequently a very shallow surface layer that contains the decaying organic matter and the pH of it may be much higher than soil an inch or more deeper.

The adaptability of different varieties of abaca to different types of soil and the influence of soil on the quality of the fiber are other problems that should be studied. Buck (30), from limited observations, concluded that "the so-called different varieties, at least as far as Cavite is concerned, depend for their difference upon the nature of the soil in which they are grown." The "abacang siniboyas" seemed to grow best on high, rather infertile soil, whereas "Kinalabaw," which produces a dark, rather coarse fiber, grows best on low fertile soil.

Rojales (151) found that the higher the percentage of organic matter in the soil, the greater was the production of fiber. This is due, he believes, to the fact that the organic matter serves both as nutrients for the plant and as a reservoir for the storage of moisture.

CENTRAL AMERICA

The best abaca soils of Central America are for the most part a very fine sandy loam to silty clay loam and might be referred to as alluvial bottoms of recent origin. They are among the best soils in Central America. This classification was made by soil survey specialists of the United States Department of Agriculture.[37]

The soil of the Panama plantation along the Changuinola River is a mellow loam, but that farther from the river is of heavier texture, approaching clay loam. In Costa Rica the best soil range from fine sandy loam, silt loam to silty clay loam with poorer soils of heavier loams to clay loam on the sections farthest from the river. In general, the better soil on the Honduran project are silty clay loams, and the loams with sandy subsoils are too droughty for best results; the best soil on the Guatemalan project are silt loam, silty clay loam and silty clay formed by silt deposits from the Motagua River, which become somewhat heavier away from the river.

Since most of the Central American plantings were made on derelict banana plantations, Wardlaw's (188), remarks in respect to banana soils are worth noting. Of the soils which he considers "intermediate" in respect to value for growing bananas, he states that the rich layer of disintegrated vegetation present at the time of planting gradually disappears, and when this occurs production declines.

The relation of disease incidence to soil acidity in the abaca soils of Central America has never been adequately investigated, but Wardlaw (188) states that whenever Fusarium cubense (Panama disease) is present in soils of low pH, e.g., 5.5., it appears to spread rapidly; in neutral or slightly alkaline soils there is usually less disease. Many banana soils in Central America are said to be deficient in lime (188), but the best and longest producing soils have an adequate supply, as evidenced by pH values of 6 or above.[38] In a soil having pH value of 6.6 or higher, other conditions being favorable, banana plants may resist the disease and continue to give high yields for 20 years or more.

PROPAGATION AND CULTURE

PROPAGATING MATERIAL

Abaca may be propagated from true seed, suckers, or by division of the bulbous base or corm--frequently referred to as "root heads." The usual way of starting a new plantation or renewing an old one is to use either root heads, entire or in sections, or the small suckers that spring from the corm of the parent plants. In case shortages of propagating material should develop in the rehabilitation of old plantations or when new areas are opened for abaca production, questions might arise in reference to the use of seed in connection with other methods. Propagation by true seed followed by selection is a useful means of developing new and superior varieties. Seeds for planting should be extracted from ripe fruit, washed well, and dried. Before planting they should be soaked overnight, then sown in clean, well-fertilized soil. In one year the young seedlings, then two or more feet high, may be transplanted in the field. Plants grown from seed usually require from one to two years longer to mature than those grown from shoots or rootstocks. Ordinarily they do not breed true to type, and for this reason their use on large plantations is not recommended, although they have been used.

Suckers are widely used in the Philippines as propagating material, but root heads, entire or in sections, may have certain advantages over suckers and are preferred in the large commercial plantings of Davao and in Central America. The root divisions (fig. 9), sometimes called "bits," "seed pieces," or simply "seed," are taken from strong, vigorously growing, mature plants. They should be 12 to 15 cm. in diameter at the top and each should contain at least two healthy buds. Plants developing from the buds of rootstocks are usually stronger and faster growing than those from suckers. Plants from rootstocks or suckers come true to variety type, in contrast to plants that come from true seeds.

Large suckers with the pseudo stem attached are frequently used to replace missing hills or mats. The pseudo stem serves as an upright marker to the new plant. Limited experimental

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[37] Descriptions of soils from Abaca Research Reports. Abaca Project, Inter-American Institute of Agricultural Sciences. Turrialba, Costa Rica. 1951. [Unpublished.]

[38] UNITED FRUIT COMPANY. RESEARCH DATA 1926-1935. [Unpublished.]

Figure 9.--Abaca "seed" or "bit" ready for planting. This section cut out of mat shows the buds or "eyes" (A, B, C) from which new plants will develop. Abaca is also propagated by the use of suckers, rarely by true seed.

data in Central America has indicated that suckers less than three inches in diameter at the base do not grow as rapidly as larger, more mature suckers, and also the smaller suckers are more likely to die in transportation and transplanting. The same experiments have indicated very little difference in growth between suckers over 3 to 4 inches in diameter at the base and "bits" from larger, more mature heads.

PLANTING

In the Philippines the land is cleared for abaca during the period from January to April, the months in which rain is lightest. In clearing forests, the underbrush is cut, and the debris is burned if the weather will permit. Planting takes place as soon as the rains begin. After planting, the larger trees are felled and left to rot on the ground (fig. 10).

On the better managed plantations the plants are set at regular intervals in rows, the distance between them depending somewhat on the variety and the conditions under which they are grown. The plants are usually set from 8 to 10 feet apart each way in the rows, this arrangement giving about 700 to 450 plants per acre (74). In Davao the distance between the hills is usually 2.74 meters (9 feet) in a square (2). For the Maguindanao variety, however, which is a very rank grower, the distance is usually 3 meters (10 feet).

In Central America experiments have been made to determine the best distance to space the plants under the conditions prevailing there. In these experiments plants were set at equal distances each way in the form of a square, and also in the form of a hexagon, since the hexagon gives a greater number of plants to the acre. Of the plantings made 10 X 10, 12 X 12, 14 X 14, and 16 X 16 feet in squares, the 14 X 14 foot spacing appeared to be the best. The 14 X 14 foot square gave 222 plant hills or mats per acre; the 14 X 14 foot hexagon, 257 mats.[39]

Holes large enough to accommodate the seed pieces are dug, a seed piece is placed in each and covered with soil to a depth usually of 2 to 4 inches. The soil around the seed piece is pressed down firmly to prevent it from drying out too quickly in dry weather and to keep water from collecting around it in wet weather.

In the Philippines a cover crop, usually cowpeas (Vigna sinensis), is sown in the plantation just before or just after the abaca is planted. This discourages the growth of weeds, keeps the ground cool and moist around the young plants, and furnishes nitrogen to the soil. The small grower who must depend upon his land for food sometimes grows beans or rice along with the abaca during the first year of the new plantation, and if these crops are not planted too close to the abaca, this practice is not particularly harmful.

The question of shade for the plants and its effect on the fiber have been the subject of much discussion and some experimentation. In Davao abaca is usually grown without shade, but in the provinces that are subject to strong winds trees are used extensively for windbreaks as well as shade.

Figure 10.--Field in the Philippine Islands newly cleared and planted to abaca. The abaca plants soon shade the ground and the forest refuse decays.

[39] UNITED FRUIT COMPANY. ABACA PRODUCTION. San Jose, Costa Rica. 1942-1943. [Unpublished manuscript.]

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Espino (62) found that plants exposed to sun and wind yielded almost double the quantity of fiber produced by those under shade and exposed to little wind.

Youngberg (194) reported that fiber produced on an open plantation was much stronger than that from a shaded one, the difference being 2,279 grams per gram meter in favor of the fiber from the open plantation.

Copeland (45) stated that plants under shade grow more slowly and develop less leaf area than those in full sunlight. The leaves grow more slowly and cease growth earlier. The average daily growth of fully illuminated plants and of plants grown in shade were, respectively, 7.9 mm. and 4.7 mm.

Cevallos (43) found that when showers were frequent and soil moisture was adequate, the plants in full sunlight grew more rapidly and appeared thriftier than those grown in partial or in fairly complete shade. On the other hand, in a season of unprecedented dryness the growth of the plants in shade so far exceeded that of the plants in full sunlight that one might reasonably have concluded that shade is essential to the successful culture of the plant.

No doubt Cevallos is right in his conclusion that shading the plant may affect the crop favorably or unfavorably according to local climatic conditions. "In some localities," he states, "the use of shade ... is necessary, because there are frequent droughts and baguios, while in other places, for example, in some parts of southern Mindanao, where there are plenty of rain, constant humidity of the atmosphere, and proper temperature of the air and of the soil throughout the year, the use of shade may be dispensed with altogether."

In the Central American plantings abaca is grown without shade.

CULTURAL OPERATIONS

On thousands of small farms in the Philippine Islands where abaca is planted in irregular formation between the felled trees and underbrush, cultivation is difficult even after the trees and stumps have disintegrated. In such cases it usually consists in no more than an occasional cutting of the larger weed growth with a bolo or machete. On the better managed plantations the plants are set in rows and cultivated until the heavy shade of the leaves prevents the growth of weeds. On the larger Japanese plantations cover crops were extensively used.

On the Central American plantations frequent cleaning of the planting and circling of the plants up to 18 months from planting is regarded as imperative. After the plants have once dominated the natural bush growth, however, two or three cleanings annually are generally considered sufficient in a well-established planting.

Pruning or thinning of the mat may be advisable if stalks become over-crowded; however, this is a debatable question. In Central America populations of eight to twelve so-called mother stalks with their suckers or followers per mat are not considered too crowded after the planting is well established. When periodic harvesting (usually four harvests a year) is under way, pruning usually consists only in the removal of excess young suckers. The United Fruit Company has done some fairly extensive research on methods of thinning. These experiments included comparisons of yields from unthinned mats and from mats thinned to five, ten, and fifteen mother plants. The results, presented in the following tabulation, show that the highest yields were obtained from the mats that contained the greatest number of mother plants with their followers; i.e., those thinned to 15 mother plants and those not thinned at all.

Total weight of stalks per mat (pounds)

Mats pruned to--	1944	1945	1946	1947	1948	1949	Total
5 and followers.....	290	460	364	640	379	403	2,536
10 and followers....	407	714	734	645	572	395	3,467
15 and followers....	445	968	892	822	726	270	4,123
No pruning..........	248	1,138	827	791	800	351	4,155

PRODUCING PERIOD

The plant stalks grow and reach maturity in two to three years, depending on the variety, the care given the young plants, and the soil and climatic conditions. The yield from the first harvest is very small, but when the new plantings reach the age of four to five years they produce a full crop of mature stalks, which may yield from one-half to two tons of dry fiber per acre (115). According to Saleeby (157), maximum production continues until the plants are seven to eight years old. Mendiola (119) states that "the yield of an abaca field assumes that of a curve beginning at a low point at the age of two or three years, according to variety, rising very rapidly through the fourth, fifth, and sixth years when it begins to decline . . ."

The length of time that an abaca plantation may continue maximum production is of more than academic interest to those concerned in the growing of the fiber in Central America, for, in 1950, after six years in production these plantations were near or past their peak. Rejuvenation methods that have been discussed include replanting, butcher harvesting, and rotation.

There is also a difference of opinion as to the period that abaca will continue to produce a profitable crop without replanting. Saleeby says that it is generally considered advisable to replant after the twelfth to fifteenth year. Edwards,[40] however, found that the consensus among the Philippine abaca planters appeared to be that the best results are obtained if the old fields are cleared and replanted after a producing period of about ten years. The length of the profitable producing period will vary according to the variety grown and the conditions under which it is grown. Some varieties mature more slowly and continue to produce for a longer period than others.

FERTILIZATION

Tests to determine the value of fertilizers for abaca are not new to the Philippines. The Spaniards instituted a series of fertilizer tests with abaca in 1895 (44), and the director of the Government Experiment Station at Cebu went so far as to analyze the bat guano that was found in caves of the islands and to test its value on a number of crops. It was this scientist, who after a careful study of the soils in the Islands, declared, "The exaggerated fertility of Philippine soils is utterly illusory. In Cebú the lands most cultivated are completely exhausted," a statement which may well be weighed in connection with the inferior growth of abaca in the old-producing provinces where fields have been cropped to abaca for generations without fertilization other than the return of the plant waste to the land.

Sherman (168) found the results of this practice of growing abaca on the same land without rotation or fertilization to be a heavy and continuous exhaustion of minerals necessary to the well-being of the plant, and a permanently acid condition of the soil. From an analysis of the ash of the fiber he found over 3 percent, or an estimated 5,000,000 kilograms of mineral constituents in the yearly Philippine abaca crop (normally about 1,250,000 bales, prewar), of which over half was composed of potash and lime salts alone. Thus he estimates that there is an annual loss to the soil of nearly 5,000 tons of mineral constituents essential to abaca production. He states that potash is probably the most important mineral constituent required by abaca for its growth and development, and he found that the percentage of potash is so uniformly low in the Bicol soils as seriously to affect the growth of the plants. Phosphates, though generally present in Philippine soils, were deficient in some Bicol districts, as were also lime and magnesia. The Davao soils, on the other hand, probably as a result of the plowing, cultivation, rotation, and also because of the fewer years that they had been cropped, compared favorably with the accepted standard for a good, well-balanced soil. The better condition of the soil, the greater yield of fiber per acre, and the uniformly high quality of the fiber in Davao, Sherman attributed to the modern agricultural methods used.

Tirona and Argüelles (178) determined the amount of essential plant food elements removed as fiber constituents alone from a hectare of soil over a period of 20 years in Davao fields. In the cleaning of fiber of good grade in Davao, they stated that about 98.5 percent of the plant is left in the field and only 1.5 percent is removed as fiber. An analysis of fiber of excellent cleaning made by the Philippine Bureau of Science showed an average of 0.080 percent nitrogen (N), 0.012 percent phosphoric anhydride (P_2O_5), 0.428 percent potash (K_2O), and 0.164 percent calcium oxide (CaO). The yield of fiber of good cleaning over a 20-year period, they point out, is about 43,933 kilos per hectare (39,114 pounds per acre). On the basis of the foregoing percentages, this weight of fiber removed from a hectare of soil 35.146 kilos (31.3 pounds per acre) of nitrogen, 5.272 kilos (4.7 pounds per acre) of phosphoric anhydride, 188.034 kilos (167.4 pounds per acre) of potash, and 72.050 kilos (64.2 pounds per acre) of calcium oxide.

Tirona and Argüelles state that with the exception of potash, nutrients in such quantities constitute so small a fraction of the available plant food in a hectare of soil after 20 years of cropping, that it can be readily replaced by a ton (about 900 pounds per acre) of fertilizer composed of 3.51 percent nitrogen, 0.53 percent phosphoric acid, 18.80 percent potash, and 7.03 percent lime. They concluded, therefore, that the quantity of essential plant food elements removed from a hectare of soil as fiber constituents alone in 20 years is unimportant. These results and conclusions are based on the hand field-stripping method and not on methods where the whole stalk is

[40] EDWARDS, H. T. Unpublished notes. [n.d.] (U. S. Bur. Plant Indus., Div. Cotton and Other Fiber Crops and Dis.)

removed from the field for cleaning as practiced in Central America. Because of the very small amount of available magnesium found in the oldest fields, Tirona and Argüelles concluded that a deficiency of available magnesium may be one of the limiting factors in the growth of second plantings.

Richmond (149) reported that 90 percent of the green weight of an abaca stalk is juice, which, on evaporation, was found to contain 2.62 percent of solids, or 275 grams (0.605 pound) from a stalk weighing 15,876 kilos (34,995 pounds). An analysis of this solid matter, obtained by evaporating the expressed liquid, showed:

	Percent
Total nitrogen	0.40
Total phosphoric acid (P_2O_5)	1.86
Potash as K_2O	30.56

Richmond concluded that the presence of nearly 1 percent (2.62 percent solids X 30.56 K_2O = 0.8) of available potash in the juice, as compared to only 5 percent in wood ashes, the best of potash fertilizers, shows the value of this constituent to the growing plant, and the juice should be returned to the soil. Abaca waste, on the other hand, he found to have a rather low fertilizing value, and he stated that its removal in a dry state would cause no appreciable loss of plant nutrients. In support of this belief he offered the following analysis:

	Percent
Total nitrogen	0.52
Total phosphoric acid (P_2O_5)	.046
Potash as K_2O	.661
Lime (CaO)	.238

While Richmond's results are valuable for understanding the fertilizer problem, the economical return of the juice to the soil with modern methods of factory cleaning presents difficult problems.

In 1895 the Boletin Oficial Agricola de Filipinas, which carried reports of research being conducted at the agricultural experiment stations of the Islands, published the following analysis of abaca (44):

The trunk of the plant is 92 percent water. Of the dry weight, 16 percent is ash; of the ash, potassium and sodium make up 27.5 percent, and a total of 70 percent is soluble. In the fiber on the market 14 percent is water; the ash is only 4 percent of the dry weight; and of the ash, potassium and sodium make 28 percent, 51 percent is soluble, and 15 percent is silica.

The author of this analysis concluded that the plant obviously needs much potash, and he recommends that the waste from harvesting and stripping be returned to the soil.

On the basis of an estimated 44,000 pounds of stalks removed annually per acre, as is done under favorable conditions in Central America, and discussed in the second paragraph following, this early analysis would indicate a total dry weight annually of 3,520 pounds per acre, of which 563.2 pounds is ash containing 154.88 pounds of potassium and sodium.

Edwards[41] reported that Sherman found the abaca stalk to contain from 90 to 93 percent of water and from 7 to 10 percent of dry matter.

Recent analyses (1949-51) made by the United Fruit Company in Honduras on one stalk of Bungulanon, 6 feet long, weighing 60 pounds, gave the following results:

	Percent		
Moisture			93.12
Nitrogen	0.0349	-	0.0449
Phosphorus	.0062	-	.0089
Potassium (K)	.5848	-	.6364
Total ash	1.15	-	1.28
Silica	.18	-	.23
Iron and aluminum oxide	.053	-	.067
Lime (CaO)	.107	-	.112

[41] See Footnote No. 40.

One thousand pounds of abaca stalk will, therefore, contain:

	Pounds
Nitrogen	0.349 - 0.449
Phosphorus	.062 - .089
Potassium (K)	5.848 - 6.364

On the basis of this analysis the loss of potash from the soils of Central America, where the whole stalks are taken from the field, must be tremendous. With bananas only about 25,000 pounds of fruit are removed from an acre in a year, which represents the removal of about 40 pounds of potash. With abaca, an estimated or calculated 44,000 pounds of stalk are removed, which represents the loss to the soil of over 250 pounds of potash per acre per year. In the Philippines, where abaca is grown for fifty years or more on the same land without rotation or fertilization (not recommended), only the fiber or the outer fiber-bearing part of the stalks is removed; the rest is left on the ground to decay and become incorporated in the soil, whereas in Central America the whole stalk is removed. These different methods would account for a much more rapid decrease in the fertility in Central America than in the Philippines and was emphasized in discussions in Washington, D.C. in 1949.[42] Some crops in the United States have as high a percentage of potash in the leaf material removed, but they do not yield as much dry matter per acre as abaca.

Abaca is classed as a "poor" industry, and the price of the product in normal times is not such as to justify continuous feeding with high-priced fertilizers. Early in the development of the Central American program it was estimated that each application of fertilizer would have to raise production more than 300 pounds per acre to justify its cost.

The fertilizer used for abaca in Central America has been primarily, if not entirely, a nitrogenous one. In the beginning sodium nitrate was applied three or four times a year at the annual rate of 400 pounds per acre, which was the standard banana application.

Abaca grows slowly at first, and fertilization may be necessary to enable it to resist the encroachment of competing vegetation. Birdsall[43] made a field inspection of the use of fertilizers for stimulating the growth of abaca both in young and in old plantings. He states that when the young plants have reached 12 to 15 inches in height and have leafed out, they may enter a phase of stagnant growth, in which case they take on a yellowish hue. This condition usually indicates a deficiency of nitrogen. In older plantings also, when, because of blowdowns, overharvesting, or for some other reason, an excessive amount of sunlight reaches the mat, grass grows rapidly and because of its shallower roots is able to compete successfully with abaca for the nitrogen that is available. In such cases it is advisable to fertilize.

The nitrogenous fertilizer carriers recommended by Birdsall are urea, ammonium sulfate, ammonium nitrate, calcium cyanamide, and sodium nitrate, containing, respectively, about 46 percent, 21 percent, 35 percent, 20 percent, and 16 percent of nitrogen.

In new abaca plantings Birdsall recommends that the first application should be made 10 to 12 weeks after planting and that it should approximate either 2.5 ounces of ammonium sulfate or calcium cyanamide; 3 ounces of sodium nitrate; 1.5 ounces of ammonium nitrate; or 1.0 ounce of urea per hill. The second application should be made 16 to 18 weeks after planting and should be increased 50 percent over that of the first application. The third application should be made 6 to 8 weeks after the second, and the amount applied should be double that of the first application.

To stimulate growth in the older plantations, from three to four applications of fertilizer in the amounts of 5 ounces of ammonium sulfate or calcium cyanamide, 6 ounces of sodium nitrate, 3 ounces of ammonium nitrate, or 2 ounces of urea per hill should be made. The fertilizer should be applied in equal amounts at intervals of 6 to 8 weeks. Three applications should suffice.

The United Fruit Company in 1949 started a series of fertilizer tests with abaca in Honduras. These tests were designed to show the response of abaca to the three principal plant foods, nitrogen, potash, and phosphorus. Fertilization began in July 1949, and more than 3,000 monthly growth-rate measurements were made for each treatment from September through December 1949.[44] The results as shown in table 3 are inconclusive. By the end of December the response to nitrogen was apparent. The young plants were robust and appeared to have good rooting systems.

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[42] PAN AMERICAN UNION. MEETING ON INTER-AMERICAN FIBER PROBLEMS. 19 pp. Washington, D. C. June, 17, 1949. [Processed.]

[43] CARREON, P. R., and BIRDSALL, B. J. ABACA GROWING FOR BEGINNERS. 22 pp. [n. d.) (Prepared by Technical Staff, NAFCO in Davao and U. S. Off. Foreign Agr. Relat.) [Mimeographed.]

[44] UNITED FRUIT COMPANY. TELA RAILROAD COMPANY RESEARCH DEPARTMENT REPORT FOR 1949. La Lima, Honduras. [Unpublished manuscript.]

TABLE 3.--Rate of stalk growth of abaca in fertilizer test plots, Cebu Farm, Guaymas District, Honduras

Month	Check (no fertilizer)	Nitrogen only	Nitrogen and potash	Nitrogen and phosphorus
	Feet	*Feet*	*Feet*	*Feet*
September	0.486	0.496	0.495	0.488
October	.298	.326	.306	.302
November	.556	.561	.575	.555
December	.400	.417	.408	.405
Total	1.740	1.800	1.784	1.750
Growth index	100	103.4	102.5	100.6

In a study of the salt and fertilizer requirements of young abaca in the Philippines, Espino and Viado (67) reached the following tentative conclusions:

(1) That both calcium nitrate and ammonium sulfate are beneficial to the growth of the young abaca plant.

(2) That ammonium sulfate is a far better source of nitrogen for this plant than sodium nitrate.

(3) That to promote vigorous vegetative development of the young abaca a moderate application of either potassium sulfate or double superphosphate should be accompanied by a relatively heavy application of ammonium sulfate. The amount of ammonium sulfate should be two or three times as much as the potassium sulfate or the double superphosphate.

Espino and Cruz (63) found that the roots of abaca plants absorbed less readily complete culture solutions containing ammonium sulfate than complete culture solutions without it. They found also that the culture solution most readily absorbed had a medium amount of either monopotassium phosphate or calcium nitrate and a relatively high content of magnesium sulfate. On the basis of their findings, they estimated that the roots of a single abaca plant of the Maguindanao variety would absorb daily about 0.23 kilogram of the culture solution found to be most readily absorbed and that the roots of the whole clump (nine large and three medium-sized plants) would absorb daily about 2.4 kilograms of the solution.

Peyronnet (135) made a study of the growth of abaca (Itom variety) in sand to which various nutrient solutions were applied. At the end of 6 months the plants that received Pfeffer's solution (calcium nitrate, ferric chloride, potassium chloride, primary potassium phosphate, potassium nitrate, and magnesium sulfate) had made good, strong growth, as had also those that received Shive's solution (calcium nitrate, ferrous phosphate, primary potassium phosphate, and magnesium sulfate), and Tottingham's solution (calcium nitrate, ferrous phosphate, primary potassium phosphate, potassium nitrate, and magnesium sulfate). Of the three solutions, Tottingham's gave the best growth.

No calcium.--A group of plants that received a solution containing potassium nitrate, ferrous phosphate, primary potassium phosphate, and magnesium sulfate, but no calcium were stunted and the leaves turned a deep yellow. None of the plants lived more than three months. Peyronnet concluded that while calcium is not an actual element of protoplasm it obviously acts in some way as a protective agent.

No phosphorus.--Plants that received calcium nitrate, ferric chloride, potassium nitrate, and magnesium sulfate but no phosphate were the only group that showed no striking exterior symptoms of physiological trouble during the first six months of growth. Nevertheless, all except one died within six months.

No magnesium.--The plants from which magnesium were withheld were among the first to show symptoms of physiological imbalance. These plants received calcium nitrate, ferrous phosphate, primary potassium phosphate, and potassium sulfate. After three months without magnesium the plants became chlorotic and the leaves began to droop and die.

No potassium.--Plants given calcium nitrate, ferrous phosphate, calcium phosphate (dibasic), and magnesium sulfate but no potassium, were flaccid and weak. At the end of six months all the plants were stunted, but the most marked result of the deficiency of potassium was a lack of rigidity in the central stem and central nerves of the leaves. The plants were soft and weak and the leaves were flabby.

Peyronnet suggests that this lack of rigidity in plants that receive no potassium or too little may be one of the causes of the lack of strength of the fibers, and he remarks, "It should not be forgotten that potash--potassium oxide--constitutes about 40 percent of the mineral matter of the ash of abaca fiber." He might have added that a deficiency of potash normally produces a thin-walled plant cell, and such cells are generally associated with lack of strength.

The Philippine Government carried on fertilizer tests with abaca, though on a limited scale, for many years. In 1927 the results of tests to determine the fertilizers best suited to bring about growth of young abaca plants were reported (138). The plants that received calcium phosphate and potassium sulfate at the rate of 300 kilos each per hectare (267 pounds per acre) showed the greatest increase both in length of stalks and in number of suckers produced. Next were the plants that received calcium phosphate alone, and last were those that received sodium nitrate, calcium phosphate, and potassium sulfate combined, at the rate of 240, 300 and 60 kilos, respectively, of each per hectare (214, 267, and 53 pounds per acre).

In 1928 (139) tests were made on young abaca and on an old plantation of the Itom variety. The results on young abaca were:

78 kilos (69 pounds per acre) of P_2O_5 with 29 kilos (26 pounds per acre) of K_2O per hectare, a yield of 429.33 kilos (382 pounds per acre) of fine fiber per hectare.

12 kilos (11 pounds per acre) of nitrogen with 78 kilos (69 pounds per acre) P_2O_5 and 29 kilos (26 pounds per acre) of K_2O, a yield of 338 kilos (301 pounds per acre) of fine fiber per hectare.

78 kilos of P_2O_5 alone per hectare (69 pounds per acre), a yield of 291.33 kilos (259 pounds per acre) of fine fiber per hectare.

No fertilizer, a yield of 252.49 kilos (225 pounds per acre) of fine fiber per hectare.

Records were taken 8 months after fertilizer was applied to the old plantation. From a plot to which a mixture of 200 kilos (440 pounds) of nitrate of soda, 200 kilos (440 pounds) of calcium phosphate, and 600 kilos (1,320 pounds) of copra cake were applied at the rate of 400 kilos per hectare (356 pounds per acre), a yield of 541.7 kilos (1,191 pounds) of coarse fiber was obtained. The yield from the untreated plots averaged 491.66 kilos of coarse fiber per hectare (438 pounds per acre). When the same mixture at the rate of 578 kilos per hectare (515 pounds per acre) was applied, a yield of 285 kilos (627 pounds, of fine fiber was obtained, as compared with 197 kilos (433 pounds) from the control.

In 1931 the Director of Plant Industry (141) stated that the application of a complete fertilizer at the rate of 19.4 kilos (17 pounds per acre) of nitrogen, 58.9 kilos (52 pounds per acre) of phosphoric acid, and 30 kilos (27 pounds per acre) of potash per hectare gave 1,168.8 kilos per hectare (1,041 lbs. per acre) of fiber as compared with 760 kilos (677 lbs. per acre) from the check plot. In 1932 (142) he reported that the use of fertilizers and the continuous planting and plowing under of cowpeas before flowering resulted in a considerably higher yield of fiber.

In a publication issued by the Philippine Department of Agriculture and Commerce in 1939 (137) it was stated that "by and large, abaca requires from 600 to 800 kilos per hectare (534 to 712 pounds per acre) of a mixture containing 4 percent nitrogen, 8 percent phosphoric acid, and 12 percent potash."

Youngberg (138), describing tests for the control of bunchy top, declared: "The resistance of the partially susceptible varieties ... can be increased by the use of calcium phosphate or potassium sulfate, but those fertilizers containing only nitrogen were not satisfactory, although certain complete fertilizers, containing nitrogen, phosphoric acid and potash (10-6-2) gave favorable results."

The fact that the use of certain fertilizers develops an increased degree of disease resistance in the plant is a factor that should not be overlooked.

DISEASES AND INSECT PESTS

PHILIPPINE ISLANDS

For centuries the Filipinos grew abaca without apparently being much troubled by loss from disease, but in 1937 a survey made by Edwards[45] showed abaca diseases to be the most widely discussed if not the most important factor in the abaca production situation.

"Bunchy top," which had practically eliminated the abaca industry from the provinces of Cavite, Laguna, and Batangas, was discovered about 1935 in the Bicol province of Sorsogon, but the plants infected had been destroyed and no other cases of the disease had been reported. In Mindoro bunchy top was said to be widespread and to be doing serious damage. In surveying the situation in Davao, Edwards found it difficult to separate rumor from fact but from his own

[45] See Footnote No. 25.

observations, he concluded that "unquestionably . . . there are abaca diseases in Davao at the present time [1937], the infection is spreading, and the situation is one that calls for prompt and effective action. The different diseases of abaca that are now found, or are believed to be found, in Davao abaca fields are bunchy top, the 'new disease' [vascular wilt], mosaic, heart rot, stem rot, and root rot."

Bunchy top.--Ocfemia reported in 1930 that bunchy top was the most destructive abaca disease known in the Philippines (127). All varieties of abaca grown in Davao--Maguindanao, Bungulanon, Tangoñgon, and Lauan--were attacked with equal severity (128).

The presence of chlorotic streaks, transparent veins, and parchmentlike areas on the youngest furled leaves is the most reliable symptom of primary infection (fig. 11) (128). The affected plants are stunted, the stem thickens, and the top sends out bunchy growths, more or less in the form of a rosette (fig. 12). The leaves become stiff and brittle, tear along the margins, and curl upward. Sooner or later the blade dries up and turns black. Fiber from diseased plants does not develop normally, and is often weaker than that from healthy plants (188).

A plant once affected with this disease never recovers, and when one member of a stool is attacked, the whole stool perishes. The progress of bunchy top through a planting is slow as compared to that of mosaic and vascular wilt, yet within ten years the bunchy top disease wiped out more than 12,000 hectares (26,400 acres) of abaca in Cavite alone (31).

Bunchy top is a virus disease transmitted by the brown banana aphid (Pentalonia nigronervosa Coq.). This aphid was the only known vector of bunchy top until 1948 when Espino and Ocfemia (68) stated that a second vector of bunchy top, P. caladii Van der Goot, had been reported by Espino in a master's thesis in 1944, but all copies of the thesis and all records of the experiments were burned during the battle for liberation of the Philippines in 1945. These writers state

Figure 11.--Leaves from abaca plant affected with the bunchy top disease. The youngest unfurled leaves (a and b) of bunchy top-infected plants show indefinite, yellowish-white chlorotic areas on the blade, especially along the margin. Parchmentlike areas may also be noted as in b; reduced size of leaves and curling along the margins are characteristic of the disease, as shown in c and d. (Photo courtesy of G. O. Ocfemia.)

Figure 12.--a, Abaca plant affected with bunchy top disease, showing characteristic crawding of leaves into a rosettelike arrangement; b, uninfected, healtby plant. (Photo courtesy of G. O. Ocfemia.)

that abaca is not a preferred host of P. caladii, however, and probably it is unimportant as a vector of bunchy top. The virus that causes the bunchy top disease is not transmitted by P. nigronervosa to its offspring (129), nor is it transmitted through the soil or by mechanical means, and if seedstocks for replanting are obtained from disease-free fields, plantations devastated by the disease can be successfully rehabilitated.

In September 1949 Reinking (148), in a cursory examination of conditions in abaca plantations near Davao City, found no evidence of bunchy top in any of the commercial plantings that he visited, and he states that there have been no reports of its presence there in recent years. Ocfemia,[46] on the other hand, in a more recent discussion of the disease situation in the Philippines, stated: "In my opinion there are, at the present time, only three major diseases of abacá. In the descending order of their destructiveness to abacá they are: bunchy-top, mosaic, and wilt."

The vascular wilt disease.--In 1939 a "new" disease was taking a heavy toll of abaca in Davao. In fact, so serious had this disease become that the Japanese sent men to Borneo to investigate the possibility of starting plantations there.

The cause of abaca wilt in the Philippines, according to Castillo and Celino (37), is Fusarium cubense (F. oxysporum f. cubense). This is the fungus that caused the dreaded "Panama" disease of banana in Central America and necessitated the abandonment of thousands of acres of rich banana lands. In the Philippines, however, this organism attacks only the Latundan variety of banana and abaca (37). The fungus is especially destructive to abaca at high elevations. It spreads rapidly, and since it is a soil-borne organism, it may be spread by rain water, by soil adhering to the feet of men and animals, by dirty or contaminated tools, and by planting corms and suckers taken from infected fields. At high elevations in Davao the wilt is said to infect abaca

[46] OCFEMIA, G. O. Letter to senior author. Feb. 28, 1950.

corms through injuries made by the banana borer (Cosmopolites sordidus Ger.), through old leaf bases where the stem borer (Odoiporus longicollis Ol.) has punctured, and through injured buds and very young suckers (6). The varieties that appear to be most susceptible to the wilt disease are Magindanao, Lauan-Tangoñgon, Balindag, and Bungulanon; the variety Tangoñgon, on the other hand, appears to be resistant and has been used to replace susceptible varieties (133).

The presence of wilt disease is first apparent as a rotting or blackening at the base of the pseudostem (31). The rotting seems to work upward, eventually reaching the leaves. There the dark-brown discoloration follows the veins, often extending from the midrib to the margin. The formation of these linear streaks is followed by a yellowing and wilting of the diseased leaf. An examination of the fibrovascular bundles of the pseudostems and corms of diseased plants shows a discoloration of the vascular strands. If a series of cross sections is cut from the rhizome to the upper part of a badly diseased plant this discoloration of the vascular strands can be traced from the stele of the rhizome into the pseudostem, then into the petioles and midrib and finally into the leaf veins (133).

Plants infected with the wilt disease die quickly. While bunchy top may require a year or two to devastate a field, the wilt disease runs its course in four to six months in infected plants and almost as quickly in a field. Of the three major diseases of abaca, vascular wilt is the most difficult to control because the causal organism lives in the soil, and once the soil is infected it may remain so indefinitely.

The only control measures that have so far proved effective for vascular wilt and bunchy top are roguing and burning of infected plants if the disease has not progressed too far, or destroying all plants not ready for harvesting if the disease is widespread in the plantation.

Mosaic.--In 1937 Edwards[47] stated: "What appears to be a typical mosaic disease has been found in several different localities in Davao. The damage done has not been serious and there is some question as to whether or not this is a true disease, as the affected plants are ordinarily found growing under unfavorable conditions in poorly drained soils." Today this mosaic disease is the most serious menace to the future production of abaca in the Province of Davao (148).

The mosaic disease is more easily detected by the layman than some other abaca diseases, and for this reason it may be easier to control. In the case of bunchy top in Cavite, the disease had a long start before anything was done to eradicate it because it is not easily recognized in its early stages, and it was difficult to convince the farmers that infected plants and fields had to be destroyed.

The characteristic symptom of mosaic of abaca is a mottling of the leaves, which consists of dark-green and pale-green or yellowish areas forming irregular streaks that extend from the midrib to the margin of the leaves (fig. 13). Mottling occurs also on the petioles, pseudostems, flower bracts, and fruit. The abaca mosaic does not cause a bunching of the leaves, but plants affected with this disease do not grow to normal size and the pseudostems produced are slender and of little or no commercial value (39).

Mosaic like bunchy top is a virus disease, and is said to be caused by Cucumis Virus I, or Marmor cucumeris Holmes (39, 130). It is transmitted from diseased to healthy plants through the feeding of aphids or plant lice. Four different aphids are known to be able to transmit abaca mosaic (39, 40, 130). These are Aphis gossypii Glov., the cotton or melon aphid; two species of Rhopalosiphum collected from grasses, namely, R. nymphaeae (L.), the water lily aphid, and R. prunifoliae Fitch, the apple grain aphid; and Aphis maidis, the corn aphid. The last-named may be an especially important vector of the mosaic virus, for experiments have shown that it is able to transmit the mosaic not only from abaca to abaca, but also from abaca to corn and from corn to abaca (40). Moreover, it is widely distributed on numerous host plants, including many grasses.

Pentalonia nigronervosa, the vector of bunchy top, cannot transmit the mosaic disease to healthy abaca (39), but individual plants have been found in Davao that showed the characteristic symptoms of both diseases (fig. 14). It would appear, therefore, that the presence of one of the viruses is no guaranty of immunity from the other (131). As a result of a series of tests with plants infected with both bunchy top and mosaic, Ocfemia and associates (131) concluded that in such plants "either of the viruses may be transmitted independently of the other, depending upon whether Pentalonia nigronervosa or Aphis gossypii is used. Neither of these two aphids will transmit both viruses."

The mosaic, like bunchy top, may be carried over to new plantations by the use of diseased planting stock or planting stock taken from diseased stools, and this, unfortunately, is frequently done. The methods suggested for the control of mosaic are the same as for bunchy top and wilt; that is, destruction of infected plants or of the entire field if many plants are infected. Such measures call for quick and determined action on the part of the Government. A

[47] See Footnote No. 25.

Figure 13.--*A*, Mosaic-infected abaca seedling showing symptoms on the leaves. Pale yellow stripes extend from midrib to margin. (Photo courtesy of G. O. Ocfemia.) *B*, Mature mosaic-infected abaca plant. (Photo courtesy of A. H. Moseman.)

Figure 14.--Abaca seedling showing a mixed infection of mosaic and bunchy top. The plant was first infected with the mosaic virus, then with the bunchy top virus. (Photo courtesy of G. O. Ocfemia.)

great deal of labor will be required to uproot and replant large areas and the costs will be high. Since the disease is spread by the use of diseased planting stock as well as by insect vectors, it may be necessary for the Government to establish nurseries from which certified planting stock can be obtained.

To some extent the planter can protect himself by making sure that no plants are grown in the vicinity of abaca that can serve as hosts for the insect vectors, such, for instance, as cotton, melon, tomato, canna, corn, and weeds. Somewhat tardily the Philippine Government began a campaign in 1949 to control mosaic,[48] bunchy top, and vascular wilt.

[48] ANONYMOUS. THE MOSAIC DISEASE OF ABACÁ AND ITS CONTROL. Philippine Islands. Bur. Plant Indus. Leaflet. 1949. [Processed.]

Under Administrative Order 14, Series 1949,[49] the Government prohibited the transfer of planting stock from provinces declared infected to noninfected provinces, and from one area in an infected province to another area. Under this order the owner of infected plantings is required to destroy all diseased plants, and failure to do so promptly after orders from the Government makes him liable to heavy penalties. This is a step in the right direction, but with the high prices of abaca and the tenuous hold on the land of some of its tenants, many of whom are "squatters," it would not be expected that the Government could easily obtain whole-hearted cooperation from the abaca farmers.

Dry sheath rot of abaca.--A disease which has gained a foothold in neglected abaca fields in the Philippines was reported as present in Cavite in 1936; it has since been found in Davao, Mindoro, and the Bicol Peninsula (147). This disease, known as dry sheath rot of abaca or Marasmius stem and root rot, is caused by a gill-bearing fungus that lives in the soil. The fungus is probably *Marasmius semiustus* Berk. and Curt. (188), the organism that causes stem and root rot of bananas and plantains in many parts of the Tropics. In the Philippines it flourishes in low, poorly drained soil during prolonged periods of warm, moist weather. Such soils are unfavorable for the growth of vigorous abaca plants.

The fungus first attacks the corms (147) but rapidly spreads to the pseudostems. The diseased sections of the leaf sheaths turn brown and take on a water-soaked appearance. The mycelium of the fungus penetrates the outer leaf sheaths, and as it spreads it causes the sheaths to stick together. On and between the dead leaf sheaths are layers of white mycelium (188). The inner leaf sheaths show dark-brown patches of diseased tissue. When temperature and moisture conditions are favorable, mushroom-like fruiting bodies appear on the affected stems (fig. 15). The fungus also attacks the roots, partially destroying the root system. Such plants are easily tipped over. Affected plants fail to make normal growth and usually die early. Those that do reach maturity are not worth stripping.

Since the fungus exists as a saprophyte in the soil, clean culture is recommended; diseased plants should be destroyed, and all planting stock should be obtained from disease-free fields.

Stem rot of abaca.--Another fungus disease of abaca that apparently is serious only when soil and climatic conditions favor the fungus and retard the growth of the plant, is the stem rot caused by *Helminthosporium torulosum* (Syd.) Ashby. Prolonged droughts, which weaken the plants, increase the virulence of the disease (136). At such times the disease may spread rapidly and become very destructive. In areas like the Bicol Peninsula and Mindanao, where climatic conditions are conducive to the best growth of abaca, the stem rot does not become severe (136), but in the highlands of Cavite, where long droughts are of almost yearly occurrence, losses are often heavy (1). Infection begins in December and spreads rapidly. A few months later when the rains begin, the disease decreases and plants only slightly infected put out new suckers, and the plantation remains healthy and green until the dry season returns and infection builds up again.

The fungus that causes stem rot of abaca (*Helminthosporium torulosum*) is the same as that which causes the black tip disease of Cavendish or Dwarf banana in Bermuda and leaf and fruit spots on banana in various parts of the world (188). Infection is first apparent as tiny brown lesions on the outer leaf sheaths. These grow larger, coalesce, and form large spots. Eventually these dark-brown or black sunken areas are overlain with a grayish growth of mycelium (148). The disease progresses inward, attacking each leaf sheath in turn. In the final stages of the disease the weakened plants fall over and the affected sheaths dry up. Of 12 varieties tested, the Sinibuyas and Kinalabao were found to be the least susceptible (32). To control the disease constant roguing of diseased plants should be practiced, shade should be provided where necessary to keep the soil from baking, and only the least susceptible varieties should be planted (1).

Heart rot.--The characteristic symptom of this disease is a rotting of the young unfurled leaves in the center of the plant. The rotting usually begins at the tip of the youngest furled leaf and progresses downward. It may continue until the whole central cylinder is decayed, in which case the plant dies.

Ramos (146) regards heart rot as a secondary infection that occurs in plants already weakened by disease or by insect or other injury. In field observations he found that about 10 to 22 percent of the plants suffering from the bunchy top disease eventually died of heart rot and from 53 to 90 percent of those injured by the banana borer (*Cosmopolites sordidus* Ger.) were infected with heart rot. Bacteria are sometimes abundant in the soft decaying tissues of heart-rotted plants. A fungus commonly found associated with the disease was identified by Ocfemia and Mendiola (132) as *Fusarium moniliforme* Sheldon var. *subglutinans* Wr. and Reink.

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[49] PHILIPPINES (REPUBLIC) BUREAU OF PLANT INDUSTRY. AN ORDER CONTAINING REGULATIONS GOVERNING INTER-PROVINCIAL QUARANTINE ON ALL PLANTS OF THE SPECIES OF THE GENUS MUSA . . . Plant Indus. Admin. Order 14, ser. 1949, 3 pp. Manila. 1949. [Mimeographed.]

Figure 15.--Marasmius semiustus, the organism that causes dry sheath rot of abaca. (From Wardlaw: "Diseases of the Banana and of the Manila Hemp Plant." Courtesy Macmillan & Co., Ltd.)

Insect pests of abaca. --Certain insects at times have proved damaging to abaca plants. The common banana borer (Cosmopolites sordidus) is widely distributed throughout the abaca provinces and does considerable damage. At high altitudes in Davao the stem weevil (Odoiporus longicollis) is also a destructive pest. Much damage has sometimes been done by "pagui pagui," a slug caterpillar (Thosea sinensis Wlk.). In 1931 an area in Davao that included more than 2 1/2 million hills was infested.[50] The larva of this insect feeds on the leaves of the plant, and so voracious is its appetite that three larvae, from hatching to adult, are said to be able to finish a leaf a meter long.[51] There are three to four generations of Thosea a year, but under field conditions only 50 percent of the pupae develop into adults.[52] The larva of this insect is relished by crows, domestic fowls, and monkeys, and it is parasitized by several insects. Since Thosea damages abaca only in the larval stage, it can be controlled by picking off the caterpillars, by spraying with insecticides, and by liberating parasites in the field.

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[50] ROXAS, M. L. Memorandum. Mar. 21, 1932. [Unpublished.]

[51] See Footnote No. 43.

[52] See Footnote No. 43.

CENTRAL AMERICA

Abaca plantings in Central America have never reached the high production figures so confidently predicted by some at the time of planting, 1942-43. The urgent war-time need for fiber caused the young plants to be overharvested, and before this situation could be remedied, disease and insect infestation multiplied to such an extent as to become a serious factor in cutting production. In 1948 production of long fiber was approximately 40, 280, 000 pounds; in 1949 it was approximately 29, 710, 000 pounds, a decrease of 10, 570, 000 pounds. The highest annual per acre yield for all of Central America, based on 26, 600 acres, was 1, 510 pounds obtained in 1948; in 1949 it was 1, 110 pounds. This obviously serious situation was the subject of much discussion. It was a factor that led to the establishment in 1950 of an abaca research project with the assignment of specialists of the United States Department of Agriculture to study these problems in Central America with headquarters and in cooperation with the Inter-American Institute of Agricultural Sciences, Turrialba, Costa Rica.

The expected high production was probably based on optimum cultural and climatic conditions and a minimum of disease hazards. The best cultural practices were difficult to insure in the war-time haste with which this crop was planted. In 1951 from knowledge gained from experience and study, together with the benefit of time which permitted more attention to the problem, approximately 10 to 15 percent of the original acreage had been abandoned because of uneconomical problems connected with correcting high water table, flood perils, taltuza infestation, etc. With these measures, the improvement in the farm management practices, a possible cyclic decrease in the damage of the borer, a better understanding of the value of sanitary harvesting for reducing the severity of dry sheath rot, etc., the possibilities appeared materially better for maintaining or improving past production.

"Tip Over". --In 1949 the heaviest losses in all of the Central American plantings came from "tip over." The losses were not as great in 1950 and 1951. The term "tip over" is applied to plants that fall over in the field before any external symptoms of disease are visible. Tip over plants are sometimes toppled by a slight breeze blowing through the field (fig. 16). Instances are recounted where the plants have been blown down by the breeze from a passing tramcar. Few, if any, tip over plants have healthy root systems. In many such plants the original root system disappears and their only means of support comes from new roots developed above the diseased areas near the ground level. Every 2 months or oftener, crews go through the field to salvage by gathering up the fallen plants. These are decorticated if they are sufficiently sound but some fiber is lost and the problems of farm management are increased. In Costa Rica the senior author was told that possibly 40 percent of the stalks then [May 1949] being delivered to the mill for processing were from tip over plants. An estimate from another official for the Central American projects was 60 percent; for poor areas in Panama the estimate was 25 percent. While these figures are no more than estimates, they do indicate how serious the tip over situation may be.

The plantations in Costa Rica were said to have made phenomenal growth during the first 3 years after planting. During the early harvesting periods it was not uncommon to cut stalks 18 feet long; now the best are 11 to 12 feet and usually from 5 to 6.[53] Wellman quotes a man connected with the abaca project to illustrate the tip over problem, as saying, "We have a potential of 500-tons cut daily from this plantation, and right now [1949] we are only harvesting 185."

Various theories to account for the tip over trouble have been advanced, but the separation of the responsible factors as pathological, entomological, the result of soil depletion, or of poor cultural practices has never been clearly made. The banana borer (Cosmopolites sordidus) is believed by some to be the agent principally responsible, yet many blown-over plants show no sign of weevil infestation or tip over related to nearby insect-infected plants going down. Wellman[53] noted that the attack of insects on the corm and roots was not the only injury to the underground parts of tip over plants. The roots themselves appeared to be decayed at the tips, and the decay became progressively worse toward the corms. The decay often resulted in a sort of clublike enlargement of the roots where the disease had apparently been checked. But in instances where checking had occurred the roots were killed to within 20 cm. or less of the corm. In some cases roots were apparently killed back so rapidly that no clubs formed and the whole root structure showed decay.

Microscopic examination of tissue from diseased roots revealed the presence of what seemed to be secondary fungi, as well as considerable bacterial decay that also looked as though it were secondary. Fungal threads were found growing in the water-conducting vessels of discolored root tissue. Within 24 hours after isolations were made what seemed to be a species of Rhizopus appeared, and a few days later a single type of Fusarium was observed. The Fusarium

[53] WELLMAN, F. L. NOTES ON "TIP OVER" OF ABACA IN COSTA RICA. 7 pp. Apr. 21, 1949. [Unpublished report.]

Figure 16.--"Tip over" in an abaca plantation in Central America. The plants suffering from a deteriorated root system have little support and fall down before normal harvest age.

seemed to be a fairly constant organism in the discolored but less decayed tissues of the roots. The significance of these findings may be questioned, however, for fungi and bacteria are likely to be found in decaying root tissue, whatever the cause of decay.

The banana borer has long been recognized as a pest in most of the banana-growing areas of the world, and it is known to be present in all of the five Central American abaca projects. Because of the importance of the borer as a pest of bananas, its life history and habits have been carefully studied and are well understood (41, 61, 75, 122).

Until 1947 abaca plantings in Central America seemed to be fairly free of insect injury, but when a survey of the situation was made by Hambleton [54] in 1948, he reported that field examinations of abaca plantings in the Changuinola area of Panama and near La Lima, Honduras, dispel any doubts as to the importance of the banana borer as a pest of abaca. He believes that the tip over of stalks in older plantings gives every indication of being directly attributable to borer injury, and he stated that judging from the actual situation in the field, the nature of the crop, and the favorable conditions for borer propagation, there is reason to believe that unless effective measures are found to control it, the borer can become a menace to the entire abaca industry in Central America.

The borer is a snout weevil (fig. 17), about half an inch in length, brown to black in color, and nocturnal in habit. Its attack often begins in the decaying butts of stalks left in the ground after the stalks are harvested. The eggs may be laid in the corms of unharvested stalks near the surface of the ground, in the sheaths near the crown of the corm, or on old leaf bases left to rot in the field. Within 5 to 7 days (61, 75) the larva hatches (fig. 18). It then bores into the corm, feeding voraciously as it goes. The whole of the larval period, which lasts from 15 to 21 days (61, 75), is spent within the tissues of the plant, and it is in this stage that the insect is most

[54] HAMBLETON, E. J. THE BANANA ROOT BORER PROBLEM OF ABACA IN CENTRAL AMERICA. 5 pp. 1948. [Processed.]

Figure 17.--Banana borer (Cosmopolites sordidus Ger.), adult stage. A, Dorsal view; B, ventral view. X 7-1/2. (Courtesy of C. F. W. Muesebeck.)

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Figure 18.--Larval stage of banana borer. X 7-1/2. (Courtesy of C. F. W. Muesebeck.)

destructive. The corms of the plants attacked by the borer frequently show tunnels made by the larvae near the ground level, and the fibrous roots are often severed by the continued feeding of the grubs. When this occurs the outer part of the corm becomes necrotic and ceases to function, and since abaca has no central tap-root (see fig. 8), the plant may then tip over.

Adult beetles are often found feeding in groups in corms, in rotting stems near the surface of the ground, and in the soil around the roots. The borer is hardy and long-lived, but it is a sluggish insect and not especially prolific. Infestations build up rather gradually. The borer seems to have no other host plants than banana (75) and abaca. The inertia of the insect, its sedentary habit, and its preference for the single host Musa would make the problem of control fairly easy except for the fact that all stages of the life cycle of the insect except the adult are passed in the tissues of the plant.

In Jamaica, where the borer has long been a pest of banana, control measures have centered largely on field sanitation. These have included the destruction of all plant refuse that might serve as a breeding ground for the borer, removal of stumps left after plants are cut, and a rapid clean-up of fallen stalks after hurricanes or high winds.

In Central America some preliminary insecticidal tests have been made in which DDT and chlordane preparations were sprayed about the bases of the plants, but these measures did not prove effective. As in Jamaica, various methods of clean culture are being tried. Where the growth of the plants is so rank as to form a dense shade around the base of the plants, cleaning of the mats and a light prune harvest are being practiced. Recently in the Panama project the destruction of all stumps or rhizomes left after harvest has been included as part of the harvesting program, and the results have been encouraging.[55] In this connection it may be mentioned that borer injury has not been as severe a problem in the 6-year-old Honduran research plots in which clean cultivation has always been practiced.[56]

Another weevil often found associated with the banana borer, and frequently mistaken for it, is Metamasius sericeus (Oliv.). Metamasius is a pest of sugar cane, but when the banana borer has tunneled into the corm of abaca, the larvae of Metamasius may often be found feeding on the disintegrating tissue. In size and shape the larvae of the two species are much alike, but the yellow markings on the wing covers of the adult Metamasius serve to distinguish it from the banana borer, whose wing covers are uniformly black.

While surveying the Panama plantation, Wellman[57] noted a stunted condition of certain plants, to which the growers applied the term "stand stop." The disease was characterized by

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[55] UNITED FRUIT COMPANY. GUATEMALA DIVISION. COSTA RICA ABACA CONFERENCE, SEPTEMBER 1949. [Unpublished manuscript.]

[56] UNITED FRUIT COMPANY. TELA RAILROAD COMPANY RESEARCH DEPARTMENT ANNUAL REPORT 1948. La Lima, Honduras. [Unpublished.]

[57] WELLMAN, F. L. NOTES ON TIP OVER OF ABACA IN PANAMA. 6 pp. Turrialba, Costa Rica. May 11, 1949. [Unpublished.]

death of the upper part of the outer leaf sheaths and compression of the crown; or, as the growers said, the plants are not "well crowned out." Many of the leaves on such plants were dead and those that were still green were smaller than the leaves of normal plants and the color was poorer. These "stand stop" plants occurred in mats closely surrounded by other abaca. The pseudostems of the diseased plants were abnormally slender and the roots were so completely decayed that the plants could easily be lifted from the mats; only the corms remained to support the plants. An examination of the corms showed no insects present. Wellman offered the suggestion that possibly the "stand stop" condition is "an advanced stage of certain still standing tip-over plants."

In view of the importance of the tip over disease and the divergence of opinion as to its cause, it would seem that a thorough study should be made of the whole situation. The following lines of investigation might yield profitable results.

1. A survey to determine the extent of the borer infestation in each of the Central American plantations in order that efforts for its control may be concentrated where the need is greatest and the increase or decrease in infestation in future years may be correctly judged.

2. Research into methods of biological control. The borer is known to have natural enemies in other parts of the world. In Java it is preyed upon by the larvae of a histerid beetle (*Plaesius javanus* Er.) and in the Federated Malay States by a hydrophilid (*Dactylosternum hydrophiloides* McLeay) (189). There is also a fly (*Chrysopilus ferruginosus* (Wied.)), whose maggots feed upon the larvae of the borer (189). *P. javanus* has been successfully established in Jamaica and it has been introduced into Central America, but whether or to what extent it survives there is not known since no counts have been made.

3. Tests to determine the effectiveness of some of the newer insecticides in reducing the borer population. These might include parathion, benzene hexachloride, toxaphene (chlorinated camphene), and insecticides that are not yet in commercial production but that showed considerable promise in tests conducted against a variety of fruit insects by the United States Department of Agriculture in 1949. Among these are an experimental insecticide bearing the code designation EPN;[58] two insecticides designated by Code Nos. CS 645A and CS 674A;[59] and two compounds called aldrin and dieldrin,[60] products related to chlordane. These sprays would be used primarily against the adult beetles after emergence.

Soil fumigants that have been used successfully against the soil-infesting stage of some insects are dichloroethyl ether alone or with DDT incorporated in it, and ethylene dibromide emulsion, but with ethylene dibromide there is a narrow margin of safety between the amount needed to control the insect and the amount that will injure the plant.

Several of the insecticides mentioned above as sprays can also be used as soil fumigants.

4. A study of the relation of fungi and bacteria to the root rot disease.

5. Importation of different varieties of abaca from the Orient for testing under Central American conditions, and an expansion of the breeding program now under way. Of the more than 100 varieties of abaca known in the Philippines, only 6 are grown commercially in Central America.

6. A study of the influence on incidence of the disease exerted by certain environmental factors, such as temperature and humidity, aeration, density of shade, number of stalks per mat, soil moisture and fertility.

Leaf spot. --While the heaviest losses in the Costa Rican plantings are undoubtedly due to tip over, Wellman[61] believes that the leaf spot is a contributing cause. The plantations in Costa Rica consist of practically solid stands of the Bungulanon variety. Large spots appear on the leaves, usually along the margins, and these are so uniformly present that the ragged, diseased appearance of the leaves is considered a normal condition.[62] Wellman counted from 20 to 37 large spots on most of the leaves examined in the field, and in many cases the disease covered more than one-third of the leaf blade.

Leaf spots examined in the laboratory were found to contain spores of *Cordana musae* and *Helminthosporium torulosum*, but no infection studies were made.

Wellman visited a planting of 6 varieties in Costa Rica. The plots were small, each consisting of about 5 by 5 mats, and all were surrounded by Bungulanon plants affected by the leaf spot disease. Counts taken gave the following results:

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[58] E. I. Dupont de Nemours & Company, Wilmington 68, Delaware.

[59] Commercial Solvents Corporation, 260 Madison Avenue, New York 16, N. Y.

[60] Julius Hyman Company, Denver, Colorado.

[61] See Footnote No. 53.

[62] See Footnote No. 53.

Variety	Number of plants per mat	Number of spots	Amount of dead hanging leaves
Sinaba	9	12	Medium amount
Puteean	22	4	Small amount
Libuton	25	4	Fair amount
Tangoñgon	7	8	Medium amount
Maguindanao	18	1	None
Bungulanon	15	85 to 240	Large amount

These data, while limited in scope, emphasize the susceptibility to leaf spot of the predominant variety in Costa Rica, and they show--for these plots, at least--that the leaf spot cannot be attributed to crowding of the plants.

In Honduras the leaf spot is said to be present to some extent on all varieties, but, as in Costa Rica, it is particularly destructive on the Bungulanon.[63] Though susceptibility varies in different locations, the Sinaba and Puteean varieties are generally susceptible and the Libuton, Tangoñgon, and Maguindanao more resistant.[64]

The extent of disease in the Honduras experimental plots other than tip over and leaf spot for the years 1945-48 is shown in table 4.

Panama disease.--The Panama disease caused by Fusarium oxysporum cubense, which wiped out the banana industry in many areas of Central America, has never proved to be a serious pest of abaca in the Western Hemisphere. However, it does occur sporadically (table 4). The symptoms produced by the fungus on banana and abaca are the same, but it attacks the abaca plants at a much earlier age, and it was reported as attacking only young plants.[65] These plants may succumb to the disease, but the mat as a whole will outgrow it. This disease in 1949 was reported to have shown no tendency to become more serious as the plantations grow older.[66] However by 1951-52 the characteristic symptoms were so prevalent in the old plants at Guaymas, Honduras, that it is questionable that the disease is limited to the young plants or a more virulent strain for abaca may have arisen.

Bud and heart rot.--This rot is rather frequent in occurrence (table 4), and, like the Panama disease, it usually attacks young plants. Since there is almost always a superabundance of suckers in the mat, however, the disease is not considered important.[67]

Sheath and stalk rot.--The sheath and stalk rot diseases are found in all abaca-producing countries, and while they have usually been considered of minor importance, in Central American plantations they have sometimes caused serious damage to the Bungulanon and Maguindanao varieties (table 4).

The dry sheath rot caused by Marasmius semiustus probably is much more destructive than has been recognized. It creates the need for removing by peeling and then discarding many of the outer leaf sheaths of the abaca stalks before they are passed through the fiber extracting machinery. Greater emphasis placed on more sanitary (removal of diseased stalks) harvesting practices should be followed to reduce the severity of the infection and losses from this disease.

Stalk rot attacks the outer sheaths and eats its way into the stalk, usually in several places, discoloring the fiber brown. If the disease progresses far enough, it may cause a collar rot, particularly on Maguindanao, that kills the plant. Stalk rot is usually less prevalent in stands where conditions favor the development of strong plants.

In 1949 rainfall was so scant in the Guaymas district of Honduras that even the abaca grown under irrigation suffered, and many almost mature plants "doubled" before maturity. Under these conditions stalk rot became severe. Laboratory and field studies showed that this trouble was associated with decay of the roots and discoloration of the rhizomes. The pathogen was found to be Micrococcus varians, a bacterium. The same organism was found in rhizomes from Costa Rica and Panama which showed the same symptoms. The United Fruit Company Report [69] states that the spread of the disease is believed to be closely associated with the banana borer or with poor growing conditions, and its control will depend upon the control of the insect or improved cultural practices.

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[63] UNITED FRUIT COMPANY. TELA RAILROAD COMPANY RESEARCH DEPARTMENT ANNUAL REPORT 1946. La Lima, Honduras. [Processed.]

[64] See Footnote No. 63.

[65] See Footnote No. 36.

[66] See Footnote No. 44.

[67] See Footnote No. 56.

[68] See Footnote No. 56.

[69] See Footnote No. 44.

TABLE 4.--Percentage of plants affected with stalk rot, bud and heart rot, and "Panama" disease in abaca experimental plantings, Honduras, 1945-48[68]

Variety	Number of plants*				Percentage of plants affected with-											
					Stalk rot				Bud and heart rot				Panama disease			
	1945	1946	1947	1948	1945	1946	1947	1948	1945	1946	1947	1948	1945	1946	1947	1948
Libuton.........	86	213	65	80	--	--	3.2	--	--	4.6	10.4	3.8	--	--	--	--
Sinaba..........	83	213	49	60	8.0	--	6.8	--	4.8	15.2	4.9	21.7	--	--	8.3	13.3
Tangoñgon........	119	641	69	85	4.0	--	4.8	9.4	.8	21.7	15.8	28.2	--	--	--	1.2
Puteean.........	93	221	60	74	12.0	--	4.2	9.5	--	14.1	9.0	23.0	--	--	.6	--
Bungulanon.......	104	900	297	305	25.0	0.6	20.0	1.6	1.0	5.8	10.0	14.1	1.9	5.5	3.3	3.3
Maguindanao......	80	305	52	66	1.0	--	7.5	10.6	8.7	9.6	6.0	19.7	--	--	--	4.5

[68] See Footnote No. 56.
* Data on all plants in 1945 and 1946, but only on harvested plants in 1947-48.

Taltusa.--In addition to insects and fungi, the industry has to contend with an animal pest, known locally as "Taltusa." "Taltusa" is a colloquial term that covers two or more genera of pocket gophers that are about twice the size of those found in the United States. According to the United States Fish and Wildlife Service,[70] species of the following genera occur in Central America: Macrogeomys, in Costa Rica; Heterogeomys, from central Guatemala to Puebla, Mexico; and Orthogeomys, from the west coast of Guatemala into the west coast of Mexico. To date few studies have been made of this pest, and there are no satisfactory measures for its control. The Fish and Wildlife Service suggests that the methods used for the control of the gopher Thomomys that occurs in the United States might be tried, but there is no assurance that they will succeed. The gophers feed on the roots of bananas as well as abaca, thus weakening the plants, which may "tip over."

The final tip over of the plant from taltusa damage or other biological causes is the symptom that is so visually evident. Taltusas, borers, root rots, etc., probably account for rather serious losses in production by dwarfing the growth of plants even though their attack is not serious enough to reach the final tip over stage. Taltusa damage has been more widespread in abaca in Costa Rica than on other Central American abaca plantations. The severity of its damage has been controlled undoubtedly to some extent by floods that have inundated the land and drowned the animals in their underground tunnels. In Costa Rica a small acreage has been abandoned from one plantation due to taltusa infection. Besides this abandonment a larger acreage of the plantation has suffered materially.

VARIETIES

There are many different varieties of abaca in the Philippine Islands, but as yet no comprehensive investigation of this subject has been made and the actual number is not known. Apparently there are also a number of different types of each variety, for at least 12 types of the variety Tangoñgon have been reported in Davao Province alone. Another source of difficulty in connection with the study of abaca varieties is the fact that any one variety may exhibit different characteristics when grown in different localities and under different conditions of soil and climate.

With respect to the nomenclature of the abaca varieties, the greatest confusion exists. In different districts of any one province, the same variety may be known by different names, or the same name may be applied to several varieties. In the widely separated abaca districts of different provinces and islands, this confusion in nomenclature is even more in evidence. The accompanying list, compiled from various published reports, includes the names of more than 130 varieties. Which of these names represent valid varieties and which are different designations for the same variety, it would be impossible to say. It is known, however, that only 8 varieties were extensively grown in Davao in prewar years, and in the southwestern part of that province commercial production was carried on practically with 2 varieties, Maguidanao and Bungulanon (2). In Cavite only the varieties Sinibuyas and Kinalabao were generally grown (151).

[70] Information by telephone.

Varieties of Abaca Grown in the Philippine Islands

Abacang bayan
Abaco Turncan (or Mosqueado)
Agenoy
Agogaron (or Agoraron)
Agutay
Alman
Alman ñga itom
Amokid
Apid
Arupan
Babalonon
Bagacayon (Bagacayan)
Baguisanon
Baguisanon-Basag (Basog)
Baguisanon-Lawaan
Balunan
Balunganon
Balunis
Balunum
Bangulanon
Banguisan
Bato
Binobui
Bisaya
Bolonganon
Bulao
Bungulanon (Bungalanon; Bongulanon)
Buntot Kabayo
Calapan
Canorahan (Canaraon)
Canorajah
Carnajon
Gamatagos
Hagenoy
Hagpas
"Hagpas" Pula
"Hagpas"-Puti
Halayhay
Halugan
Ihalas
Ilayas
Imosa (Inosa)
Inisarog
Inte
Inusa
Itehin Balud (Balod; Itehin-balud)
Itom
Itom Sport
Jolo
Jolo-lambutin
Jolo-tigasin
Kalaao
Kalado
Kawayanon
Kilala
Kinalabao (Kinalabaw)
Kinosol
Lagnis
Lagorjoan
Laguis (Laguise)
Laguna
Lagurhuan
Lagurhuan-Burawen (Buranen)
Lagurhuan Dogami (Dagami)
Lakig
Lausigon (Lansigon)
Lawa-an (Lauaan)
Layahon (Layajon)
Lawisid (Lewisid)
Liahan (Liahon)
Lianwaan (Linawaan)
Libotong
Libutanay (Lebutanay)
Libuton
Lono
Luno
Maguindanao
Makiling
Marinduque
Minalabao
Mininonga
Moro
Moro blanco
Moro colorado
Moro negro
Mosqueado
Pagoonayan (Pacoonayan)
Palayog
Panaon
Pinamalayan
Pinoonan
Polahan
Pongay
Ponokan
Poti-an
Pula
Pulahan (Pulajan)
Punucan (Punacan; Punukan)
Puspos
Puti
Putian (Puteean)
Putianin
Puti-tumatagacan (tomatogacan; tomatagakan)
Quidit
Saba
Sabaon
Salumpikit
Samarong itom
Samarong puti
Samina
Samoro-Puti
Samorong Mapula
Sawayo
Sinaba
Sinaguilala
Sinamora pula (Sinomoro Pula)
Sinamoro (Sinamore)
Sinamoro-puti (Sinomore Puti)
Sinantacruz (Santa Cruz)
Sinapi
Sinibuyas (Siniboyas)

Sugmod
Sumok
Tagacan blanco
Tagacan colorado
Tangkoñgon
Tangoñgon
Tinbalus
Tuigon
Tumatagacan blanco
Tumatagacan colorado
Verdosa
Visaya

Among the more important characteristics which serve to distinguish one variety of abaca from another are: Size, shape, and color of the stalk; size, shape, and texture of the leaves, and the manner in which the leaves hang on the stalk; color and shape of the flower bud; stooling habit of the plant; rapidity of development and length of life of the plant; degree of drought and wind resistance, and degree of adaptability to various soil conditions; resistance to disease; quantity and quality of the fiber, and relative ease or difficulty with which it is stripped.

There is no one variety of abaca that possesses all the good qualities of the other varieties. In order to select for planting from available plant material a variety that is exceptionally hardy, one that will produce a heavy yield of fiber, or one that will produce exceptionally fine fiber, some sacrifice of qualities in other characters is necessary.

A description of the varieties of abaca cultivated in any one province of the Philippine Islands is not an entirely accurate description of the varieties of any other province. There are, however, a limited number of fairly distinct types. These include the large, hardy varieties, of which Tangoñgon is a representative; those that are somewhat smaller in size and more exacting with respect to climatic and soil requirements, such as Bungulanon; and the large group of undesirable varieties, represented by the Baguisanon.

The province of Davao, in southern Mindanao, is the one abaca-producing province in the Philippine Islands where there has been a fairly thorough investigation of the varieties of abaca. The former plantation owners in Davao were familiar with the good and bad qualities of the different varieties found in that province, and used great care in selecting propagating stock of the superior varieties. Even in Davao, however, there was some confusion regarding the nomenclature of abaca varieties, and there was a marked difference of opinion among the planters in respect to the relative value of the different varieties.

The following 14 varieties of Davao abaca have been described by Edwards and Saleeby (60): (1) Tangoñgon, (2) Maguindanao, (3) Bungulanon, (4) Libuton, (5) Panucan, (6) Arupan, (7) Puteean, (8) Sinaba, (9) Agutay, (10) Baguisanon Lawaan, (11) Baguisanon, (12) Pulajan, (13) Puspos, and (14) Kawayanon. Of these the first 8 only are said to be desirable. Actually only 3 varieties - Tangoñgon, Bungulanon, and Maguindanao - were being planted in Davao in 1950 on a large scale. The Libuton and the Lauan-Tangoñgon are also planted to some extent.

Tangoñgon.--This variety is an excellent representative of the large, hardy, vigorous varieties of abaca found in nearly all the Philippine provinces. It is the most popular variety in use in the replanting program.[71] Tangoñgon stalks measuring from 15 to 18 feet in height, and weighing from 175 to 200 pounds are not unusual. This is a beautiful plant, as the large stalks, which are ordinarily dark in color, ranging from a deep purple to black, have a characteristic glossy aspect. The Tangoñgon has a relatively large leaf, and the leaves have a tendency to grow straight upward, in contrast to the drooping leaves of certain other varieties.

With respect to soil requirements, Tangoñgon is the least exacting of the valuable Davao varieties. It has given satisfactory results on a wide range of well-drained soils of average fertility, but makes the best growth on a clay soil. Of the 3 varieties which are most commonly grown in Davao, the Tangoñgon is the most resistant to drought and disease. On the other hand, it has some undesirable qualities. It does not stool as well as the other varieties; the number of suckers is relatively few and the hills have a tendency to "run out." Its development after planting is slower than that of Maguindanao, but more rapid than Bungulanon. In the Philippines the rootstocks of Tangoñgon often push above the surface of the soil, the hold of the plant on the soil is weakened, and the large heavy stalks are frequently blown down even during wind storms of moderate severity.

The yield of fiber is heavy, ranging from 2.5 to 2.75 pounds of dry fiber to each 100 pounds of stalk (60). Tangoñgon is one of the most difficult varieties to strip, however, and is avoided by many of the strippers. Tangoñgon fiber is coarse and strong and not as white as the fiber of other varieties. Its coarseness and lack of luster are due in part to imperfect stripping.

Bungulanon.--Bungulanon and Maguindanao are the 2 varieties in large-scale commercial production in Central America. Bungulanon has a number of good qualities. In the Lais-Malita, P.I., district, in which the greater part of the abaca plants brought to Panama were obtained, Bungulanon is the most popular variety of abaca. The stalk is medium size, considerably smaller than that of Tangoñgon. In color it is a dark greenish black, without the glossy appearance of

[71] See Footnote No. 43.

the Tangoñgon stalk. The typical Bungulanon leaf is somewhat narrower than the leaves of the other varieties, but the most marked characteristic of the Bungulanon is its free stooling habit. It produces a larger number of suckers than any of the leading varieties, ordinarily about 30 stalks to the hill and occasionally from 50 to 60. It comes into bearing somewhat earlier than the Maguindanao, but does not continue to produce suckers for as long a period. After the fifth or sixth year the yield begins to decline because of the heavy stooling. It strips about as easily as Maguindanao, and because of the smaller stalks it is more easily handled. The yield of fiber is heavier than that of Maguindanao, but the fiber is not as white. In Central America it has been more susceptible than other varieties to leaf spot disease.

Bungulanon is an excellent variety for cultivation in localities where the soil conditions are favorable, but without favorable soil conditions it is a pronounced failure. It requires a moist, friable, well-drained alluvial loam, and cannot be grown either on a stiff clay or on a dry sandy soil. It is not a drought-resistant variety, but it has a better hold on the soil than either Tangoñgon or Maguindanao. Bungulanon has the reputation of being rather "dirty" in the field because of the large number of dead leaves that are ordinarily found on its numerous stalks.

The fiber yield of Bungulanon is good, approaching that of Tangoñgon, but it is more easily stripped than Tangoñgon. The fiber is not as long as that of some of the other varieties, and it lacks the luster of Maguindanao. It is, however, a strong white fiber of excellent quality.

Maguindanao. --Maguindanao has long been regarded as one of the best of the Davao varieties of abaca. It is one of the large varieties, closely approaching in size the Tangoñgon. There are two fairly distinct types of Maguindanao with respect to the color of the stalk. One of these has the dark purplish-black coloring of the Tangoñgon, and the other a stalk that is dark green in color.

The development of Maguindanao is rather more rapid than that of some of the other varieties, and under favorable conditions the first stalks can be cut in 15 to 18 months after planting. In stooling it is midway between Bungulanon and Tangoñgon, producing from 15 to 20 stalks to the hill. A characteristic quality of the Maguindanao is the peculiar umbrella-like arching of the leaves. In a typical plant this is very noticeable. Maguindanao is a relatively hardy variety, though not as hardy as Tangoñgon. It has a somewhat wider range of soil adaptability than Bungulanon, but it does not do well in heavy clay soils. Though it is somewhat more resistant to drought than Bungulanon, it is by no means a drought-resistant variety. With its heavy expanse of leaves and rather shallow root system, the plant is easily blown over by strong winds.

Maguindanao fiber, which is of superior quality, is strong, white, soft, and has a pronounced luster. It is easily stripped by hand, and for this reason is a favorite with abaca strippers. The yield of fiber--about 1.75 pounds to every 100 pounds of stalk (60)--is somewhat less than that of Tangoñgon and Bungulanon.

Libuton. --This variety is not generally popular with the abaca planters, and has not been planted in any large areas. The reason for this is probably its rather low yield of fiber. Libuton is one of the hardy varieties of abacá. It produces a large stalk, though ordinarily not as large as Tangoñgon. Dark shades of green and brown predominate in the coloring of the Libuton stalk. A peculiarity of Libuton is the color of its flower cone, which is lighter and greener than the flower cones of the other varieties. Another of its peculiarities is the tendency of the stalks to bulge at the base. The margins of the leaves of the Libuton, after the leaves have dried on the plant, have a saw-toothed appearance. In normal Libuton plants this is a typical feature.

With the exception of Bungulanon, Libuton produces more suckers than any of the other good varieties, usually from 20 to 25 stalks to the hill. Although somewhat less hardy than Tangoñgon in the matter of its soil requirements, Libuton surpasses the other varieties both as a drought-resistant plant and in its hold on the soil. Libuton plants are rarely blown over by the wind. The development of the Libuton plant is similar to that of the Tangoñgon, being somewhat slower than Maguindanao and more rapid than Bungulanon. Its fiber is nearly as white, but it does not have the luster of Maguindanao fiber. The yield of fiber is rather less than that of Bungulanon and Maguindanao and much less than that of Tangoñgon. Libuton is more easily stripped than Tangoñgon, and is not materially different in this respect from Bungulanon and Maguindanao.

Sinaba. --This variety, although not generally regarded as one of the superior varieties of abaca, is cultivated to some extent in the Islands. It has characteristics both of the Maguindanao and the Libuton and may be a hybrid of these varieties. The stalk is of medium size and has a pronounced greenish color. Sinaba produces a large number of suckers, though ordinarily not as many as Bungulanon.

Sinaba is easily stripped, and for this reason is popular with the strippers. The fiber is very white, light, and fine, but is not as strong as that of some of the other well-known varieties, and the yield is rather low.

Puteean.--The term "Puteean" is somewhat indiscriminately applied to inferior varieties of abaca. For this reason Puteean abaca has a bad reputation that may not be altogether deserved. The real Puteean may easily be mistaken for Maguindanao. In size and color of stalk it is similar to Maguindanao, but the Puteean stalk is less tapering and the leaves are less arched than those of Maguindanao. This is a medium-sized to large variety. It is not generally regarded as hardy. It produces relatively few suckers, about the same number as Tangoñgon. The fiber is very white, fine, and light but difficult to strip.

The ideal variety of abaca would combine resistance to drought, adaptability to many different types of soil, high yield of easily stripped fiber of good quality, earliness of bearing, and a long productive life.[72] That variety has yet to be developed.

Espino and Novero (65) made a study of 43 varieties of abaca and evaluated them on the basis of vegetative characters, ignoring fiber properties. As criteria they used number of stalks per hill, length and size of stalks, and number and depth of roots. The varieties found to have the maximum number of desirable qualities were Baguisanon Basag, Baguisanon Lawaan, Bulao, Itom, Lagurhuan, and Libuton. In spite of the fact that these varieties are above the average in their ability to stool well, to produce stalks of exceptional size and length, and to send out roots capable of anchoring the heavy stalks, none of them have gained wide acceptance among Philippine abaca planters. Since fiber is the prime prerequisite in abaca, perhaps the reason for their lack of popular favor is to be found in the quantity or quality of their fiber; Libuton, for instance, produces a relatively low yield of fiber, and Bulao and the Baguisanons produce a weak one.

In 1927 the Philippine Bureau of Agriculture, after testing 40 varieties of abaca, distributed 8, as follows (153):

Variety	Percentage of fiber per stalk	Tensile strength, grams per gram-meter
Layahon	2.90	61,964
Sinamoro	2.98	54,139
Alman	2.50	54,135
Lagurhuan ñga Itom	2.66	51,211
Libuton	1.40	52,150
Sinaba	1.80	50,327
Bungulanon	2.30	47,366
Maguindanao	1.75	45,344

In 1939 the Philippine Department of Agriculture and Commerce (137) listed as the important varieties of commerce in the Islands:

Mindanao:	Tangoñgon, Bungulanon, Maguindanao
Leyte:	Layahon, Alman, Sinamoro, and Lagurhuan
Albay:	Itom, Samina Putitomatogacan, and Puti
Laguna:	Putian [Puteean]

Only 6 varieties are grown commercially in Central America: Tangoñgon, Bungulanon, Maguindanao, Libuton, Sinaba, and Puteean.[73] Of these Bungulanon represents roughly 85 percent, Maguindanao, 10 percent, and the other varieties 5 percent of the acreage.

Three varieties have been introduced into Malaya, and the Department of Agriculture has carried out a series of experiments to determine the relative value of the three (13). Of these Tangoñgon was found to be especially hardy, with a fiber yield of 1.9 to 2 percent; Bungulanon was less hardy, but yielded 2.25 to 2.3 percent of fiber; Baguisanon yielded only 1.0 to 1.5 percent.

Canton, Amokid, and Pakol.--There are several species of plants belonging to the banana family which go under the name canton, but only Canton-pute is stripped and marketed in large quantities. The plant from which canton fiber is obtained is said to be a natural hybrid between the edible banana (*Musa paradisiaca* var. *sapientum*) and abaca (*M. textilis*) (167) or between abaca and pakol, the wild banana (3).

Canton is easily distinguished from abaca when growing in the field. In shape the canton leaf is about midway between that of the abaca and the banana--less rounded at the tip than the banana and less pointed than the abaca. The leaves of canton, particularly the young ones, have a pinkish tinge on the under side, while the midrib has a marked pinkish color. The abaca leaf

[72] See Footnote No. 43.
[73] See Footnote No. 39.

is more brittle than the canton leaf, and the banana leaf is tougher than either. The dark marginal line on the under side of the leaf that is characteristic of abaca (fig. 4) is not found in canton.

There are at least 4 varieties of canton recognized in Albay, of which Morado and Itom are the commonest. The fiber of these 4 varieties is not materially different in general appearance, but it differs in strength. The variety Morado produces the best and strongest of the canton fibers. The stalk has a pinkish tinge, but this is a more or less general characteristic of all varieties of canton. Itom is a large variety. Its fiber has a greenish tinge, and is second in strength only to Morado. The plant of the Taguiptipon resembles the Itom plant, except that the stalk has blackish spots. In strength its fiber ranks third. The plant of the Panlayog variety resembles Itom in color, but it grows taller and is slenderer than Itom. If the stalk grows straight, the fiber is as strong as that of Itom; but if the stalk is inclined, the fiber is less strong, and, if much inclined, the fiber is very weak. The fiber of this variety is generally regarded as the weakest of the 4.

Canton fiber closely resembles that of abaca. The fiber produced by the best varieties of canton, when freshly cleaned, is nearly as strong as abaca, but tends to deteriorate in quality after a few months. The production of canton fiber creates a difficult problem for the fiber inspection service for, although canton is readily distinguished from abaca in the field and in the strick, it is not easily recognized when it is mixed in as an adulterant of abaca fiber. If it is impracticable to separate the two, Government regulations require that the whole admixture be labeled canton, even though canton may form only a small part of it.

According to Dewey,[74] it is easier to distinguish the fine grades of canton from the fine grades of abaca than it is to distinguish the coarse grades of canton from the coarse grades of abaca. The fine grades of canton tend to be light and fluffy in appearance.

Among the points of difference between canton and abaca mentioned by Dewey are the following:

<u>Smell</u>. --Canton always has a characteristic musty smell, which is quite different from the fresh, clean smell of abaca. Even 25 percent of canton mixed with abaca will clearly show this difference.

<u>Ends</u>. --In canton the ends, or tips, of the fiber are somewhat different from the tips of abaca. In the lower grades, the tips of canton are coarser and more like coarse hay than the tips of abaca. The tips of canton are usually lighter in color than those of abaca, but in the babá grades of canton this is not noticeable. In the finer grades of canton the tips tend to be curly and fluffy.

<u>Breakage</u>. --Abaca breaks with more of a snap than canton. The broken ends of canton are more straggling than those of abaca. The canton ends usually show several very fine slender fibers, while the abaca ends are clean and sharp.

<u>Ash</u>. --Canton, when burned, leaves less ash than abaca and the ash is whiter.

Two other inferior fibers that present a problem when mixed with abaca are those stripped from amokid, which appears to be a true but inferior variety of abaca, and that from pakol. The fiber produced by pakol is softer than that of normal abaca, is rather dull and dingy in appearance, and is relatively weak. It is not satisfactory for cordage purposes.[75]

PLANT IMPROVEMENT

Scientists in the Philippines have long recognized the need for developing varieties of abaca adapted to different types of soil and climate, to find drought-resistant varieties, and varieties that would provide a superior quality of fiber. Only in Davao has attention been given to these things. Most of the breeding experiments carried on by the Government have been for the purpose of developing varieties resistant to certain destructive diseases, and these experiments have not been numerous.[76] The persistent desire of the farmers to return to the growing of abaca in Cavite, Batangas, and Laguna after the plantations were destroyed by the bunchy top disease prompted the Bureau of Plant Industry of the Philippine Government to undertake a series of breeding experiments for the purpose of developing varieties that would be immune to this disease.

The experiments were begun by Calinisan and Hernandez (<u>33</u>) in 1928 at Silang, Cavite. Ten varieties were chosen for the experiments, namely, Tangoñgon, Maguindanao, Baluñganon, Balunan Jolo, Lawisid, Punucan, Putian (Puteean), Sinamoro Pula, and Sinamoro Puti. No completely resistant variety was found among these 10. Some varieties developed a certain degree of resistance, whereas others that had shown slight resistance at first became more susceptible and succumbed to the disease.

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74 DEWEY, L. H. Unpublished notes. (U. S. Bur. Plant Indus., Soils, and Agr. Engin., Div. Cotton and Other Fiber Crops and Dis.) [n. d.]

75 EDWARDS, H. T. REPORT ON FIBER INVESTIGATION IN NEW YORK, JAMAICA, COLOMBIA, THE CANAL ZONE, PANAMA, COSTA RICA, GUATEMALA, AND CUBA. 15 pp. Mar. 27, to Apr. 21, 1940. [Unpublished manuscript.]

76 BOYLE, H. H. HEART ROT OF THE ABACA (MANILA HEMP). 4 pp. 1923. [Unpublished manuscript.]

After about 2 years of field observations, the Putian variety was found to be highly resistant to the bunchy top disease. It was also well adapted to local conditions, and the fiber is fairly good. Since none of the other varieties merited further study they were dropped and the experiment was continued with the Putian. Field observations were made from November 1930 to August 1934. The results of 4 years' observations showed the Putian variety to be almost 96 percent resistant to bunchy top. Artificial inoculations confirmed the results of the field experiments. Of 96 Putian plants to which aphids (Pentalonia nigronervosa) were transferred, none became infected. In 1936 Calinisan and Hernandez reported that the possibility of rehabilitating the abaca industry in Cavite had been demonstrated by the results with the Putian variety. Nevertheless in 1937, after a survey of the situation in Cavite, Laguna, and Batangas, Edwards[77] stated that, "there continues to be discussion regarding the rehabilitation of this industry by the planting of resistant or immune varieties of abaca, but very little has been done in this direction as yet."

The need for better varieties adapted to Central American conditions is recognized by those interested in the production of abaca in the Western Hemisphere, and some breeding experiments are under way. The object of a breeding program, as assembled from various references, would be to develop a variety that will contain the desirable qualities of the best varieties and none of their undesirable ones. The desirable qualities in abaca are large and tall stalks, 3 meters in height, 20-cm. diameter at base; more than 20 leaf sheaths per stalk; more than 150 roots on each mature plant; roots as deep as 1 meter below the surface of the soil and more than 300 roots around the hill; more than 7 leaves; and 2.5 percent of fiber or more.

The undesirable qualities in abaca are less than 10 stalks per hill; stalks less than 1 to 2 meters in height; stalks less than 15 cm. at base; less than 140 roots around the hill; less than 6 leaves each; and 2.4 percent of fiber or less.

The qualities to be considered in breeding for superior varieties are those related to (1) production, namely, high fiber content, adaptability to different soil and climatic conditions, stooling habit, resistance to drought, resistance to lodging, earliness of bearing, diameter and length of stalk, a long productive life, and hybrid vigor; (2) disease resistance; and (3) quality of fiber--stem type as it influences decortication, color, softness, strength, fineness, and other fiber characters.

Since the quality of fiber differs in different varieties and in varieties grown in different localities, it would be advisable to use many varieties in the tests. This, of course, would mean the importation of new varieties from the Philippines. At present the material available for breeding work in Central America consists for the most part of the varieties Bungulanon, Maguindanao, Tangoñgon, Libuton, Sinaba, Puteean, and some crosses and seedlings.

New varieties may be developed by the use of true seed. Abaca is an open-pollinated plant and the seedling progeny, therefore, are hybrids. As might be expected, great variability has been found in seedlings, even from the same parent plant. Good abaca seeds are hard to secure, and some varieties are known to be self-sterile; the seeds are slow in germinating; and seed production from seedlings requires 30 months. In spite of these difficulties the growth of numerous plant seedlings from true seeds offers the possibility of obtaining a good seedling with the desirable characters.

Attempts should be made to self abaca varieties. This would not be simple, for by the time the male flowers in a spike shed their pollen, the female flowers are no longer receptive. Pollen of other plants like maize and Rubus has been kept viable in cold storage for several days to 2 years, and possibly abaca pollen could be kept viable in the same way and used to pollinate female flowers on another stalk in the same hill that flowered later. Thus selfing would be accomplished, even though a different flower stalk were pollinated. If varieties can be selfed and made genetically pure, such lines could be crossed and greater hybrid vigor might be obtained, as has been done with corn and other crops. Abaca could be asexually propagated from a hybrid, and if the hybrid showed exceptional hybrid vigor or other desirable characters, the end results would be obtained. The main obstacles in abaca breeding are the 30 months required for a generation from seed to seed, and some self-sterility.

In many crop plants maturity can be hastened by lengthening or shortening the period of exposure to light. How abaca would be affected by such treatment is not known, but its response to length of day and intensity of illumination are factors that should be studied.

The use of X-ray, radium, and colchicine for inducing polyploid chromosome mutations in abaca, as has been done so successfully with some other plants, would certainly be worth the time and effort required. Treatment of jute seeds with X-ray is reported to have had spectacular results (15). A gigantic jute plant has been grown from X-ray treated seeds, reaching 22.5 feet in height with a basal diameter of 2.5 inches, whereas the record size of a plant from untreated seeds is 15 feet in height and 1 inch in basal diameter.

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[77] See Footnote No. 26.

A triple hybrid cotton derived from Asiatic cotton, American upland, and a wild cotton has recently been produced through the use of colchicine, a treatment that doubled the number of chromosomes. Fiber of this hybrid has a breaking strength 75 percent greater than that of commercial varieties in general use.

If vegetative mutations are produced by means of chromosome mutations, the plants can be propagated asexually, thus continuing the polyploid structure.

To summarize: the procedure called for in an abaca-breeding program in the Western Hemisphere would include:

(1) New introductions from the Philippines.
(2) Seed (true) selection and nursery testing.
(3) Hybridization.
(4) Selfing and hybridization for hybrid vigor.
(5) X-ray and colchicine treatments to produce mutations.

HARVESTING AND CLEANING

When the blossom appears the abaca stalk is ready for cutting. The first stalks should be ready for harvesting about 1 1/2 to 2 years after planting, at which time the mat consists of 12 to 30 stalks in all stages of development. Usually 2 to 4 can be harvested at one time and subsequent cuttings can be made every 4 to 6 months for 10 to 15 years. In the Philippines the minimum height of a stem suitable for harvesting is considered to be 8 feet. In harvesting the crop the whole stalk is cut down, and soon thereafter the extraction of fiber begins (fig. 19).

PHILIPPINE ISLANDS

The process of extracting the fiber practiced almost universally in the Philippines consists of two operations (1) separating the outer layer or "tuxy" from each leaf sheath (fig. 20), and (2) scraping the pulp and extraneous matter from the tuxy by drawing it under a knife. The two operations are known as tuxying and stripping or cleaning.

The first operation in the extraction of the fiber is to insert the point of a knife between the outer and the middle layers of a sheath and then pull off the outer fibrous layer in strips (tuxies) 2 to 3 inches wide running the whole length of the sheath. Each successive sheath is "tuxied" in this fashion until the center fiberless core is reached. According to their position in the pseudostem, the sheaths vary in length, shape, color, and in the texture and character of their fiber. One trunk may yield as many as 20 or more leaf sheaths that can be stripped for fiber (62).

On the basis of color and quality of fiber the sheaths of Philippine abaca fall into four groups, namely, babá (usually 3 sheaths), segunda babá (3 or 4 sheaths), middle (4 or 5), and ubud (7 or 8), the babá being the outermost sheaths and the ubud the innermost.

The total weight of the tuxies from the outside sheaths (babá) is about 13 to 15 percent of the total weight of all tuxies, and about 2 percent of the total weight of the stalk; the total weight of the tuxies from the sheaths next to the outside (segunda babá) usually averages about 17 percent of the total weight of all tuxies and about 2-1/2 to 3 percent of the total weight of the stalk; the weight of the tuxies from the middle sheaths averages about 27 percent of the weight of all tuxies and about 4 to 4-1/2 percent of the weight of the stalk; and the weight of the tuxies from the inner sheaths (ubud) averages about 42 percent of the total weight of all tuxies, and about 6 percent of the total weight of the stalk (157).

Since each series of leaf sheaths produces a definite grade of fiber, separation of tuxies according to origin in the pseudostem would greatly facilitate the grading of the fiber, and in Albay the tuxies are usually separated at the stripping knife into three groups, first and second babá and the innermost leaf sheaths. Failure to make this preliminary classification results not only in losses to the planters, but also in deterioration in the quality of the fiber.

Since the fiber represents so small a proportion of the stalk (2 to 3 percent of the weight of the stalk), it is advantageous to strip the fibrous layer from the sheath in the field, and this the Filipino does. As he removes the outer fiber-bearing layer of each sheath he discards the rest, leaving it to decompose in the field. As soon as a sufficient quantity of these strips or tuxies has accumulated they are tied into bundles and carried to the stripping shed. There they are cleaned of the adhering pulp and cellular matter.

Three methods of cleaning abaca fiber are used in the Philippines: (1) stripping by hand; (2) stripping by small spindle machines; and (3) by large semiautomatic machines. As late as 1937 Edwards [78] estimated that about 70 percent of the total Philippine production was cleaned by the hand-stripping method. By this method the tuxy is held in the hand and drawn under a

[78] See Footnote No. 26.

Figure 19.--Cutting abaca stalks in Davao Province, Republic of the Philippines.

serrated knife pressed against a block of wood by means of a spring pole (fig. 21). The more numerous the serrations of the knife and the greater the pressure on the tuxy, the finer will be the fiber and the smaller the yield. Waste will be greater and work will be harder. The finest fiber can be and is produced by the hand-stripping method, but when prices are low or when the difference in price between fiber of coarse and excellent cleaning is not such as to justify the strenuous labor required to remove all the waste from the fiber, the worker is likely to release the pressure on the tuxy, thus producing a larger quantity but a coarser grade of fiber. During the depression year of 1932, when prices were exceptionally low, it was estimated that most of the fiber produced in Leyte was pulpy and about 80 percent of the fiber from Negros was damaged (182). Part of the trouble arose from the use of knives of uneven teething. With such knives it is impossible to strip a uniform grade of fiber.

Figure 20.--Ribbons or tuxies are stripped from the abaca sheath (right), then drawn under a knife (center) to remove the pulpy tissue, after which the cleaned fiber is hung up to dry (left).

Figure 21.--Stripping fiber by hand, Republic of the Philippines.

Because of the seriousness of the situation the Bureau of Plant Industry of the Philippine Department of Agriculture ran a series of experiments to determine the type of knife that should be used to produce the precise grade of fiber required by the market (182). "Benito" knives (fig. 22) were set on the block of wood with the force applied as follows: No. 0 knife (no serrations), 84 pounds; No. 46 (46 serrations to the inch), 72 pounds; No. 40 (40 serrations), 64 pounds; No. 30, 56 pounds; No. 24, 52 pounds; and No. 16, 48 pounds.

The tuxies, all from the variety Itom, were separated according to origin in the pseudostem into four groups: 4 outermost leaf sheaths; 4 second outer leaf sheaths; 4 inner leaf sheaths; and innermost leaf sheaths. The results of the tests showed that to produce fiber of Good Current (CD) grade, knife No. 0 should be used; for Midway (E) grade, knife 46; for F grade, knife 40; for Superior Seconds No. 1 (J1) grade, knife 24; and for Coarse (L1) grade, knife 16. The experiments also showed that the fewer the number of serrations per inch of blade the greater was the quantity of fiber produced; knife No. 0 (unserrated) produced the smallest quantity but the highest quality of fiber, and knife No. 16 produced the most.

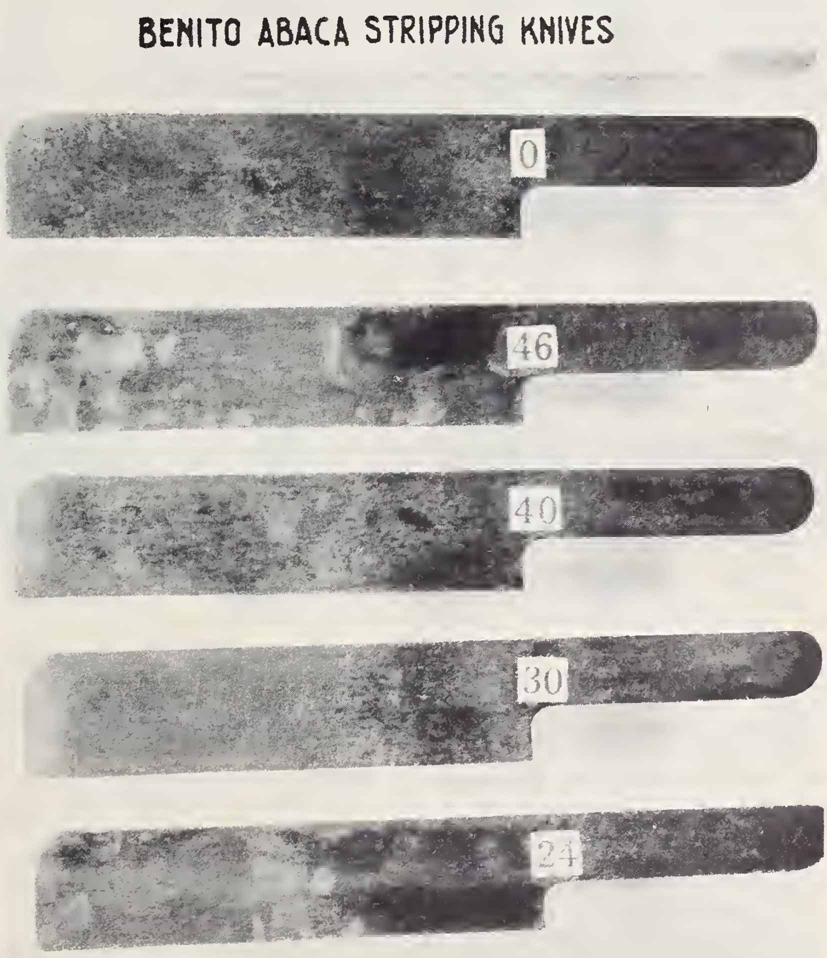

Figure 22.--"Benito" knives used for stripping abaca in the Republic of the Philippines. Figures indicate number of serrations per inch. The number of serrations and the pressure applied to the knives largely determine the quality of fiber produced. (From Torres and Cruz: "Efficiency of Different Benito Knives for Stripping Abaca." Philippine Journal of Agriculture.)

At the prices prevailing in February 1940 the quantity produced with knife No. 46, at a force of 72 pounds, would have exceeded in value that produced by any of the other knives.

In the Philippines the fiber is hung in the sun to dry as soon as it is stripped (fig. 23). The length of the drying period depends both on the weather and on the quantity of pulpy material adhering to the fiber. Torres and Cruz (182) determined the number of hours required for drying fiber stripped with the different knives, as follows:

Nos. 0, 46, and 40 .... not exceeding 5 hours on a clear day.
Nos. 30, 24, and 16 .... as much as 22 hours.

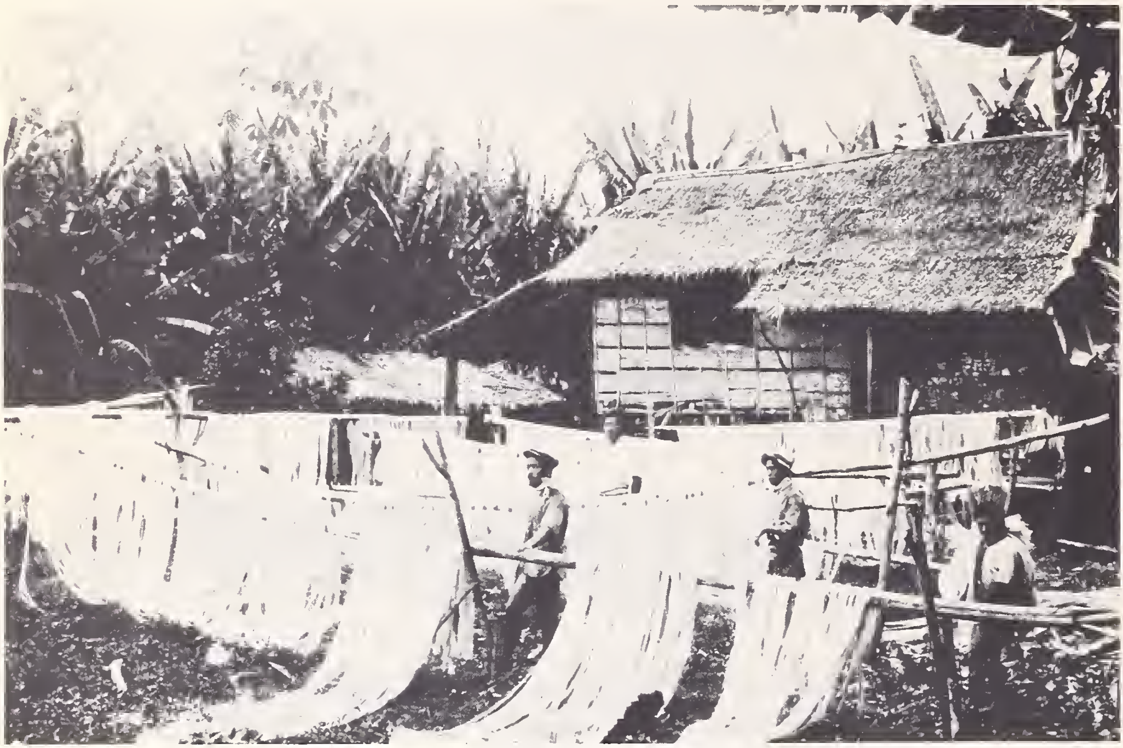

Figure 23.--Drying abaca in the Philippines.

Fibers requiring as much as 22 hours to dry, especially if the days are cloudy or rainy, are liable to attack by molds and other deteriorating agents.

The percentage of moisture present in the fibers varied inversely with the number of serrations of the stripping knife; i. e., the fewer the serrations the greater the quantity of moisture present in the fiber.

Balmaceda and Bartolome,[79] discussing cultural and cleaning operations on Philippine abaca plantations shortly before the outbreak of war, divided the plantations into three groups: (1) The well-organized plantations; (2) the big haciendas; and (3) the ordinary small plantations.

To the first group, represented by the Japanese in Davao, belong the plantations that apply modern agricultural methods, such as uniform planting, cultivation, use of the small spindle machines, artificial methods of drying fiber or drying it as soon as it is stripped. To the second group belong the big haciendas that still follow the old methods of planting and caring for the crop, but use small machinery or animal power for cleaning and either dry the fiber immediately after stripping or hang it under a roof to dry during the night. To the third group belong the thousands of small farmers who have no knowledge of modern agricultural practices and "who cannot afford or do not care to have a better knife than a piece of metal serrated with the aid of their own bolo. When the fiber is stripped they hang it in the open to dry. If it rains they leave the fiber alone until good 'Old Sol' shines again and dries it. . . The majority of the plantations are still in the last group."[80]

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[79] See Footnote No. 1.

[80] See Footnote No. 1.

Only two large semiautomatic decorticating machines such as are used for cleaning sisal were employed in the Philippines before World War II.[81] One of these belonged to the International Harvester Company, the other to the Furukawa plantation.

On most of the Japanese plantations, however, a small, "hagotan" machine - an American invention - was in constant use. Its principal feature is a revolving cylinder kept in motion by a small engine or a water wheel. The tuxy is inserted under the blade and the butt end is wound around the cylinder or spindle. The cylinder as it revolves helps to pull the strips under the knife (fig. 24).

The advantage of this machine is that it reduces the amount of labor required to do the work, eases the burden on the stripper, gives a larger out-turn of fiber, and lowers the cost of production. These machines when properly operated will produce medium to high grade fiber, but they do not produce the highest grade. Although the greater part of the fiber on the Japanese plantations was cleaned with the small spindle machine, the Japanese developed a system of hand stripping that was efficient and profitable. A gang of strippers under the supervision of a foreman were paid so much per kilo for the fiber cleaned, the amount depending on the quality cleaned. The strippers were required to produce not less than a certain quantity of fiber per day, the minimum requirement being usually about 10 kilos of wet fiber, or about 6-1/2 kilos (14-1/3 lbs.) of dry fiber. On many plantations the use of serrated knives was forbidden. In 1928 Edwards (57) reported that a good stripper could, without difficulty, earn from 1.50 to 2 pesos (1 peso= 10 cents) per day.

It has been estimated that 6 men using a hagotan can clean from 2 to 3 piculs of fiber of good quality in one day, or about 50 to 70 pounds per man without any undue physical exertion. Using the common hand stripping knife, 2 men, by extremely hard labor, can only produce about 25 to 40 pounds of fiber of the same quality, or at most 20 pounds per man per day. Laborers who strip by hand usually work only 3 or 4 days a week, whereas those using the hagotan can work throughout the week without rest.

In spite of the obvious advantages of the hagotan and the Government's efforts to extend its use, it has never been popular in the northern provinces.

In 1935 Balmaceda and Bartolome,[82] comparing the primitive methods of these provinces with the advanced methods of Davao, predicted that "if, during the next ten years, no imprcvement is made in the present method of stripping and handling of fiber in the Bicol and Visayan regions, it is feared that the plantations in these regions will gradually disappear or be abandoned."

After the fiber is cleaned it must be dried immediately. Failure to do so results in reduced luster and loss of tensile strength. The International Harvester Company uses an artificial drier along with its decorticator in Davao. This machine dries the fiber as soon as it is extracted.

In prewar days the dried fiber was usually sold by the small farmer to a Chinese middleman, but the Japanese through an efficient auction system, sold theirs to the highest bidder.

All fiber intended for export is taken to a warehouse (fig. 25), where it is inspected and graded. There an inspector selects at random about 5 percent of each lot, opens and examines it. Should he find it below the fixed standard he marks it "I. C." in red, meaning inspected and condemned, and it cannot be exported under the grade mark intended by the packer. A sharp watch is kept by inspectors for adulterated fiber and for bales that contain wet fiber. The latter are opened, and the fiber is dried and reinspected. Fiber for export is packed in bales weighing 278.3 lbs., and the weight of the bales is checked before shipping.

CENTRAL AMERICA

In Central America there is no small-holder system of growing abaca where the farmer and his family do their own planting, cultivating, stripping, drying, and selling. Practically all the abaca grown in Central America is on large plantations owned by the United Fruit Company and operated for the United States Government. The long experience of this Company in the cultivation of another Musa, the banana, has given it a working knowledge of the requirements of Musa textilis and an understanding of how to cope with many of the problems that have arisen in its production. The Filipinos, because they had a monopoly of the industry, never received the benefits of research on abaca that competition from other countries might have given them.

Following the accepted practice in the Philippines, the harvesting program in Central America was so designed that each area would be cut over 4 times a year and only mature stalks would be harvested. Because of the necessity of salvaging the fiber from the numerous "tip-over" plants, however, this plan has had to be modified.

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[81] See Footnote No. 1.
[82] See Footnote No. 1.

Figure 24.--A, Hagotan or spindle machine used in cleaning abaca fiber in the Philippines. B, Battery of hagotans on an abaca plantation in Davao Province. (Photo from Lucky Studio, Davao.)

Figure 25.--Grading abaca fiber, Philippines. Proper grading is essential to maintain confidence of buyers and insure highest values for different qualities.

Before harvesting the stalks, the cutters remove all the leaves from the plant to be cut with a banana knife or pulla (fig. 26) and then cut the stalk close to the ground, discarding the upper part from about the point of attachment of the last dead leaf. The stalk is then cut into sections or "junks". The maximum length of a junk is 6 feet, which is the greatest length that the decorticating machines can process, and the minimum length is 4 feet, which is the shortest length that can be efficiently cleaned and is desired for manufacturing. Keeping in mind a 6-foot maximum and a 4-foot minimum, the cutter is instructed to cut the junks the maximum length when practicable, but to be sure to conserve the utmost fiber possible. For example, stalks of 8 and 12 feet should be divided into 2 junks of even length, stalks of 18 feet into 3 junks of even length. In cases where some fiber must be lost, however, as when stalks are over 6 feet and less than 8, the junk is cut from the lower part of the stalk where the quantity of fiber is largest.

In addition to the tip-over plants, which must be salvaged, many small plants are broken during harvesting operations. Since even small plants contain valuable fiber, all damaged plants that will yield a junk of 4 feet are harvested.

After the stalks are sectioned, the junks are carried from the cutter to the railroad by pack mule. The average load is 300 to 400 pounds, carried in slings, the junks being pushed in first on one side of the animal, then on the other. To unload, the slings are unhooked and the junks are allowed to fall to the ground.

Before the junks are loaded on to the cars, all dead leaves are removed and any sheaths shorter than four feet are discarded. The junks are then placed crosswise on the flat cars. Once loaded, the junks are taken immediately to the decorticator.

In early 1940 when the 1,000-acre plantation of abaca planted in 1937 near Almirante, Panama, had matured and was ready for stripping, no satisfactory large fiber-cleaning machine was available for stripping it. Accordingly, 24 small machines of the hagotan type were constructed and installed with a view of saving fiber that would otherwise be lost and of determining if it would be possible to operate these machines economically in Panama.

Figure 26.--Cutting off the leaves preparatory to harvesting abaca stalks in Central America.

Edwards [83] reported that the operators were being paid 5 cents per pound of dry fiber cleaned and were cleaning from 20 to 30 pounds of dry fiber per day.

It was estimated that the total cost of producing this fiber was from 10 to 12 cents per pound, and the value of the fiber in the New York market was from 5 to 6 cents. Large automatic machines of the "Corona" type had for some time been successfully used in Sumatra, where practically all abaca was machine-cleaned, and to a very limited extent they had been used in the Philippines for cleaning a type of abaca fiber known in the trade as "Deco" (decorticated) fiber. The Sumatra machine-cleaned fiber, though used to some extent in the United States, has not been considered the equal in quality of the highest grades of hand-cleaned and hagotan-cleaned Philippine fiber, and the Philippine Deco fiber is rather below the average quality of Sumatra abaca fiber.[84]

[83] See Footnote No. 75.
[84] See Footnote No. 75.

The Panama abaca project was planned with the end in view of cleaning the fiber with a machine of the Corona type (fig. 27), the expectation being that this machine, if efficiently operated, would produce a fiber that could be sold at a price approximately equivalent to the current price of the medium grades of Philippine abaca fiber. Certain improvements were made to speed up operations and to reduce the hand labor required, and as soon as practicable, these machines were installed.

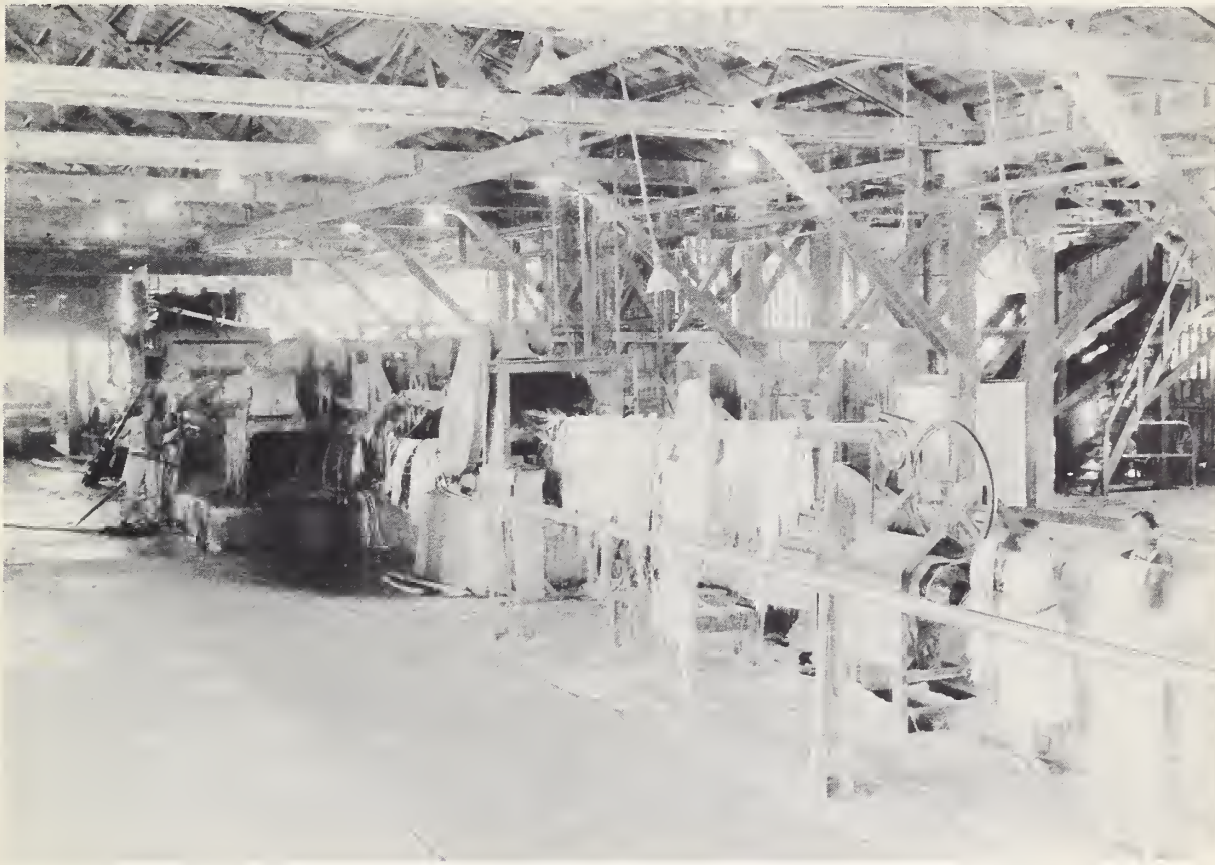

Figure 27.--Abaca decorticator or fiber cleaning unit. This includes: feed table for stalks, crusher (background), decorticator, fiber wringer rolls, mechanical brusher (foreground) and the line for fiber grading. (Photo courtesy of H. E. Counter).

The abaca stalks to be processed on this machine are placed on a conveyor, which carries them through an automatic stamp crusher or rolls that partially crush each stalk to the form of a flat blanket. This "blanket" then moves on a flat conveyor to a rope line conveyor, which grasps and holds it a little to one side of its center, allowing the ends to hang down free on either side. This rope line conveyor then carries the abaca through the cleaning units. First the longer end of the fiber in the rope conveyor is scraped and simultaneously cleaned with a spray of water under pressure, after which the blanket of cleaned fiber is grasped by another rope conveyor and a second scraper cleans the other end. The cleaned wet fiber is then drawn through wringer or squeeze rolls which squeezes out excess water to partially dry the fiber. The fiber then passes on into a dryer and from there to a baling press. Before January 1, 1949, Central American abaca was put up in bales of 275 pounds each; now each bale contains 300 pounds.

THE FIBER

DESCRIPTION

The term "abaca" is used in the Philippine Islands to designate both the plant Musa textilis and its fiber. "Manila hemp" or simply "manila" are trade terms used in the United States and some foreign countries to designate the fiber alone. The term "abaca" is being used more commonly in the United States than formerly and it would be very desirable if it were used by all and the term "Manila hemp" entirely discontinued.

As previously stated, the false stalk or "trunk" of the abaca plant is made up of a number of leaf sheaths. The commercial fiber is extracted from these sheaths; no fiber is obtained from the expanded leaf blades that form the upper canopy of the plant or from the fleshy central flower stalk. The raw fiber of commerce is a long strand that runs the entire length of the leaf sheath. The length of the fiber varies therefore with the height of the plant and the age of the sheath from which it is obtained. All leaf sheaths do not run the entire length of the false stem. The fiber from the oldest or outside sheaths is usually the shortest fiber obtained from the stalk, and that from the inner sheaths is the longest. Thus abaca fiber may vary in length from 3 to 9 feet or more. Regulations of the Philippine Islands governing the grading of abaca fiber designate fiber as "very long" when it exceeds 3 meters; "long" when it is 2-1/2 to 3 meters; "normal" when it is 1-1/2 to 2-1/2 meters; and "short" when it is under 1-1/2 meters (92). The Philippine Fiber Inspection Administrative Order No. 4, Manila, 1934, states that the minimum length is 60 centimeters, and the same order illustrated graphically the width of the fibers when the cleaning is either fair, coarse, or very coarse, varying from 1 mm. to 3 mm. in width of strands. The description states that in good cleaning the fiber is produced in the form of filaments which do not exceed 1/2 mm. in average width; for fair cleaning the filaments do not exceed 1 mm. in average width; and for coarse cleaning the filaments are often flat, averaging over 1 mm. but less than 1-1/2 mm. Filaments over 1-1/2 in width are graded as very coarse cleaning or waste as the inspectors may decide. Length in itself is not a determining factor in the quality of Philippine abaca. In cleaning abaca on the large semiautomatic decorticator the length is governed by the ability of the machine to handle long fiber.

In Central America, where all abaca fiber is cleaned on decorticating machines, the minimum length of fiber admitted in the principal grades is 30 inches.[85] All stricks of less than 30 inches or all in which the bulk of the fiber is below this limit must be graded as tow. However, all long fiber as well as tow is abaca fiber and the length classification is one of trade differentiation in respect to utilitarian value. In most discussions of the fiber descriptions involving length are applicable to the long fiber, not the tow grades.

The color of abaca fiber is influenced by a number of factors. Primarily these are: the color of the leaf sheath or the variety from which the fiber is extracted; the extent of the cleaning; and the care taken in drying the fiber after it has been extracted. The fiber varies from light purple, red, or brown to "light ivory" or almost white. The white fiber is obtained from the innermost leaf sheaths and the light purple or red from the outer sheaths. Brown in various shades appears in some of the lower grades of fiber. Oxidation of the pulpy material remaining on the fiber as a result of poor cleaning influences the color. The colors mentioned above are more or less natural colors resulting from factors encountered in the usual method of preparation. But the fiber may also reveal various shades and hues resulting from damage from unnatural causes.

An interesting study to improve the color and appearance of abaca fiber by chemical treatment was reported by Sherman (166). The research which he described was undertaken to change, say, J grade or lower to F grade or higher without serious loss of tensile strength. While Sherman reported improvements in the color, appearance, and texture of the fibers bleached, his technique involved several liquid immersions in alkali and acid solutions which would certainly prove costly in labor and production. Further, the difficulties and danger of insufficient removal of the chemicals when treating large tonnages of fiber, which were not discussed by Sherman, would certainly tend to hinder the general adoption of such methods.

MICROSCOPIC CHARACTERS

The commercial fiber strand is composed of numerous fiber cells lying side by side with overlapping ends and cemented together in bundles. These fiber strands are the strengthening tissue of the fibrovascular bundles of the leaf sheath. A cross section of the abaca stalk (fig. 6) shows that the individual leaf sheaths consist of 3 layers, but it is only from the outer layer that the fiber of commerce is obtained.

The dimensions of the ultimate fiber cells which make up the fiber strands are of such importance in identifying fibers and estimating their probable value that they have been the subject of study by many plant histologists and morphologists. The ultimate cell measurements of approximately 175 species of fiber plants reported in the literature are summarized in table 5. In some cases the results of different authors vary widely. Nevertheless, the table may be useful for reference in identification in conjunction with staining and similar test treatments mentioned under Fiber Adulterants.

[85] U. S. OFFICE OF DEFENSE SUPPLIES. STANDARD GRADES OF CENTRAL AMERICA ABACA. Washington, D. C. 1946.

TABLE 5.--Length (millimeters) and breadth (microns) relationships of the ultimate cells of various fibers as reported by different workers

Botanical name	Length			Breadth			Authority and reference number*
	Min.	Max.	Mean	Min.	Max.	Mean	
Abelmoschus tetraphyllos (Hibiscus tetraphyllus)	1.0	1.6	--	8	20	16	Wiesner (190)
Do	1.0	1.6	--	8	20	16	Lecomte by Beauverie (20)
Abroma augusta	1.4	4.2	2.2	6	39	17	Mendiola (118)
Do	2	3	--	12	20	--	LeJeune (109)
Abutilon, sp	.9	2.3	--	--	--	--	Lüdtke by Schönleber (161)
Do	.9	2.3	--	12	30	--	Herzog (93)
Abutilon avicennae (Abutilon theophrasti)	1	2.1	--	8	37	--	Saito (155)
Acrocomia totai	--	--	2.1	--	--	--	Tobler (180)
Agave americana	.7	1.9	--	20	40	--	Saito (155)
Do	1.5	4.0	2.5	20	32	24	Vetillart (186)
Do	--	--	2.5	20	30	--	Lecomte (107)
Agave cantala	1.5	2.6	--	--	--	--	J.v. Wiesner and H. Baar. (192)
Do	1.0	5.0	2.4	20	30	20	Copeland
Agave sisalana	2.4	4.4	--	--	--	--	J.v. Wiesner and H. Baar. (192)
Aloe perfoliata (Aloe barbadensis)	1.3	3.7	--	15	24	--	Wiesner (190)
Alpinia nutans	--	2.2	--	--	--	--	Kew Bul. 1912 (152)
Do	.6	2.7	--	10	25	--	Saito (155)
Amomum hemisphaericum	--	2.5	--	--	--	--	Kew Bul. 1912 (152)
Ananassa sativa (Ananas comosus)	3.0	9.0	--	1	26	18	Lecomte (107)
Ananas sativa (Ananas comosus)	3.0	9.0	5.0	4	8	6	Vétillart (186)
Andropogon rufus	2.0	3.5	--	10	20	--	Hoyer (96)
Apocynum sibiricum (floss)	--	--	20.0	4	20	--	Karawajew (102)
Apocynum venetum	--	80	--	--	--	--	Dewey Index Rus. 1929[86]
Araujia sericifera	--	--	--	--	--	17-20	Camin and Ulbricht (35)
Do	--	--	--	--	--	70-100	Do.
Asclepias, sp	7.0	30.0	--	18	25	--	Wiesner (191)
Asclepias curassavica (floss)	10.0	30.0	20.5	20	44	--	Do.
Asclepias gigantea (Calotropis gigantea)	--	--	--	30	40	--	Aisslinger and Wiesner
Asclepias incarnata	20.0	30.0	--	3	25	--	Tobler
Asclepias syriaca	15.0	30-50	--	12	30	--	Ulbricht
Do	--	--	10-30	--	--	12-20	Lüdtke
Asclepias syriaca (floss)	--	--	33	5	32	--	Dischendorfer (54)
Asclepias syriaca (floss tufts)	18.2	50.6	38.0	20	34	27	Pearson (134)
Do. (floss)	--	--	22-28	14	33	--	Meitzen (117)
Bambusa sp	2.2	2.6	--	17	71	--	Hoyer (96)
Bambusa blumeana	--	--	1.8	--	--	5	Copeland
Bambusa lumanpao (Bambusa lumampao)	1.2	4.1	2.6	5	28	16	Do.
Bambusa stenostachia (Bambusa stenostachya)	0.7	2.8	--	7	25	--	Saito (155)
Bauhinia racemosa	1.5	4.0	--	8	20	--	Lecomte by Beauverie (20)
Do	1.5	4.0	--	8	20	--	Wiesner (190)
Beaumontia (silk)	30.0	45.0	--	33	50	--	Do. (190)

TABLE 5.--Length (millimeters) and breadth (microns) relationships of the ultimate cells of various fibers as reported by different workers--Continued

Botanical name	Length			Breadth			Authority and reference number*
	Min.	Max.	Mean	Min.	Max.	Mean	
Boehmeria nivea	60.0	250.0	120	--	80	50	Vétillart (186)
Do	--	580.0	150-250	20	80	40-60	Hassack by Schönleber (161)
Do	--	220.0	--	40	80	50	Wiesner (190)
Do	12.3	24.5	--	40	90	50	Saito (155)
Do	60.0	250.0	--	40	100	--	Lecomte (107)
Boehmeria spicata	7.0	26.0	--	11	72	--	Saito (155)
Boehmeria tenacissima	--	80.0	--	--	--	--	Wiesner (190)
Bombax, sp. (floss)	10.0	30.0	--	19	43	--	Wiesner, J.v. (191)
Bombax malabaricum	1.2	3.0	--	--	--	58	Hanausek by Hoyer (85)
Bromelia karatas	2.5	10.0	5.0	20	32	24	Vétillart (186)
Do	1.4	6.7	--	27	42	--	Wiesner (190)
Bromelia pinguin	.7	2.5	2.0	8	16	13	Vétillart (186)
Broussonetia kazinoki	1.5	10	--	10	34	--	Saito (155)
Broussonetia papyrifera	6.0	25	15	25	35	--	Vétillart (186)
Do	6.0	25	15	--	--	25-30	Lecomte (107)
Do	10.0	20	--	12	30	--	Hanausek (84)
Do	7.0	21	--	--	36	--	Wiesner (190)
Calotropis gigantea (bast)	7.0	30.0	--	18	25	--	Do. (190)
Do. (floss)	20.0	30.0	--	12	42	--	Do. (190)
Cannabis sativa	--	--	--	15	28	--	Do. (190)
Do	5.0	55.0	15-25	16	50	22	Vétillart (186)
Do	7.0	50.0	--	10	35	--	Saito (155)
Do	5	41	25	12	32	20	Lecomte (107)
Do	--	--	--	--	42	--	Cramer
Do	10.0	50.0	--	16	50	--	Hanausek (84)
Do	8.0	55.0	28.0	7	59	32	Solaro by Schönleber (161)
Do	--	--	--	12	15	--	Wiesner (190)
Do	5.0	55.0	--	15	28	--	Wiesner (190)
Ceiba pentandra (floss)	15.0	35	21.4	--	--	--	Dewey Index 1922[87]
Celastrus articulatus (Celastrus orbiculatus)	20.0	70.0	--	80	135	--	Saito (155)
Celastrus scandens	--	--	43.0	--	--	24	Lüdtke by Schönleber (161)
Chamaerops humilis	--	--	1.5	--	--	10	Sorges (172)
Cocos nucifera	.4	1.0	.7	12	24	20	Lecomte by Beauverie (20)
Do	.4	1.0	--	12	20	--	Wiesner (190)
Do	.4	1.0	.7	12	24	20	Vétillart (186)
Columbia serratifolia	1.0	2.5	1.6	5	27	14	Mendiola (118)
Corchorus, sp.	.8	4.1	--	10	21	16	Wiesner, J.v. (191)
Do	--	--	4.0	10	30	--	Schlesinger by Schönleber (161)
Do	1.5	5.0	2.0	20	25	23	Vétillart (186)
Do	1.0	9.0	--	--	--	18	Lecomte (107)
Do	.8	4.1	--	10	32	--	Herzog (93)

TABLE 5.--Length (millimeters) and breadth (microns) relationships of the ultimate cells of various fibers as reported by different workers--Continued

Botanical name	Length			Breadth			Authority and reference number*
	Min.	Max.	Mean	Min.	Max.	Mean	
Corchorus, sp.--Continued	--	--	2.0	--	--	24	Solaro by Schönleber (161)
Do	--	--	2.0	--	--	16	Roux by Schönleber (161)
Do	--	--	2.0	--	--	20	Tobler-Wolff by Schönleber (161)
Do	1.0	4.0	--	15	25	--	Tobler (180)
Do	1.3	2.0	1.5	14	17	15	Horst (95)
Do	.8	4.1	2.0	15	25	20	Wiesner
Do	1.2	3.8	2.0	--	--	--	Lecomte (107)
Corchorus capsularis	.6	6.4	--	13	22	--	Saito (155)
Do	--	--	--	10	21	16	Wiesner (190)
Corchorus olitorius	--	--	--	16	32	20	Do. (190)
Cordia gerascanthus	--	--	9.0	12	16	15	Tobler (181)
Cordia holstii	.4	--	8.0	12	16-25	15	Do. (181)
Cordia latifolia	1.0	1.6	--	--	--	15-17	Lecomte (107)
Do	1.0	--	1.6	15	17	--	Wiesner (190)
Corypha umbraculifera	1.5	5.0	3.0	16	28	24	Vétillart (186)
Do	1.1	2.8	2.1	10	15	13	Copeland
Crotalaria juncea	4.0	12.0	7-8	25	50	30	Vétillart (186)
Do	3.4	8.0	6.0	18	40	30	Lecomte by Beauverie (20)
Do	4.0	12.0	7-8	--	--	30	Do. (20)
Do	--	--	6-8	--	--	30	Marchand by Schönleber (161)
Do	--	--	--	13	50	25-30	Hanausek (84)
Do	.5	6.9	4.5-6.9	20	42	--	Wiesner (190)
Cryptostegia grandiflora	2.5	40.0	15-20	20	162	--	Schwede (163)
Daphne mezereum	2.0	3.5	2.9	10	18	12	Lecomte by Beauverie (20)
Daphne pseudomezereum	1.3	6.2	--	10	25	--	Saito (155)
Edgeworthia papyrifera (Edgeworthia tomentosa)	.7	4.5	--	14	31	--	Do. (155)
Elaeis guineensis	1.5	3.5	2.5	10	13	11	Vétillart (186)
Eucalyptus sp	1.0	1.5	--	--	--	--	Hoyer (96)
Firmiania platanifolia (Firmiana simplex)	1.5	3.0	--	15	20	--	Saito (155)
Genista scoparia (Cytisus scoparius)	2.0	9.0	5.0	10	25	15	Lecomte (107)
Do	2.0	9.0	5-6	10	25	15	Vétillart (186)
Gnidia eriocephala (Lasiosiphon eriocephalus)	.4	5.1	--	8	29	--	Wiesner, J.v. (191)
Gossypium spp. (floss)	10.0	50.0	--	12	42	--	Do (191)
Grewia multiflora	1.1	2.7	1.8	6	24	15	Mendiola (118)
Hedychium coronarium	--	--	2.6	--	--	83	Kew Bul. 1912 (152)
Helianthus annuus	.5	1.3	1.0	--	--	--	Lüdtke by Schönleber (161)
Hibiscus cannabinus	2.0	6.0	5.0	14	33	21	Vétillart (186)
Do	4.0	6.0	--	20	41	--	Wiesner (190)
Do	--	--	6.0	14	16	--	Hanausek (84)
Do	2.5	3.0	--	18	28	--	Aisslinger by Schönleber (161)

TABLE 5.--Length (millimeters) and breadth (microns) relationships of the ultimate cells of various fibers as reported by different workers--Continued

Botanical name	Length			Breadth			Authority and reference number*
	Min.	Max.	Mean	Min.	Max.	Mean	
Hibiscus cannabinus--Continued	4.0	12.0	--	20	41	--	Herzog
Do.	1.0	5.0	--	--	--	20-25	Tobler (179)
Do.	1.5	2.8	2.0	11	30	20-21	Horst (95)
Hibiscus esculentus	1.5	8.8	3.7	12	32	20	Braga (28)
Hibiscus sabdariffa	1.2	3.3	1.9	10	32	20	Mendiola (118)
Hibiscus syriacus	2.5	5.4	3.2	--	--	15	Lecomte by Beauverie (20)
Do.	.6	1.7	--	12	35	--	Saito (155)
Hibiscus tetraphyllus	1.0	1.6	--	8	20	16	Wiesner (190)
Holoptelea integrifolia	.9	2.1	--	9	14	12	Do. (190)
Humulus sp.	--	--	12.8	--	--	28.7	Reimers
Humulus lupulus	3.5	20.0	10-12	--	15	30	Singer by Schönleber (161)
Do.	4.0	19.0	10.0	12	26	16	Vétillart (186)
Do.	--	--	--	23	30	--	Hanausek (84)
Hyphaene thebaica	.5	3.6	2.1	13	15	--	(10)
Imperata sp.	.5	2.5	--	4	10	--	Raitt (145)
Imperata exaltata	.5	1.8	1.0	5	21	11	Copeland
Ischaemum angustifolium	1.0	2.9	--	9	16	--	Raitt by Hoyer (96)
Kanahia laniflora	15.0	25.0	--	20	30	--	Castiglioni (36)
Kleinhovia hospita	.9	2.4	1.5	8	31	15	Mendiola (118)
Kydia calycina	1.0	2.0	--	17	24	--	Wiesner (190)
Lagetta funifera (Funifera utilis)	--	--	5	--	--	12-14	Lecomte (107)
Lagetta lintearia	3.0	6.0	5	10	20	--	Vétillart (186)
Lasiosiphon speciosus	.4	5.1	--	8	29	--	Wiesner (190)
Linum usitatissimum	15	29	20	11	22	16	Lecomte (107)
Do.	14.0	85.0	--	18	25	20	Saito (155)
Do.	--	--	--	10	15	--	Schacht by Schönleber (161)
Do.	4.0	66.0	25-30	15	37	20-25	Vétillart (186)
Do.	20.0	40.0	--	12	26	16	Wiesner (190)
Lupinus sp.	--	--	2-3	--	--	16-20	Doǹa Dalle Rose (55)
Do.	2.0	2.5	2.7	--	--	20	Riso, R. 1939
Lygeum spartum	1.3	4.5	2.5	12	20	15	Vétillart (186)
Malachra capitata	1.6	4.5	2.8	7	29	15	Mendiola (118)
Malachra fasciata	1.2	5.1	2.0	6	42	16	Do. (118)
Malva sp.	11.3	29.1	17.0	9	22	15	Schönleber (161)
Marsdenia (silk)	10.0	25.0	--	19	33	--	Wiesner (190)
Mauritia flexuosa	1.0	3.0	1.5	10	16	12	Vétillart (186)
Melilotus alba	5.0	18.0	10.0	20	36	30	Do. (186)
Melochia umbellata	1.1	3.1	2.0	11	27	16	Mendiola (118)
Morus alba (primary)	7.0	32.0	16.0	--	--	25	Schilling (159)
Do. (secondary)	2.7	5.1	4.3	--	--	25	Do. (159)

TABLE 5.--Length (millimeters) and breadth (microns) relationships of the ultimate cells of various fibers as reported by different workers--Continued

Botanical name	Length			Breadth			Authority and reference number*
	Min.	Max.	Mean	Min.	Max.	Mean	
Morus papyrifera (Broussonetia papyrifera)	6.0	25.0	15	--	--	25-35	Vétillart (186)
Musa ensete	.5	5.0	2.3-2.5	7	26	18	Fibres and Fabrics Jour... (7)
Musa paradisiaca var. sapientum	--	--	5.0	20	40	28	Vétillart (186)
Musa sapientum	2.7	6.4	3-5.5	18	31	--	Saito (155)
Musa sapientum var. paradisiaca (Musa paradisiaca var. sapientum)	4.2	7.3	5.5	18	26	20	Copeland
Musa textilis	2.5	6.0	4.0	--	21	17	Copeland
Do	3.0	12.0	6.0	16	32	24	Vétillart (186)
Do	2.0	2.7	2.7	12	46	29	Wiesner (190)
Do	3.0	12.0	6.0	16	32	24	Lecomte (107)
Musanga smithii	2.5	3.0	--	--	--	36	Hoyer
Neoglaziovia variegata	2.8	6.8	--	27	88	--	Denniston (50)
Ochroma lagopus	--	--	--	--	--	30-40	Hanausek (84)
Onopordon ascanthium (bast)	--	--	5.9	--	--	6	Lüdtke by Schönleber (161)
Do. (leaf)	--	--	5.8	--	--	4	Do. (161)
Oryza sativa	--	--	.9	--	--	3	Copeland
Do	.5	2.5	--	4	15	--	Hoyer (96)
Do	.6	1.9	--	4	15	--	Saito (155)
Pachypodium rutenbergianum	3.0	7.0	4-5	15	35	--	Heim (89)
Pandanus odoratissimus	.7	2.2	--	15	25	--	Saito (155)
Do	1.0	4.2	--	--	--	20	Wiesner (190)
Phoenix dactylifera	2.0	6.0	3.0	16	24	20	Vétillart (186)
Phormium tenax	1.8	5.0	3.0	10	17	14	Lecomte (107)
Do	2.7	5.6	--	8	19	14	Wiesner (190)
Do	5.0	15.0	8-10	10	20	16	Vétillart (186)
Do	--	--	--	10	18	16	Hanausek (84)
Picea excelsa (Picea abies)	.7	5.4	2.5	13	67	39	Hoyer (96)
Pipturus arborescens	3.8	6.0	5.1	42	100	69	Mendiola (118)
Do	3.8	6.0	--	10	42	--	Do (118)
Populus spp	.4	1.4	.8	--	--	27	Hoyer (96)
Pueraria thunbergiana	--	--	2-3	--	--	12	Motte (121)
Do	1.0	4.2	--	10	22	--	Saito (155)
Raphia ruffia	.6	1.8	1.7	10	16	14	Lecomte (107)
Raphia taedigera	1.5	3	2.5	12	20	16	Vétillart (186)
Ricinus communis	--	--	10	--	--	45	Paroiskaia (98)
Saccharum sp	2.2	2.6	--	--	--	25	Hoyer (96)
Saccharum spontaneum	.8	2.8	1.6	12	20	15	Copeland
Salix sp	.5	2.4	1.5	(Secondary)		12	Herzog (94)
Do	--	--	1.1	--	--	12	Reimers
Do	--	--	--	(Primary)		18	Herzog (94)
Salix alba	--	3.0	2.0	17	30	22	Vétillart (186)

TABLE 5.--Length (millimeters) and breadth (microns) relationships of the ultimate cells of various fibers as reported by different workers--Continued

Botanical name	Length			Breadth			Authority and reference number*
	Min.	Max.	Mean	Min.	Max.	Mean	
Salix viminalis	--	--	1.0	--	--	12	Reimers
Sansevieria zeylanica	--	--	2-2.5	--	--	20	Lecomte (107)
Do	1.5	6.0	3.0	15	26	20	Vétillart (186)
Sarothamnus scoparius (Cytisus scoparius)	--	--	4.0	--	--	16	Reimers
Sarothamnus vulgaris (Cytisus scoparius)	2.0	9.0	5-6	10	25	15	Vétillart (186)
Sesbania grandiflora	1.8	3.8	2.7	8	37	22	Mendiola (118)
Sida arborea (Abutilon arboreum)	--	--	3.0	--	--	14-16	Lecomte (107)
Sida retusa (Sida rhombifolia)	.8	2.3	--	15	25	--	Wiesner (190)
Soja hispida (Glycine max)	1	4.5	--	8	28	--	Schwede (162)
Soja max (Glycine max)	1.0	4.5	--	8	28	--	Do (162)
Solanum tuberosum	2.0	45.1	15.9	--	--	25	Herzog
Do	--	--	22.9	34	38	35	Lüdtke (112)
Sophora flavescens	2.1	4.2	3.0	--	--	39-45	Schilling (160)
Spartium junceum	5.0	16.0	10.0	--	--	20	Vétillart (186)
Sponia wightii (Trema orientalis)	--	--	4.0	--	--	21	Wiesner (190)
Sterculia villosa	1.5	3.6	--	17	25	20	Do (190)
Stipa tenacissima	--	--	1.5	--	--	10-13	Lecomte (107)
Do	.5	1.9	--	9	15	--	Wiesner (190)
Do	.5	3.5	1.5	7	18	12	Vétillart (186)
Stropanthus sp. (hairs)	10.0	56.0	--	49	92	--	Wiesner, J. v. (191)
Thespesia lampas	--	--	1.9	--	--	--	Danteer (48)
Do	.9	4.7	--	12	21	16	Wiesner (190)
Thespesia macrophylla	.9	4.7	--	12	21	16	Do (190)
Do	--	--	--	18	27	21	Aisslinger by Schönleber (161)
Tilia sp	1.1	2.7	--	--	--	--	Wiesner
Do	1.3	5.0	2.0	14	20	16	Vétillart (186)
Do	1.1	2.7	--	--	--	15	Wiesner (190)
Do	--	--	2.0	--	--	16	Herzog
Tilia cordata	1.5	2.4	--	17	23	--	Saito (155)
Tilia europaea platyphyllos (Tilia platyphyllos)	1.3	5.0	2.0	14	20	16	Vétillart (186)
Tillandsia sp	.2	.5	--	6	15	--	Wiesner (190)
Trifolium pratense	3.0	6.5	4.5	12	25	--	Hanausek (86)
Triticum sativum (Triticum aestivum) (bast cells)	.4	4.1	1.3	8	38	19	Hoyer
Do. (Parenchyma)	.1	.9	--	50	113	--	Do.
Do. (Epidermis)	.1	.3	--	13	76	--	Do.
Triumfetta bartramía (Triumfetta rhomboidea)	1.1	2.8	2.0	9	27	16	Mendiola (118)
Triumfetta sp	--	--	9.0	40	70	--	Paroiskaia
Typha sp	--	--	1.2	--	--	12	Reimer
Do. (leaf bast)	.6	1.7	--	5	12	9	(5)
Do. (fruits)	--	--	5	--	--	7	Kihara (104)
Ulmus montana	1.5	7.5	--	10	20	7	Saito (155)

TABLE 5.--Length (millimeters) and breadth (microns) relationships of the ultimate cells of various fibers as reported by different workers--Continued

Botanical name	Length			Breadth			Authority and reference number*
	Min.	Max.	Mean	Min.	Max.	Mean	
Urena lobata	.8	2.4	--	--	14	26	Do. (155)
Do.	--	--	1.8	--	--	15	Teixeira (174)
Do.	1.0	2.5	1.4	9	27	13	Mendiola (118)
Urena sinuata	1.1	3.3	1.8	9	24	15	Wiesner (190)
Urtica dioica	--	--	10-20	20	80	25	Lecomte (107)
Do.	4.0	55.0	25-30	20	70	50	Vétillart (186)
Do.	23.0	56.0	46.3	--	--	36	Reimers
Do.	--	--	--	--	120	--	Moeller by Schönleber (161)
Urtica thunbergiana	5.0	60.0	--	20	63	--	Saito (155)
Vitis coignetiae (primary)	1.0	3.0	--	25	30	--	Do. (155)
Do. (secondary)	.4	1.0	--	10	25	--	Do. (155)
Wikstroemia ovata	1.7	4.2	3.0	3	21	12	Mendiola (118)
Wikstroemia sikokianum	2.5	5.3	--	10	30	--	Saito (155)
Wistaria chinensis	1.3	3.7	--	10	20	--	Saito (155)
Yucca sp.	.5	6.0	3.5-4	10	20	--	Vétillart (186)
Yucca aloifolia	1.2	5.2	--	7	14	--	Camin (34)
Yucca angustifolia (Yucca glauca)	1.6	4.7	--	11	14	--	Do. (34)
Yucca filamentosa	.7	2.4	--	9	24	--	Do. (34)
Yucca gloriosa	1.2	3.7	--	11	26	--	Do. (34)
Yucca karlsruhensis	.8	2.5	--	11	19	--	Do. (34)
Zea mays: (Bast)	.4	5.3	1.2	8	38	17	Hoyer (96)
Zea mays (Parenchyma)	.1	.5	--	29	231	--	Do. (96)
Zea mays (Epidermis)	.1	.2	--	17	71	--	Do. (96)
Zostera marina	--	--	3.0	--	--	6	Lecomte (107)

86 Russian. Experiments with Kendyr in U.S.S.R. Economic Review of the S.U. Bur. Foreign and Dom. Com. No. 3. May 17, 1929.

87 U.S. BUREAU OF PLANT INDUSTRY. DIVISION OF COTTON AND OTHER FIBER CROPS. DEWEY INDEX. CEIBA PENTANDRA (L.) GAERTN. Length tests of kapok fiber. 1922

* Numbers in this column in parentheses refer to Literature Cited, p. 122.; others refer to footnotes.

The earliest workers emphasized the fact that the cells of important textile and cordage fibers have a ratio in which the length exceeds the width by several hundred times. For example, the approximate ratio of some of the more important textile and cordage fibers are: Flax, 1,200; hemp, 1,000; abaca, 250; phormium, 550; jute, 100. In contrast, the ratios of some common paper fibers are: Pinus strobus 148, P. ponderosa, 103, Larix laricina 87, and Picea sitchensis 100. Although jute has a short ultimate cell and a low length to width ratio, its spinnability is increased over a so-called paper fiber by the fact that the fiber cells of jute separate out of the stem as a bundle of cells, while the cells of the specific paper fibers listed here disintegrate from each other in preparation. Individual plant cells of less than one-half inch in length are at the lowest limit of practical mechanical spinnability.

While in general the length-width ratio is very important, the degree to which the cementing materials that bind the cells together may break down is also important. In the common textile and cordage fibers, in which the fiber cells cling together in bundles, the actions of retting, scutching, decortication, and washing do not readily separate them from one another. However, in a plant like Asclepias syriaca which has a long fiber cell, 30 mm., and a length-width ratio of over 1,000, the retting action cannot be sufficiently controlled in practice to prevent most of the cells from separating, and when this occurs the result is a mass of tow fiber which is difficult to clean and is low in value. In ramie also the very long cells have a tendency to separate in the degumming process, which accounts for the difficulty of obtaining ramie line fiber in degumming and by ordinary flax and hemp retting and scutching methods.

The strength of the yarns manufactured from fibers depends in part upon the ability of their plant cements to withstand dissolution in ordinary use from wetting and atmospheric changes. One might postulate that in general the longer the fiber cells and the more compact the fiber bundles, the slower will be the destructive action on the cements which bind the fibers together. If this is a correct assumption, it will account in part for the fact that the fibers with a ratio above 200:1 (length to width) are the most important in commerce.

In abaca the ultimate fiber cells which make up the fiber strands have been measured by numerous research workers. Espino and Esguerra (64) have shown the fiber dimensions obtained from six varieties of abaca taken from different portions of the leaf sheath. The fiber cells of these varieties ranged in length from 2.6 to 8.4 mm. on the average, while the gross diameter for the different varieties ranged from 14 to 35 microns. The thickness of the cell walls ranged from 3.2 to 8.0 microns and the diameter of the lumen from 3 to 28 microns.

Espino and Esguerra found that the variety Bungulanon had the longest and also the widest fiber cells of the 6 varieties studied and Punucan had the shortest. The walls of the fiber cells near the outer epidermis were found to be very much thicker than those of the fiber of the discarded leaf portion. The lumina of the fiber cells from the discarded portion of the leaf had the widest diameter. The fibers from the outermost and the innermost leaf sheath were weaker than those from the sheaths in between. The variety Maguindanao, one of the commonest varieties in the Western Hemisphere, occupied a more or less intermediate position in reference to the dimensions of its fiber cells but was below average in tensile strength.

CHEMICAL COMPOSITION

A chemical analysis of abaca fiber was reported by Richmond (149) as early as 1906. The chemical composition of abaca fiber as determined by a number of investigators is shown in table 6. Care should be taken not to interpret the data too literally, however, because the results of the different workers were not obtained on the same moisture basis and they did not use the same technique in arriving at their results. In some cases the results as presented on a percentage basis include the moisture, in other cases they do not. Nevertheless, the results are believed to show the relative amount of the different chemical constituents in which the reader may have an interest.

Sherman (168) analyzed the ash of abaca fiber. Averaging his results of composite samples made up of different varieties from different districts, he found the ash analyses in terms of percentage to be: SiO_2 12.32; Fe_2O_3 and Al_2O_3 6.73; CaO 7.85; MgO 2.96; K_2O 43.26; SO_3 0.96; Cl 5.80; MnO_2 1.11; and P_2O_5 1.77. From these figures Sherman concluded that the principal constituents of the fiber other than nitrogen coming from the soil are potash, iron, alumina, lime, magnesia, and silica.

Norman (125) presented analyses of the organic constituents of different fibers which showed the relation of abaca to other fibers. His analyses indicate that abaca is similar to jute in its content of cellulose and total furfural but lower than jute in lignin and higher in xylan in the cellulose. Xylan has shorter molecules than the long cellulose chains, and fibers with high yields of xylan are not associated with high quality textile fibers such as flax and ramie. Norman's analyses for abaca are somewhat similar to ones for sisal.

TABLE 6.--Percentage composition of abaca fiber as reported by different investigators whose methods of analyses were not uniform

	A.G. Norman (125)	G.F. Richmond (149)	Hugo Müller (123)	A.J. Turner (184)
Oven-dry basis	Yes	No	No	No
Moisture	--	8.10	11.85	10.0
Ash	--	1.08	1.02	--
Lignin	8.51	--	--	5.1
Fat and wax	--	--	.63	0.2
Aqueous extract	--	--	.97	1.4
Cellulose	74.14	73.68	64.72	63.2
Hemicelluloses	--	--	--	19.6
Hydrolysis (a)	--	13.86	--	--
Hydrolysis (b)	--	20.79	--	--
Furfural yield	9.07	--	--	--
Cellulose furfural yield	9.04	--	--	--
Xylan in cellulose	14.01	--	--	--
Furfural from hemicellulose	0	--	--	--
Pectin	--	--	--	0.5
Incrusting and pectic matter	--	--	21.83	--

AGENCIES CAUSING DEGENERATIVE CHANGES

Biological Action.--Probably the most frequently encountered and the most destructive type of degeneration in the physical properties of abaca fiber occurs from biological action as the primary active agent. While the properties of the fiber are known to vary because of hereditary and environmental factors, these agencies normally do not produce as radical differences or as severe damage as that caused by biological action. Closely associated with biological destruction are changes resulting from atmospheric oxidation accelerated in some cases by sunlight and hydrolysis.

Bañuelos and Sherman (19) in a study of Philippine fiber found from observations made in the field and supported by laboratory experiments that all commercial abaca fiber produced by present methods of stripping is more or less heavily contaminated with bacteria and that the juices and soluble substances accompanying the fiber furnish the medium for their prompt and vigorous growth. The damaging effect produced on the fiber by biological flora appears to be caused by the acid fermentation products of its soluble constituents as well as by direct action of the bacteria on the fiber. To understand the biological deterioration that occurs in abaca fiber, it must be remembered that the preparation of the fiber in the field is carried out under conditions where cellulose-decaying organisms are very prevalent because of the large amount of plant tissue other than fiber that is permitted to decay at the base of the plants. This refuse provides ample inoculating material to which the fiber is exposed when stripped in the field.

In 1934 the acting secretary (136) of the Department of Agriculture and Commerce of the Philippine Islands in his annual report stated that complete disinfection of infected abaca by means of formalin fumes had been accomplished in the laboratory, and it remained only to apply this finding in adequate airtight chambers in order to disinfect the abaca bales economically on a commercial scale. Elaborating further, he said: "The studies on deterioration of abaca tend to show that fumigation with formalin and sea water treatment partially arrest the process. From the behavior of the casual organisms Aspergillus sp. with best growth at 30.6° to 38.7° C., Penicillium sp. and Chactonium [Chaetomium] at 27° to 28° C., control of deterioration would seem to hinge on modification of conditions in the bodega [warehouse], that is, lowering the temperature by means of good ventilation."

About 1920 there were many complaints from England regarding unsound fiber imports, and the belief was freely expressed that some of the abaca was adulterated with canton and pakol. The deterioration appeared to be more pronounced in the poorly cleaned, lower grades than in the excellent or good cleaning high grades of fiber. Deterioration was not confined to the fiber produced in any one locality. The defective fiber was characterized by weakness, brittleness, a dull dirty dark color and a musty odor, which was stronger in moist than in dry fiber. To determine the cause of the damaged fiber a study was made by Serrano (164), who reported that organisms belonging to the cellulose-digesting type such as Aspergillus flavus, Penicillium glaucum, Chaetomium elatum, and various other species of these three genera, were more common in the deteriorated samples than in normal fiber, and he showed that these organisms will cause deterioration when conditions are favorable for their growth.

Serrano stated that examination of fresh newly stripped fiber showed complete absence of any cellulose-digesting or any other kind of organism. Unfortunately, it is impractical to keep all organisms off the fiber as they are present in the air and on any surface with which the fiber may come in contact. However, deterioration can be controlled by taking precautions to prevent the organisms from developing in dangerous numbers.

Improper drying. --It is well known that organisms develop where there is abundant moisture. Drying the fiber promptly and thoroughly after cleaning and maintaining a low percentage of moisture in the baling and storage operations are prime requisites in preventing deterioration. Too much stress cannot be laid upon these points. It must be remembered that abaca is grown in regions of abundant moisture, high humidity throughout the day and night, and warm temperature. All of these factors are conducive to the growth of the organisms that cause cellulose deterioration. It is not as important to have an average low percentage of moisture, possibly 10 percent or less, as it is to have a uniformly low moisture content. In practice frequently the fiber is hung on racks or placed in stricks or hands to field-dry in the sun. The surface layer of the fiber in the strick, or many stricks with small amounts of fiber, will dry completely, while larger stricks or ones that have not been as well aerated will dry only partially. Hence, in practice it frequently occurs that while most of the fiber is sufficiently dry to prevent rapid biological growth, there are stricks that are baled and stored with too high a moisture content. Later these cause trouble.

Tirona (176) reported that fiber air-dried for a period of 20 hours tended to be stronger than that dried only 10 hours. The general practice in the Philippines is to dry fiber 8 to 12 hours or more, upon the assumption that the period of drying is immaterial. Tirona's studies were made with more than one variety of abaca and on plants grown under different environmental conditions. His conclusions suggest the advisability of taking the length of the drying period into account when determining the comparative strength of abaca fibers, and he points out that a study of the effective sun-drying period on the strength of abaca fiber might give results of practical interest.

Bañuelos and Sherman (19) state that "the freshly stripped fiber is bright in luster, high in color, very elastic, and somewhat weak. Quick and thorough drying accomplishes the triple purpose of making permanent the luster; of keeping the color from darkening, except very slowly; and hardening and toughening the fiber strands, together with the more or less pulpy substances surrounding them, and thereby reducing the elasticity to normal. The fiber, promptly and well dried, is then in its best possible physical condition to perform its allotted commercial functions, which are to maintain its tensile strength, color, and resistance to wear for a reasonably long time."

Inadequate circulation of air. --Various experiments not only on fibers but on numerous crops have shown that inadequate circulation of air in the warehouse is conducive to the growth of cellulose-digesting organisms. This is particularly true when the fiber stored has a high moisture content. So far as we now know, the major physical factors that induce biological deterioration of abaca through a flora infestation are conditions of high moisture, high temperature, poor air circulation, and long storage, together with some degree of improper cleaning.

Acid content. --As previously stated, abaca fiber deteriorates more readily when it has not been well cleaned. Sherman and Sherman (169) attempted to demonstrate how the presence of organic acids on the abaca fiber brings about deterioration. They found that the natural acid content of abaca is greater in the fiber having low tensile strength. They did not state that the acidity of the abaca sample was a determining or causative factor of its tensile strength, but they did present results which show a uniform parallelism between its tensile strength and its acid content.

Action of heat. --The Imperial Institute once made an extensive investigation to determine why the fiber then being exported by the Philippines arrived in England in a weak or damaged condition. The investigation (76) showed that the damage was due to a degradation of the cellulose, doubtless of bacterial origin, promoted by prolonged storage in a moist condition at a tropical temperature. Altson[88] showed that abaca fiber exposed to temperatures of 100° C. for 2 days or to 70° C. for 20 days under moist conditions became weaker and more brittle and the color turned darker. Abaca fiber subject to the same temperatures for the same length of time but kept under dry conditions was not found to have deteriorated if the fiber was reconditioned after the heating and allowed to regain its normal atmospheric moisture. Altson repeated his experiments a second time but did not obtain such conclusive results. He concluded that it would not be desirable

[88] ALSTON, R. A. REPORT ON DEFECTIVE MANILA HEMP. 24 pp. South Kensington, England. 1922. (Imperial College.) [In Manuscript.]

to test lower temperatures because the detection of changes would be difficult unless the experiments were carried out over an unreasonably long period.

To explain the deterioration of abaca fiber due to biological action on samples on which no spores were detected, Altson suggested that certain nonsporing species of bacteria might have been present which were easily killed by thorough drying. Altson's work is of value in indicating the changes that may be expected to occur in abaca fiber when it is subjected to high temperatures for prolonged periods.

Serrano (165) found that abaca fiber is affected by heat, the effect being noticeable in color, tensile strength, and stretch. Dried samples subjected to 120° C. showed no appreciable loss in strength and stretch, but at 50 percent moisture the losses were marked.

Matthews (116) cites Dietz as having determined the specific heat of Manila hemp as 0.322, which is very similar to that of other vegetable fibers such as cotton, flax, and jute.

Standards of the National Board of Fire Underwriters for the "storage and handling of combustible fibers," September 1941, which presents information regarding the flammability or combustibility of textile fibers, gives Manila hemp as highly combustible but not subject to spontaneous heating and with a high salvage value.

Imperfect cleaning.--The association of greater amounts of pulp cells with the lower qualities of abaca fiber is said to account for the more rapid deterioration of fiber of these grades as compared to the higher grades which are freer from pulp cells. While various authors have found to their satisfaction that the good grades of fiber contain practically no pulp cells or parenchyma, in contrast to a high percentage of parenchyma in the lower grades, Altson[89] found as a result of an examination of many samples, that good and bad fibers alike contain parenchyma. It is unfortunate that no one has determined by actual test the quantity of parenchyma cells associated with fiber of different cleaning.

Theoretically the terms "excellent cleaning," "good cleaning," "coarse cleaning," etc., used in the trade are associated with different quantities of parenchyma cells adhering to the fiber, but actually the quantities may vary little. As a matter of fact, the term "excellent cleaning" may have greater significance in respect to the fineness of the fiber than to its purity. This is pointed out because of the general belief that abaca men associate cleanness with the presence of pulpy material and give less weight to fineness. Possibly in grading abaca the reverse is true, for fineness is the major end factor in the degree of cleaning.

In practice purity of fiber is determined largely by observation or sight. To some extent the association of fineness through feel and the sense of sight may also have some relation to purity. This is due to the fact that in general fineness is correlated with purity and coarse strands or ribbons of fiber are apt to have more encrustment and foreign material present. This is apparent from the chemical analysis of fiber representing excellent, fair, and very coarse cleaning, as shown in table 7. The purity of cellulose in fiber as represented by cellulosan is much higher in samples of excellent cleaning than in samples of less perfect cleaning.

TABLE 7.--Chemical analysis of various grades of abaca fiber with different degrees of cleaning[90]

Philippine Government grade	Cellulosan*	Xylan in cellulose	Total furfural	Furfural in polyuronides	Lignin	Protein	Ash
	%	%	%	%	%	%	%
DL DAET Coarse (very coarse cleaning)	67.8	16.3	12.9	4.85	9.22	2.36	3.34
K Medium (fair cleaning)	69.0	16.8	13.1	4.67	11.20	2.40	4.24
A Extra Prime (excellent cleaning)	82.7	16.3	12.4	2.57	6.58	1.21	1.10

[90] U. S. BUREAU OF PLANT INDUSTRY. DIVISION OF COTTON AND OTHER FIBER CROPS AND DISEASES. Unpublished data. [n.d.]
*Cellulosan = Cellulose + xylan in cellulose.

In an investigation (77) made at the Imperial Institute of certain samples of damaged abaca (76), it was found that the quantities of ash which they yielded varied from 3.7 to 5.1 percent, while two commercial samples of good quality gave 1.1 and 2.4 percent, respectively. In this connection, it is of interest to note that the Philippine Bureau of Science at Manila found that the percentage of ash varies with the grade of the fiber in such a way as to render the determination

[89] See Footnote 88.

of the ash an approximately accurate method of ascertaining the grade.[91] The percentages of ash yielded by the various Government grades of abaca were reported as follows: A. Extra Prime, 1.14; B. Prime, 0.62; C. Superior Current, 0.99; D. Good Current, 1.33; E. Midway, 0.81; F. Current, 1.93; S1. Streaky No. 1, 1.62; S2. Streaky No. 2, 2.15; S3. Streaky No. 3, 1.31; G. Seconds, 2.03; H. Brown, 2.32; I. Good Fair, 2.46; J. Fair, 3.00; K. Medium, 4.10; L. Coarse, 4.56; M. Coarse Brown, 3.36; DM. Daet Coarse Brown, 2.76.

These results would indicate that cleaning is a factor in the presence of different amounts of ash in the fiber and that the higher quantities of ash show more adulteration of the relatively pure cellulose of abaca fiber cells with foreign tissue high in ash.

Storage.--The influence of length of storage on deterioration of fiber is a subject about which far too little is known. The general assumption has been that the annual loss of strength of fiber stored under relatively dry conditions is about one percent a year. The data for abaca, henequen, sansevieria, and abutilon shown in table 8 seem to support this belief.

TABLE 8.--Annual decrease in thousand pounds per square inch breaking strength of different fibers stored under relatively dry conditions[92]

Fiber	Source of origin	Age (years)	Breaking strength		
			Present (1949)	Percent total loss*	Percent annual loss*
Abaca	Not known	45	49.1	35.6	0.792
	Philippines	42	49.4	35.2	.839
	do	37	24.6	67.7	1.831
	Borneo	23	48.2	36.8	1.601
Henequen	Mexico	42	31.8	47.5	1.131
Sansevieria	East Africa	44	29.6	51.3	1.165
	Florida, U.S.A.	44	30.3	49.6	1.127
	Puerto Rico	44	30.3	49.6	1.127
	Africa	40	35.3	41.3	1.032
	Guadeloupe	36	48.1	20.0	.555
	Nicaragua	33	38.4	36.1	1.094
	Florida, U.S.A.	28	45.4	24.5	.874
	Mexico	28	36.4	39.4	1.409
	do	28	48.4	19.5	.695
	Cuba	17	40.1	33.3	1.958
Abutilon	Iowa, U.S.A.	49	23.5	25.1	.513
	Delaware, U.S.A.	47	16.2	48.4	1.030
	Manchuria	39	19.2	38.8	.996
	do	39	16.9	46.1	1.184
	do	35	14.2	54.7	.565
	Mexico	29	22.5	28.3	.977
	do	22	18.5	41.0	1.867

[92] See Footnote No. 90.
*Comparisons are with assumed original strengths based on many fresh samples tested in the same laboratory by the same technique, i.e.: Abaca 76.3, henequen 60.6, sansevieria 60.1, and abutilon (malvaceous) 31.4.

Sherman and Sherman (169) found that abaca stored in a room in which the moisture content of the fibers ranged from 9 to 11 percent showed losses in tensile strength after a 6-month period. Sablan and Villaraza (154), in a somewhat related study on the deterioration of abaca in storage, found that abaca fiber with adhering pulp deteriorates faster than clean fiber. These results were obtained from testing various grades of abaca as influenced by the degree of cleaning. Thus the fiber graded excellent cleaning deteriorated in strength after 6 months 2.17 percent, good cleaning 4.41 percent, fair cleaning 6.78 percent, and coarse cleaning 18.07 percent.

[91] Cordage World, Nov. 1921, p. 41.

TESTS FOR DETECTING DIFFERENT TYPES OF DEGRADATION

Miscellaneous tendering. --Castle and White (38) attempted to develop tests to differentiate various types of deterioration. Quick laboratory treatments were used to bring about deterioration from biological action, oxidation, heat, acids, pentosan removal, and delignification. After exhausting several methods, Castle and White concentrated upon microscopic examination of such tendered samples. They recommended the following procedure:

(1) Boil a few fiber strands in water, tease out with a needle, and boil for 1 minute in 5 percent sodium carbonate solution. Rinse immediately in cold water and make three separate mountings in zinc chloriodide. Then heat the slides on a steam bath for 3, 6, and 9 minutes respectively, re-stain, and examine under the microscope, using polarized light.
 (a) If bubble swelling is shown at any stage, then tendering by oxidation, heat, or alkalis is indicated.
 (b) Segmentation of the fibers as illustrated by the authors indicates acid tendering.
 (c) If the fibers are stained a uniform bluish-purple color which does not change when the polarizer is rotated, then it is clear that delignification has occurred.

(2) If bubble swelling has been observed in test (1) the test should be repeated in exactly the same way as above except that the boil in sodium carbonate solution is omitted.
 (a) If bubble swelling is still obtained the tendering has been due to removal of pentosans.
 (b) If the appearance is now the same as that of normal fibers then the tendering must be due to oxidation or heat.

(3) If the fiber appeared normal in the above tests it may be undamaged, or else tendered by the action of micro-organisms. Cross sections are prepared and mounted in zinc chloriodide.
 (a) Sections traversed by dark bands or irregular dark patches which do not disappear on warming for 2 minutes indicates that biological attack may be suspected.

Fiber adulterants. --Frequently it is necessary to test abaca fiber to determine whether degradation is due to a mixture of fibers of lesser value. The Textile World Record, September 1905, showed that abaca fiber could be distinguished from sisal by the color of the ash, the ash of abaca being grayish black while that of sisal is white. Later, Swett (173) reported that Manila fiber in rope and twine after being freed from oil and soaked for 20 seconds in a solution of chloride of lime containing 5 percent of available chlorine, acidulated with acetic acid (30 cc. of bleaching solution and 2 cc. of glacial acetic acid), rinsed in water, then in alcohol, and finally exposed for a minute to the fumes of ammonia, would turn a russet brown while all other rope fibers turned a cherry red.

As canton fiber may occasionally be mixed with abaca, because of the alleged practice of performing this operation in the Philippine Islands where both fibers are common, it is important to be able to distinguish the two. In identifying the fiber of canton the principal diagnostic character is the pit (3). The pit, or unthickened portion of the cell wall looks under the microscope like a hole through the wall. The pit of canton is almost parallel to the long axis of the cell, whereas in most varieties of abaca the pits lie at a more or less sharp angle to the cells. Those varieties of abaca whose pits lie almost parallel to the long dimensions of the cells may be distinguished from canton by the dimensions of the cells, especially by the thickness of the wall and the size and abundance of the stegmata. The stegmata, which are silicified cells, look like small bricks with small circular excavations on one surface. Aldaba (3) found that canton fiber had abundant stegmata cells, whereas the stegmata of abaca were scanty and sometimes it was necessary to examine a number of samples before they were discovered. Aldaba (3) reported also that when a match was applied to single strands of abaca and canton fiber the canton burned more readily than the abaca and with almost a white ash while abaca produced a darker ash.

Sherman (167), however, after rigid comparison of the ash color with color charts, stated that the two fibers could not be differentiated by the ash test and that potassium chlorate solution would not produce distinguishing color differences between canton, abaca, and maguey. Sherman did find that canton was weaker than abaca, less elastic, contained a higher natural acidity, higher ash content, and a greater "mercerization curl" with 20 percent NaOH.

Excellent summaries of microscopic and staining methods for use in identifying abaca and other common fibers are found in "Microscopic Methods Used in Identifying Commercial Fibers" by Thora M. Plitt, Circular C. 423, U.S. Department of Commerce 1939, and "Identification of Fibers," Journal of the Textile Institute, Vol. 32, June 1941.

It would appear from the literature cited above that an anatomical study of abaca for pit and stegmata cells plus the "mercerization curl" are the most reliable means of differentiating canton from abaca. Unfortunately, the tests are slow and require some experience on the part of the technician.

Billinghame (24) described an "Amoa" test for the detection of sisal when mixed with manila fiber. He stated that phormium, Mauritius, and maguey can also be distinguished from manila by this test. In the Amoa test the fiber sample is steeped from 5 to 10 minutes in a boiling 5-percent solution of HNO_3, rinsed in water, and then placed in a cold solution of 1 part of 52° T_W NaOCl and 3 parts of water for 10 minutes. Abaca fiber after drying "regardless of origin" colors bright orange-red, whereas sisal, phormium, Mauritius, and maguey fibers color pale yellow.

PHYSICAL CHARACTERISTICS

Since abaca fiber is valued mainly for industrial use, such physical characters as luster, color, smoothness, etc., are of less importance than they would be in a textile clothing fiber. The first physical properties that enter into the judgment of abaca fiber are those used in grading the raw material in the area of production. These in order of decreasing importance are (1) degree of cleaning or purity of the fiber; (2) color; (3) uniformity; and (4) strength. Indirectly the degree of cleaning influences the fineness of the fiber, as previously noted, since the higher grades, which are obtained from excellent cleaning, represent finer fiber than that obtained from coarse cleaning. Of all the other physical characters, only length is considered, and length is of minor importance since the fibers must be above a definite specified length to be classified as cordage grades.

Where hand stripping or the spindle machine is used, these cordage properties in the order given should be considered in the field or in the stripping shed preliminary to Government inspection. The fiber stripper busy at his job of turning out fiber cannot concern himself with testing fiber from different hand lots for strength, but factors that he can easily and quickly control are the type of knife and its influence on the degree of cleaning; the segregation of hand lots into different colors; the segregation of unusually short, tangled or off-color lots to insure uniformity and, finally, the elimination of weak or damaged material.

Differences in chemical or physical properties may make one fiber more valuable than another. In practice many factors influence the properties of a fiber, such as the amount of foreign matter or encrustants which are present on it, the batching fluids or sizing which are added in the manufacturing process, as well as the structural changes that take place as it is manufactured into yarns and fabrics. For the present, however, we are concerned primarily with the properties of the individual raw fibers. There are a tremendous number of physical properties that may in one way or another influence the value of a particular fiber for a particular use. No one fiber has all the good characters of the others and hence it may not be utilized to advantage over other fibers for all uses. In some cases what is considered a poor physical property in a fiber may actually be an advantage for a special use. Jute might be cited as an example. Strength in fibers and yarns is recognized as one of their most valuable properties, yet the basic weakness of jute has given it preference over stronger fibers for use by the Post Office Department as a twine for tying letters. The twine employed by the Post Office must be of such diameter and weight that it will not cut through the envelopes when used in tying, and yet will be of such low strength that an employee can break it with his hands. Cotton twines of the same diameter and weight would be too strong to serve the purpose. Thus it may be seen, as a selected illustration, that here is a fiber whose weakness is actually an asset in reference to its utilization.

While the number of physical properties of a fiber is large, including among the more important purity, length, fineness, elasticity, breaking strength, pliability, luster, molecular structure and orientation, tenacity, ductility, absorbency, hygroscopicity, resiliency, combustibility, etc., it is an unfortunate fact that many of the fibers have not been adequately studied and compared in reference to some of their more important properties. One has only to visit a group of textile mills to realize how inadequate some are in their methods of testing to determine differences in performance of various varieties, grades, or types of the fiber or fibers that they manufacture.

Although cordage fibers in the raw or in manufactured form do not normally command as high a price as textile fibers and their fabrics, it is just as important that their physical properties be studied and known. Moreover, cordage fibers may require testing in respect to a number of physical properties that are unimportant in fabrics. For example, it is important to know the buoyancy of a manila rope as compared to that of sisal, coir, or hemp. Perhaps it might be asked how important a knowledge of the physical properties of a particular fiber would be to a manufacturer whose machinery limits his business to the preparation of certain types of fibers. For all practical purposes, one might visualize that a manufacturer could only use the relatively few fibers of which supplies are available, namely, abaca, sisal, henequen, hemp, flax, and cotton. From past experience a manufacturer of binder twine knows well that only hard fibers such as abaca, sisal, and henequen are available in quantities which are particularly applicable to his type of spinning machinery and are wanted by the trade. His economy and efficiency of operation further narrow him down to the fact that henequen is normally the cheapest fiber available that has satisfactorily served his requirements and hence is the fiber that he must use. However, such a manufacturer having decided upon the use of henequen for the production of binder twine, may be confronted with many problems in connection with its physical properties or its manufacturing construction such as twist per inch, fineness, quality, color, length, and strength as influenced by grade, and whether or not a cheap grade of sisal would be better for his purpose than a medium grade of henequen.

Purity.--Stem and leaf fibers in the raw state as prepared in most agricultural industries contain relatively large percentages of encrustant materials. These are the remnants of cells (parenchyma) and their cell-wall structures which have surrounded the thicker wall fiber cells (sclerenchyma) and have not been entirely removed in the cleaning process. In addition to the encrustants that are present on abaca, sisal, flax, hemp, and jute, there are frequently small pieces of wood, called "shives" in flax and "hurds" in hemp, that have not been removed in cleaning because they became entangled with the fiber. These encrustants, plant parts, and foreign material influence the grade and the manufacturer's choice of a grade as well as the cost of manufacturing the fiber into the final product. Over a period of years cleanliness or purity of the fiber, not so much in reference to encrustants as to the other foreign material mentioned above, has been the manufacturer's first concern in selecting fiber of certain plant species.

Purity determines the grade of abaca. The Philippine abaca fiber is grouped into different classes each of which contains several grades. The groupings are ranked according to the degree of cleaning as excellent, good, fair, coarse, and very coarse cleaning. High purity with sisal, henequen, and abaca to some extent is taken for granted as the physical classification of the fiber partly eliminates its being a factor that registers in observation. However, in tow grades of these fibers, purity becomes more important. The analyses of fiber of several grades with different degrees of cleaning, presented in table 7, show large differences between grades. Especially noteworthy is the higher content of noncellulose constituents in the fiber of poorer cleaning.

Color.--As previously explained, in the field with hand stripping or in the smaller machine-cleaning establishments of the Philippines the first grading is mainly a visual one involving the separation of fiber on the basis of cleaning, color, uniformity, and strength, in that order. The next step is performed by inspectors of the Fiber Standardization Board where the relative importance of these characters may be changed. Strength, for example, may play a more important part in the classification of a lot of fiber when it is compared with lots from other sources of production, and the color of an individual lot may be uniform within itself but in comparison with other lots differences may be observable.

The work of the Fiber Standardization Board is still based on hand testing combined with visual examination. A more scientific approach to the determination of color is the spectral reflectance test developed by Becker (21) and Becker and Appel (22). By this test it is possible to determine quantitatively the color value of fiber of the different standard Philippine grades of abaca and also to evaluate the color of abaca rope. As this measurement, known as the "Becker value," has been adopted in the United States Federal Specifications for Manila rope, it deserves attention here. Fibers are cut into lengths of 1.5 to 2.5 mm., mixed, and an 8-gm. portion is extracted in a Soxhlet apparatus for 2 hours with petroleum ether. The extracted fibers are spread on clean filter paper, dried over night and the spectral reflectance and the colorimetric measurements of the fiber are determined in certain specified ways on the following day.

Although, strictly speaking, the Becker test is not a measure of color, it does give a value that is related to the color characteristic which is one of the principal elements in the grading of abaca rope fiber.

The average values for abaca fiber of different grades recorded by Becker (21) for the spectral reflectance of wave length 500 mu follow: AB, 59.3; CD, 54.9; E, 49.9; F, 46.5; S_2, 45.4; S_3, 33.5; I, 42.5; J1, 40.0; G, 31.3; and H, 21.5. There was overlapping in the measurements for some of the different fiber grades.

The minimum values for rope for Government purchase are:

43 for rope 1/2 to 2 inches in nominal circumference, inclusive;

40 for rope 2-1/4 inches and above.[93]

Becker stated that her results indicated the possibility of using such measures as quantitative spectral reflectance to supplement, if not to replace, the present method of grading abaca for color. To the authors it would appear that the Becker test is one requiring judgment in the manipulation of technique in preparing the samples as well as a long time element which are factors that cannot be adapted to the quick visual inspection necessary in the trade to insure economy.

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[93] U. S. GENERAL SERVICES ADMINISTRATION. FEDERAL STANDARD STOCK CATALOG. Section IV (Pt. 5). Federal specification for rope: Manila. T-R-601a. Nov. 26, 1935, and T-R-601a Amend.-2. Dec. 10, 1943.

Uniformity.--The subject of uniformity in abaca has received little attention from scientists engaged in research on abaca fiber. Possibly the term as used in grading abaca in the field or by Government standards is too general, covering as it does uniformity of color, length of fiber, cleanness, fineness, strength, and other important characters. As these characters are not weighted against each other in any measurable degree, it is not hard to understand why uniformity as a whole has received so little study.

With abaca uniformity in grading is important to the spinner, for it affects both the efficiency and the quality of performance. The importance which he attaches to this character is reflected in the fact that he hesitates to pay a high price for fiber from new areas where standardization methods are poor and variations may be expected to occur.

Variations in abaca grading are defined in different grade descriptions by degrees of tolerance as based upon trade customs and understandings rather than by specific measurements, as, for example, the statements that if the "fiber is impaired in any way, the fiber shall be graded as 'damaged'; 'Good cleaning' denotes fiber some filaments of which may be stuck together and to which some moderate amount of extraneous pulpy material may adhere"; and "normally possess a good sheen or luster... will have noticeably less sheen than the fiber included in the first three grades..."

These examples taken from Standard Grades of Central American abaca illustrate the unspecific modifying adjectives. However, in practice they are well understood and create a minimum of arbitration.

Strength.--Strength is the most sought after of all physical properties in abaca because the end use of this fiber is in articles in which strength is the prime requisite. Strength is a basic quality in abaca, for fiber that is below average strength will be thrown out of any of the established standards and graded as "damaged" irrespective of coloring or cleaning.

Kaswell and Platt[94] in 1949 published the results of a well-planned study to determine the basic mechanical properties of abaca, sisal, henequen, and sansevieria. The results on strength and elongation follow:

Fiber	Strength	Coefficient of variation	Elongation	
	Gms/denier	*Percent*	*Percent*	*Coeff. of variation*
Abaca	7.0	21	2.78	21
Sisal	4.4	21	2.72	18
Henequen	3.3	20	4.77	21
Sansevieria	4.5	25	2.70	20

Table 9 presents a summary of several important studies on the subject of strength in cordage fibers. The table does not show data obtained by similar methods, but it does show that by different methods and with different samples abaca displays extraordinary strength as compared with other fibers. In order of decreasing strength the fibers rank in general as follows: Abaca, sisal, phormium, henequen, cabuya, jute, and ambari.

Physical chemists have shown that fibers are made up of chained molecules. This structure is often compared to a string of beads. These beads may be in crystalline form or in an amorphous form, or the two may be somewhat intermixed. The strength of the fiber is correlated with the orientation of the chained molecules. In ramie and flax the chain and crystalline molecules are more parallel to the fiber axis, and fibers with this structure possess great strength. In other fibers like cotton the molecules are rather more in the form of a spiral, are less perfectly crystallized, and are in a more amorphous form. Such fibers are weaker. Berkley (23) found from a study of X-ray defraction patterns in cross sections of abaca fibers taken from different parts of the leaf sheath that the cellulose molecular chain of fibers from the outer or dorsal region of the leaf sheath showed a higher order of structure than that from the central or the inner or ventral region of the sheath. This is important because of the different methods used in extracting abaca fiber. When the leaf sheaths are "tuxied" and cleaned by hand or by hagotan machine the fiber is extracted only from the outer or dorsal region of the leaf sheath, but when the large semiautomatic decorticators of the Corona type are used, the entire leaf sheath is transported to the

[94] KASWELL, E. R., and PLATT, M. M. INVESTIGATION OF THE MECHANICAL PROPERTIES OF HARD FIBERS WITH REFERENCE TO THEIR USE IN CORDAGE STRUCTURES. U. S. Off. Naval Res., Contract No. N7 ONR 421. Tech. Report 3, 36 pp. Jan. 1, 1949. [Unpublished.]

TABLE 9.—Breaking strength of abaca and other fibers as reported by several investigators.

[The separate results are not directly comparable as they represent different methods of testing and reporting.]

Fiber	Breaking strength[a]		Breaking strength[b]		Breaking strength[c]		Breaking strength[d]		Breaking length[e]	Strength abaca specification[f]	Breaking strength per gram meter[g]
	Not knotted	Knotted	Not knotted	Knotted	Dry	Wet	Dry	Wet			
	X 100/fineness		*1,000 lbs. per sq. in.*		*Pounds*	*Pounds*	*Grams*	*Grams*	*Kms.*	*Percent*	*Grams*
Abaca	39.50	10.76	76.3	17.9	87.3	69.0	958.90	792.00	62.0	1.128	2,254
Hemp	33.10	20.25	—	—	49.0	28.3	—	—	47.3	—	—
Sisal	29.38	10.80	57.1	16.1	68.6	60.0	1,379.00	659.00	43.0	.942	1,472
Sunn	30.03	15.31	—	—	—	—	150.10	159.27	—	—	—
Ambari	27.72	5.20	—	—	44.0	40.0	131.17	78.36	—	—	—
Zapupe Vincent	—	—	—	—	—	—	—	—	—	—	1,394
Flax	26.5	21.80	52.9	29.8	—	—	—	—	—	—	—
Cabuya	—	—	38.7	14.2	—	—	299.00	288.70	—	—	1,297
Phormium	25.34	10.08	—	—	—	—	442.00	373.40	—	—	1,222
Ramie	61.00	40.22	67.4	33.0	—	—	—	—	—	—	—
Jute	24.13	9.96	44.1	19.4	48.0	40.0	93.68	84.44	33.2	.799	—
Paka	21.56	3.64	—	—	—	—	108.31	80.57	—	—	—
Palma istle	—	—	—	—	—	—	—	—	43.1	—	—
Henequen	—	—	60.6	—	49.0	42.0	950.20	876.00	—	.649	1,085
Kenaf: Retted		—	31.4	12.5	—	—	—	—	—	—	—
Kenaf: Decorticated		—	33.3	15.3	—	—	—	—	—	—	—
Sansevieria	—	—	51.2	12.4	—	—	—	—	—	—	—
Cantala	—	—	—	—	—	—	—	—	—	—	625

a Breaking strength multiplied by the quotient of 100 divided by diameter of fiber (88).
b Breaking strength in 1,000 pounds per square inch.[95]
c Breaking strength of bundle weighing 5 grains per 15 inches in length (0.34/40 cm.) (170).
d Breaking strength in grams per bundle (29).
e Breaking length (kilometers) to cause fiber to break by its own weight (27).
f Breaking strength divided by abaca specification - percentage abaca specification (51).
g Breaking strength calculated for fiber strand weighing 1 gram per meter of length (53).
95 See Footnote No. 90.

machine for fiber extraction. In the latter case the fiber is made up of the vascular bundles from the dorsal as well as the ventral side of the leaf sheath. This fact might indicate that fiber cleaned on the large decorticators would be weaker than that cleaned by the hagotan method. In practice, however, other factors influence cleaning and little difference of practical importance has been found between the strength of fiber cleaned by one method and that cleaned by another.

FACTORS CAUSING VARIATIONS IN TENSILE STRENGTH

In addition to the variations in the tensile strength of abaca fiber resulting from deterioration caused by various agents and methods of cleaning and handling, there are other factors of sufficient importance to be worthy of discussing. These are more or less hereditary factors such as variety and location of the fiber in the plant and factors of an environmental nature such as locality of growth.

Fiber from different leaf sheaths of one stalk.--Tirona (177) found wide variability in fiber strength within the same variety and plant sheath location. Variability increased from the outer to the middle to the inner leaf sheaths.

Espino (62) reported that the fibers from the inner sheaths are finer and weaker and better adapted to textile use than those from outer sheaths, which produce a coarse, strong, and often discolored fiber suitable for cordage. The intermediate sheaths give the strongest fibers. Espino states that this is probably so because the excessive amount of stegmata in the fiber from the outside sheaths makes the fiber brittle and the lack of well-developed walls in the cells of the innermost sheaths makes the fiber weak. Another point shown by Espino that is of more academic interest than of practical importance is the fact that the fiber in the outer edges of a sheath are stronger per unit of weight than those from the middle part of the same sheath. Espino's results are shown in table 10.

Berkley and co-workers (23) concluded from tests of abaca fiber samples collected in different Central American countries that fiber strength is greatest in the streaky sheaths (near outer sheaths), somewhat less in the outer brown sheaths and the ocher or cream-colored sheaths just beneath the streaky, and least in the white fiber near the center of the plant.

It can be concluded from these separate investigations which yield almost identical results that the younger, immature fiber cells of the inner sheaths have weaker fiber than the older, more mature fiber cells of the outer sheaths.

Fiber from different heights in the stalk.--The fiber cells in the upper tip of an abaca leaf sheath are older than those in the base of the same leaf sheath at the ground level. Since it has been shown that the younger cells of various fiber plants are weaker than the older cells, it would be expected that the weakest fiber in abaca would be that from the lower base section of the leaf sheaths. To determine the correctness of this assumption, Berkley and co-workers (23) studied the strength of samples of fibers of different varieties from four Central American countries taken at different heights in the plant. They concluded: "The fiber properties vary with height in plant for both varieties [Maguindanao and Bungulanon]. Tall plants grown in deep shade show little difference in fiber properties up through the first 10 feet, but near the top the fiber strength, flex life, and resistance to abrasion decline. Short, stunted plants grown in inadequate shade show a marked reduction in physical properties with height in the plant above the first 4 or 5 feet ... In short plants the first 6-foot section, going up from the base, may be as much as 20 to 30 percent higher in fiber strength, flex life, and resistance to abrasion than the second section or top." In Berkley's work the basal samples were taken from a 4- to 6-foot section, and the fiber tested was from near the middle of the 4- to 6-foot section, and no tests were made on the fiber much closer than 2 feet from the base of the plant. This might indicate that he missed testing the most immature part at the base of the sheath. Further, it might indicate that the abaca fiber matures rather quickly to attain its greatest strength and that fiber cells a short distance up the stalk have already reached their maximum strength. The low strength in the tips is harder to explain.

In an attempt to obtain additional information on this subject, fiber taken from a full length stalk of 12 feet was specially cut close to the ground, cleaned, and sent to the United States Department of Agriculture for further tests. The results are shown in table 11. These results indicate minor weakness in the basal section and more marked weakness in the tip sections. The weakness in section 3 cannot be explained.

Fiber from different varieties.--Varietal tests usually include comparisons of yield, resistance to disease, degree of suckering, longevity, etc., but little work appears to have been done on the relative fiber strength of different varieties. Hereditary variations in the strength of fiber of different varieties have been found in cotton and flax and may be expected to occur in abaca. They are characters that the abaca breeder should constantly keep in mind in any improvement program.

TABLE 10.--Strength and the stretching of fibers obtained from different leaf sheaths of one trunk

Sheath	Edges				Middle portion			
	Stretching	Breaking weight	Weight of sample	Strength calculated to gm. basis	Stretching	Breaking weight	Weight of sample	Strength calculated to gm. basis
	Mm.	Gm.	Gm.	Kgm.	Mm.	Gm.	Gm.	Kgm.
1	12	6,256	0.12	52.133	11.5	7,416	0.14987	49.483
2	9	6,367	.1209	52.704	12	7,767	.1503	51.676
3	10	6,367	.12022	52.663	12	8,515	.1702	50.029
4	14	6,442	.11986	53.737	12	8,617	.1697	51.367
5	12.5	6,487	.1102	58.865	16	10,667	.2000	53.365
6	13	7,972	.15	53.147	14	9,547	.16974	56.245
7	8.5	5,367	.11032	48.649	10	9,399	.1804	52.100
8	11.5	8,405	.15	56.033	14.5	11,477	.1800	63.781
9	14	7,964	.13	61.261	13.5	11,055	.19572	56.483
10	13	9,777	.15086	64.801	12.5	10,769	.21026	51.168
11	8	6,859	.13072	52.470	12	8,616	.19032	45.271
12	9	6,388	.12054	52.994	8.5	7,114	.15078	47.247
13	8.5	6,238	.11088	56.259	12	7,642	.1704	44.847
14	13	6,488	.11068	58.619	10.5	7,103	.16036	44.292
15	9	6,762	.1498	45.147	8	6,864	.15034	45.656
16	9	3,987	.0804	48.345	9	5,496	.13672	40.198
17	8	3,655	.0807	45.266	8	4,305	.12044	35.743
18	6	1,891	.04062	46.555	7.5	3,558	.10843	32.813
Average				53.313				48.431

TABLE 11.--Strength of abaca fiber in thousands of pounds per square inch as influenced by vertical location in the stalk

Means

Type of fiber	Base section 1	Next higher section 2	Section 3	Section 4	Section 5	Tip section 6	Mean
Clear	58.8	69.1	57.6	65.5	57.0	51.6	59.9
Streaky	53.9	58.4	57.8	60.8	58.7	48.0	56.3
Both*	56.4	63.8	57.7	63.1	57.8	49.8	58.1

*Statistically a difference of 3.9 thousands of pounds for results under "Both" is significant.

Berkley and co-workers (23) found from comparisons of fiber samples of abaca grown in four Central American countries that the fiber strength of Bungulanon was significantly greater than that of Maguindanao wherever the two varieties were grown. These varieties are the two most commonly grown in Central America, and the results in some instances showed differences as large as 15 percent.

Espino and Esguerra (64) and Espino and Reyes (66) reported on comparative strength of fibers from different varieties when grown side by side under Los Baños conditions of soil and climate. They state, "as was to be expected on account of the extraordinary thickness of the walls and narrow lumina of the fiber-elements in the Bongulanon, this variety of all the varieties tested, produced the strongest fibers." These tests involved the weight required to break five average-sized fibers 50 centimeters in length, but when the breaking load was computed to a one-gram sample of 50 centimeters length, the ranking of the varieties was: Sinaba, 100; Punucan, 99; Itom, 97; Libuton, 96; Ilayas, 94; Maguindanao, 93; Bongulanon, 87; Samoro puti, 86; Pinoonan, 79; Bulao, 75; Agogaron, 74; and Kalado, 71. These results indicate that Bongulanon, a popular variety, is midway in strength due to its coarseness. Actually it had the thickest cell walls and

Balao, the thinnest. The authors concluded that although the coarseness of the fibers and the thickness of the cell walls are largely responsible for the strength of the fibers, yet the data seemed to show that fibers of certain varieties are naturally either strong or weak irrespective of these qualities.

While many morphological and physiological characters of a plant influence the strength of its fiber, the work discussed above shows that hereditary differences in varieties also influence fiber strength. This being true, it should be possible through selective breeding to take advantage of varietal differences in fiber strength and create a new variety with greater strength than any of the common varieties existing today.

Fiber of different grades.--Table 12, obtained through the courtesy of the Philippine Department of Agriculture, shows the average breaking strength in grams per gram meter length of fiber of different grades of abaca. Somewhat similar data were published in the Philippine Agricultural Review (92, 154). It is evident from table 12 that the coarser and lower grades of abaca fiber are weaker than the grades of good cleaning, and that the streaky grades, which are obtained mainly from the outer leaf sheaths and hence represent the oldest fiber in each leaf stalk, contain the strongest fiber. These results were also confirmed by the studies of Berkley and associates (23) on fiber collected in Central America. It is possible that the coarse grades with low strength as presented in the table do not in reality always measure the full strength of the fiber. Strength was determined on the basis of weight per gram meter; hence the coarse grades, containing greater amounts of pulp and other encrustants, would naturally test out weaker. The percentage stretch of the fiber, averaging approximately 2.5, is what one would expect from a knowledge of other vegetable fibers, being similar in this respect to flax, hemp, and jute. There is little evidence of any correlation of stretch with strength and grade designation.

Bishop and Curtler (25), in a report on the fiber strength of abaca from North Borneo, carried out by the Department of Agriculture of the Federated Malay States, also found that fiber of the low standard grades lacked the strength of fiber of the higher grades.

The foregoing results indicate clearly why commercial cordage manufacturers are willing to pay the small premium that the higher standard grades normally command.

TABLE 12.--Average breaking strength (per gram meter) and percentage strength of Philippine abaca fiber of different grades[96]

Grade and description		Breaking strength (grams)	Percentage stretch
A	Extra Prime	50,419	2.62
B	Prime	51,369	2.60
C	Superior Current	52,232	2.42
D	Good Current	53,675	2.39
E	Midway	51,815	2.30
S1	Streaky No. 1	53,818	2.60
S2	Streaky No. 2	54,391	2.67
S3	Streaky No. 3	55,809	2.87
F	Current	48,902	2.65
G	Seconds	47,980	2.72
H	Brown	48,658	2.68
I	Good Fair	46,646	2.79
J1	Fair No. 1	42,787	2.59
J2	Fair No. 2	44,213	2.46
K	Medium	40,730	2.52
L1	Coarse	40,226	2.85
L2		37,884	2.69
M1	Coarse Brown	39,711	2.57
M2		38,189	2.52
DL	Daet Coarse	36,523	2.39
DM	Daet C. Brown	35,209	3.01

[96] Data furnished by Vicente C. Aldaba, Philippine Islands, Bureau of Plant Industry. 1935.

Fiber from plants of different ages.--The Fiber Division of the Philippine Bureau of Agriculture has supplied results on the breaking strength of abaca fiber obtained from plants of different ages. These results are given in table 13.

TABLE 13.--Tensile strength of abaca fiber obtained from plants (Sinibuyas variety) of different ages, from Cavite, P.I.[97]

Plants	Breaking strain per gram meter		
	Highest	Lowest	Average
	Grams	*Grams*	*Grams*
3 months old	59,090	33,149	42,471
6 months old	68,252	39,333	50,897
1 year old	60,901	43,068	54,544
2 years old, flower comes out	64,287	48,510	55,303
Flower opens	63,636	50,438	56,874
Fruit well formed	61,190	51,014	55,025
Matured stalk with fruit ripe	67,741	41,071	58,832
Over-matured stalk with all leaves and fruit dried	70,886	33,088	56,247

[97] Philippine Islands. Bureau of Plant Industry. Fiber Research Division.

The results in table 13 show that the strength of the fiber increases as the plants grow older even up to and past the time of flowering. These results conform to what would be expected from the fact that the fiber cells become thicker-walled and stronger with age. The degree of increased strength is important as well as the rate of increase. These results if they may be taken to illustrate what can be expected in general indicate that at the early age of six months the fiber has approximately 85 percent of its ultimate strength. Plants one year old and immature as far as flowering is concerned have strong fiber. Possibly the total yield of fiber per plant is not at its maximum in one-year-old plants, so from the economic standpoint it would undoubtedly be advisable to let the harvest go longer. Even the old plants with dried leaves and fruit have strong fiber and should be harvested when practices have not made it possible to do so earlier.

TENSILE STRENGTH OF HAND-CLEANED FIBER VERSUS MACHINE-CLEANED

Berkley and co-workers (23) were not able to show from samples collected in Central America significant differences in the strength of abaca fibers cleaned by the hagotan method and those cleaned by the large semiautomatic Corona type machines. They stated that the hagotan-stripped fiber was coarser and stronger but that its superior structure and lack of mechanical cleaning injuries could account for the greater strength of the hagotan-stripped product. Somewhat similar results were obtained from the Furukawa Development Company, Davao, P.I., in 1926. These results, as reported by Sherman,[98] follow.

Cleaning method	Maguindanao	Tangongon	Bungulanon	Average
Prieto machine	53,979	53,657	57,565	55,067
Power knife	56,120	56,814	56,350	56,428

Bacon (17), attempting to learn if the strength of fiber cleaned by the hagotan or spindle machine was as strong as that cleaned by hand, found an increase in strength of 64 to 130 percent in favor of the machine-cleaned fiber. These results were obtained even when leaf sheaths were split in half and one-half was cleaned by machine and the other by hand. Bacon explained the greater strength of the machine-cleaned fiber by saying that the steady pull of the fiber under the knife of the machine resulted in fewer broken fibers than the intermittent jerky pulls of an operator cleaning by hand.

[98] SHERMAN, P. L. Correspondence. November 1926.

It must be remembered, however, that lack of attention to the adjustment of machine cleaning knives and insufficient clearance in the large semiautomatic machine can result in damage to the fiber, as shown by Berkley and co-workers (fig. 28). Nevertheless, it is a matter of interest and importance in an age of machine development to know that machine cleaning does preserve the natural strength of the fiber.

TENSILE STRENGTH OF ABACA FROM DIFFERENT REGIONS OF PRODUCTION

Because of the various interrelated factors that influence the strength of a fiber, such as soil, climate, variety, and methods of production it is hardly possible to attribute to any one factor the differences observed in fiber strength. However, it is possible by testing fibers originating in different areas to learn whether abaca from one area is stronger than that from another.

Berkley and co-workers (23) found significant statistical differences between abaca fiber grown in different Central American countries, but because of unavoidable delays in making their tests, they attached little importance to the results. From comparisons of Central American with Philippine abaca, they found that the samples of prewar Philippine fiber produced before 1942 were on the average stronger than those of postwar 1945 Central American fiber. The strength of Philippine postwar fiber was equal to that of Central American, indicating either the variability that exists between seasons or a deterioration of the Philippine product.

In the trade, Sumatra abaca is generally considered weaker than the Philippine product. There are few published data to support this belief, but the results of tests conducted by the Fiber Research Division of the Philippine Bureau of Plant Industry, shown as table 14, seem to substantiate it.

TABLE 14.--Tensile strength tests of Philippine and Sumatra abaca

[Average breaking strength of more than 50 tests][99]

Philippine abaca			Sumatra abaca		
Grade	Gram meter	Stretch	Grade	Gram meter	Stretch
	Grams	*Percent*		*Grams*	*Percent*
E	50,656	2.21			
F	52,585	3.24	Superior	46,147	1.82
I	48,122	3.80	Good	46,906	1.64
J1	48,541	3.50			
S1	52,363	3.19			
S2	52,847	3.32			
S3	55,683	3.20	Medium	45,584	1.52
J2	44,334	2.85			
E and F	51,620	--	Superior	46,147	1.82
F and I	50,353	--	Good	46,906	1.64
S1 and S2	52,605	--			
S2 and S3	54,265	--	Medium	45,584	1.52
S1 and S3	54,023	--			
E,F,S1,S2 and S3	52,826	--			
F,I,S2, and S3	52,309	--			

[99] Data from Eladio Sablan, Assistant Agronomist, Philippine Islands, Bureau of Plant Industry, Fiber Division. Nov. 15, 1930.

Ynchausti y Cia., in 1931,[100] reported on breaking tests of rope yarns made of Sumatra and Philippine hand-cleaned and Deco fiber and stated that the Philippine was superior.

From these and other tests it is concluded that Sumatra abaca made into yarn lacks the strength and elasticity, as well as the luster of Philippine abaca.

KNOT STRENGTH

The test for knot strength is a type of shearing test. In such a test the internal force is tangential to the section on which it acts. It will be influenced by various factors, but for

[100] YNCHAUSTI Y CIA. REPORT. 4 pp. Manila. 1931. [Unpublished.]

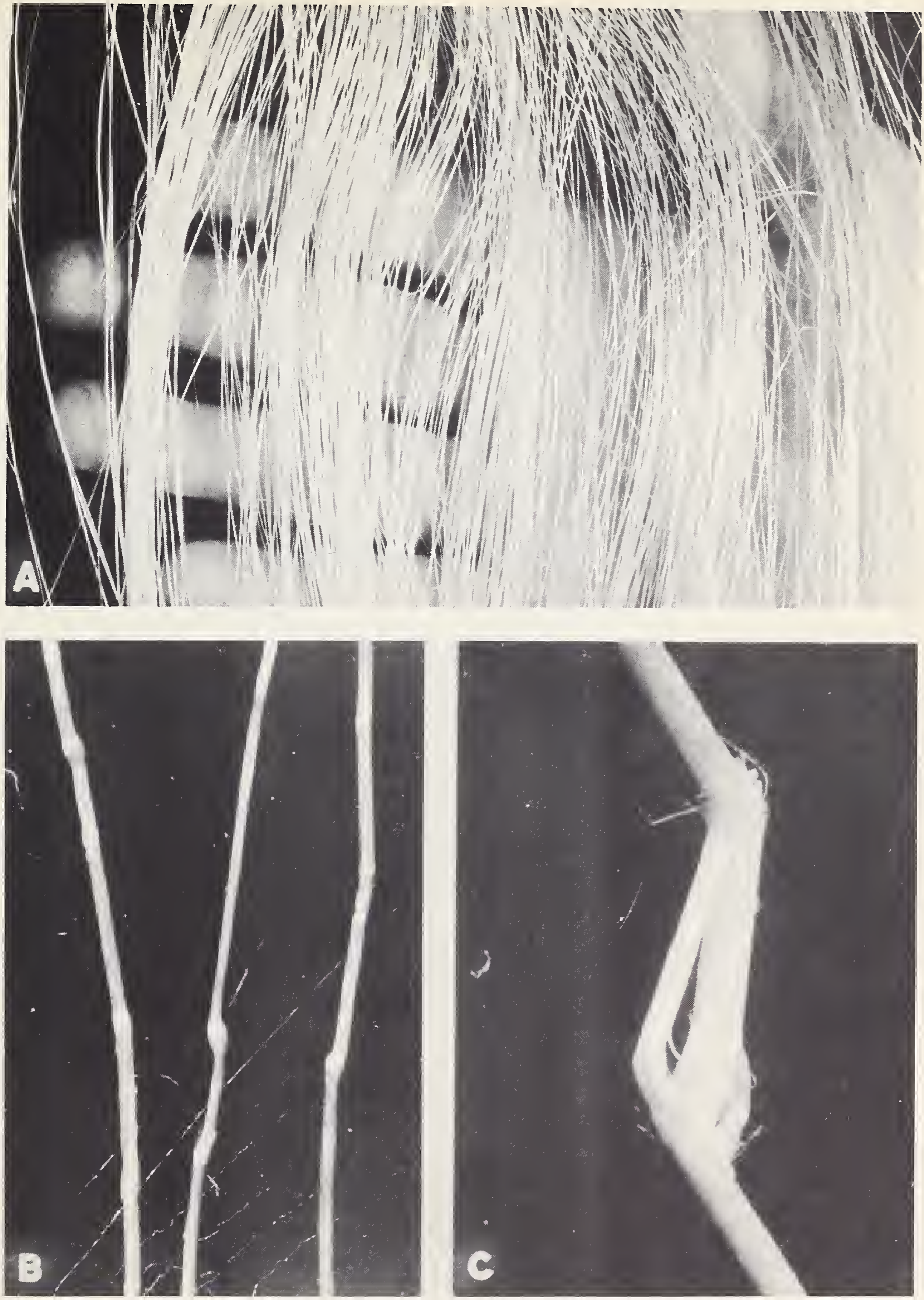

Figure 28.--A, Abaca fiber of excellent cleaning. This fiber possesses a uniform degree of fineness, freedom from pulp, and undamaged strength. B, Machine-damaged fiber. C, Enlargement of one of the injured spots shown in B.

purposes of discussion here only the type of knot or degree of angle that the material is distorted and the fineness of the filaments making up the test sample are considered.

The results of Heim and Roehrich in columns 2 and 3 of table 9 show the great decrease in strength that occurs in a shear or knot test. It has generally been thought that hard fibers (coarser leaf fibers) suffer more in such a test than soft fibers (finer stem fibers), but while abaca and sisal do show considerable reduction in strength as compared to hemp and flax, this relation does not hold for all soft fibers. For example, ambari (Hibiscus cannabinus), paka (Urena lobata), and jute (Corchorus spp.), all soft fibers, show a very marked reduction in strength in the knot test.

Unpublished data of the United States Department of Agriculture presented in table 9 further substantiate reductions in strength due to knotting. In these tests, performed on small strands or fine yarns of fibers in bundles, the fibers were subjected to a much more severe treatment than they would actually encounter in commercial practices. Big ropes or cables could not be knotted or kinked in such a way as to create as severe torsional strains on individual fiber strands as would result from knotting a fine yarn. Hence it is believed that the knot strength tests in yarns is too severe a test by which to judge alone the ranking of fibers used in big cables. Unfortunately there are few or no data available on knotting ropes to prove that the loss in strength is proportionately less than in fine yarn samples. Such data as are available, however, indicate that for tying twine of small diameter--several hundred feet per pound-- the soft fibers of good quality, even jute, would be as strong as or stronger in the knot than the hard fibers.

The Boston Navy Yard reported a test [101] to show the effect of abrasion resistance of abaca on different size pulleys with consequent different lengths of abraded surface. While additional factors other than knots enter into this test it is presented to indicate that yarns twisted over small pulleys with great angles of torsion but a smaller surface for abrasion have less resistance to the abrasion than yarns twisted over wide angles and abraded over a longer surface. The torsional and abrasional effects on sharper angles as might be experienced in knots of different sizes is illustrated by these data in table 14a.

TABLE 14a.--Resistance to failure of abaca yarns abraded over different lengths as influenced by greater torsional angles

Abaca yarns	A	B	C	D
Average turn per foot	11.9	11.9	12.2	12.2
Breaking strength, lbs	438	343	300	228
Size, feet per lb	214	302	347	460
	Revolutions to failure			
Tension weight 20-3/4 lbs.				
1-3/4" length abraded	246	289	398	456
5-3/8" length abraded	222	289	330	438
10-7/8" length abraded	210	264	329	432
Tension weight 15-9/16 lbs.				
1-3/4" length abraded	249	269	408	460
5-3/8" length abraded	212	276	311	395
10-7/8" length abraded	233	315	365	480
Tension weight 7-3/4 lbs.				
1-3/4" length abraded	246	311	350	508
5-3/8" length abraded	208	342	394	482
10-7/8" length abraded	206	320	392	509

[101] U. S. NAVY DEPARTMENT. ABRASION RESISTANCE TESTS ON MANILA YARNS. Sept. 6, 1944. (Navy Yard, Boston. Materials Lab. Report 8821. 2nd Prog. Report.) [Unpublished.]

It must be emphasized that the soft tying twines used in the comparisons referred to in table 9 were high-quality line grades. As a rule in the soft fiber trade the higher qualities of flax, ramie, and jute are used only for highly valued threads and fabrics and the lower qualities, either weak or tows, are used in low-priced tying twine.

The strength of sansevieria as compared with that of abaca is disappointing (table 9). This is true not only of the breaking strength but even more of the knot strength. As sansevieria is a very fine fiber it might be expected to have reasonably good knot strength. The reduction in strength of sansevieria from 51.2 to 12.4 (75.7 percent) thousand pounds per square inch is comparable to that of abaca, 76.3 to 17.9 (76.5 percent), on a percentage basis. It is possible that unfavorable cultural, environmental, or processing conditions may account for the low knot strength of the fiber from these Florida-grown sansevieria plants.

ABRASION AND FLEX

In cordage use the properties of abrasion and flex rank high. Heavy ropes and cables, which are made mainly of hard fibers, are normally stiff and permit little flexing as compared with the soft fibers used in twines or fabrics. Yet the use of ropes in pulley blocks necessitates some degree of flexing and the use of cables in refueling at sea and the "snake-like" lashing of boats side by side in refueling or transfer of cargoes in one form or another create abrasion on the ropes that may significantly alter their useful life.

How to measure abrasion and flexing and the relative degree of these characters exhibited by one fiber over another is still an unstandardized procedure. Johnson and Stephenson (100) (101) flexed 18 samples of 2-1/4 inch circumference abaca rope of different grades and found the quality of the rope in relation to the grade of fiber could not be determined from the results. They believed that variations in the rope as yarn twist (10%), lay, oil content (100%), yarn size (40%), etc., affected the results. Results of tests conducted at the Boston Navy Yard and made available through the courtesy of the United States Department of the Navy are presented below.

TABLE 14b.--Abrasion revolutions--77 per minute--to failure on yarns of 300 feet per pound

Load	Abaca	Sisal
Percent	*Number*	*Number*
10	--	400
8	250	800
5	1,050	1,500
4	1,550	3,000
3	2,350	4,300

TABLE 14c.--Flexing durability of abaca and sisal--90 oscillations per hour

Rope size	Sheave dimensions		Load	Length in contact with sheaves	Oscillations to failure	
Circ.	Diam.	Width			Abaca	Sisal
Inches	*Inches*	*Inches*	*Pounds*	*Inches*	*Number*	*Number*
1-1/2	2-13/16	3/4	452	18	5,677	8,895
1-1/2	2-13/16	3/4	452	18	4,193	11,915
3	4-3/4	1-1/4	1,730	36	3,765	3,210
4	6-3/8	1-3/4	2,930	36	3,446	3,222

The data on abrasion here recorded show that sisal, though recognized as lower in strength than abaca, surpasses it in resistance to breakage under abrasion. Results obtained by Schiefer (170) in tests with different fibers confirm this finding. In Schiefer's tests strands of fiber were twisted, one twist per inch of length for testing. This represented to some degree a manufactured yarn and eliminated any noticeable lack of tension on some fiber strands that would have been difficult to avoid in testing hard fibers if they had not been twisted. Schiefer pointed out that one outstanding result of his abrasion tests was the profound effect that the direction of the twist, SS and SZ--that is, an S twist in the bundle of fibers and an S or Z twist in the ply of two bundles--had on the resistance to abrasion of the fibers. In general the resistance to abrasion for the SZ twist was much greater than for the SS twist. The amount of twist in the bundle and in the ply and the addition of lubricants also affect the resistance to abrasion. Schiefer found that the resistance of the fibers to abrasion in descending order was henequen--sisal--abaca.

With essentially the same methods, Berkley and associates (23), working only with abaca, but abaca that had been grown under different environmental conditions or had been subjected to different methods of processing, were not able to show such marked differences. Berkley concluded that there was a tendency for the fibers from the inner sheaths to be more resistant to abrasion than those from the intermediate and outer sheaths and more resistant near the base than at the tip, but because of the high variability of the results they were unable to show that these differences were significant.

In general, flex life may be expected to increase with fineness of the fiber, but this does not always hold true, for Schiefer found that abaca had nearly double the dry strength of henequen and yet henequen had the highest flexural endurance. The henequen used in Schiefer's work, and henequen in general, is coarser than abaca. Berkley and co-workers found no significant differences in the flex life of abaca resulting from differences in the cultural practices followed in its production. However, the trend was for the strongest fiber to have the greatest flex life.

The Navy Department tests reported above indicate greater flexing in small sisal than in small abaca ropes and less flexing in bigger sisal ropes than in abaca ropes of similar size. Although the size of the experimental error in these tests is not known, it is evident that sisal has remarkable abrasion resistance and nearly equals or may even surpass abaca in flexing ability.

RIGIDITY

A certain amount of stiffness or rigidity is considered desirable in a cordage fiber, especially in one that is to be used in the cutter on the knotter of a grain binder, for twine made of a soft flexible fiber does not cut off in a worn loosely adjusted cutter as easily as one made of a hard fiber. Humphries and Gray (97), reporting on studies to find a suitable extender for diminishing hard fiber supplies, reached the conclusion that much of the trouble arose from knotter failures, especially with soft twines, and that cotton and paper twines and paper in mixtures with hard fibers did not give as good results as hard fibers alone.

The measurement of rigidity has not been standardized or performed on many cordage fibers. Dantzer and Roehrich (90) presented an index of rigidity on abaca, sisal, and henequen that gave the following results: Abaca G 2.42, K 2.50, M_2 2.83; sisal Sudan A 2.31, Sudan C 2.20, African 1 2.14, Java 2.73; and Mexican (henequen) 2.73. These measurements vary so much between grades of an individual fiber that the average differences between fibers would not appear to be significant. However, the experience in trade would not indicate as great differences in these three leaf fibers as might exist if a stem fiber such as jute had been included.

BREAKING LENGTH OR STRETCH

Abaca fiber is similar to most leaf and stem fibers in that its ability to elongate without breaking is small in the dry state. Stretch in abaca, as reported by Tirona (176), ranges from a minimum of 2.12 to a maximum of 3.54 percent.

Table 12 shows an average stretch of 2.61 percent for all grades of abaca with a range of 2.30 to 3.01 percent. Interesting differences in the breaking elongation of abaca from different sources was reported by Sablan (table 14). Differences between Philippine and Sumatra abaca amounted to 100 percent, indicating that origin as influenced by environment and preparation may affect this property of stretch.

FINENESS

Europeans frequently have designated fineness by a number which represents the number of kilometers of the fiber that weighs one kilogram - called the metric number. Dantzer and Roehrich (90), using this measure found abaca to be slightly finer than sisal, and sisal from Africa and Java finer than Mexican (henequen). The kilometers of fiber in a kilogram for different samples were: Abaca G 41,600, K 52,500, M_2 23,000; sisal Sudan A 37,300, Sudan C 35,800, African 1 40,900, Java 27,400; and henequen 26,600.

Another way of expressing fineness is by "denier." This term is used more commonly with silk and synthetic fibers than with the coarser long vegetable fibers. A denier equals the number of unit weights of 0.05 gram per 450-meter length. According to this system (9) cotton equals 1.7, flax 2.2, hemp 3.0, ramie 5.4, and jute 15.0.

For comparison with these fibers the denier was calculated for various other cordage fibers using the fiber weights given by Schiefer (170). The results show: Jute 15-27, kenaf 50, pita floja 54, sansevieria 64-97, Yucca elata 78, abaca 139-273, sisal 206-406, and henequen 362-383.

The greater coarseness of the hard fibers as illustrated by these measurements may account to some extent for the differences in rigidity and flexibility found between the hard leaf and the finer, softer stem fibers. It should be pointed out, however, that fineness as measured and discussed here for long vegetable fibers is not a measurement of the ultimate cells but rather of the commercial trade strand which is made up of many ultimate cells lying side by side with overlapping ends. These measurements of fineness as given are influenced by the ability of the fiber bundles to divide or the groups of bundles to split up into finer strands. Fineness is desired or preferred to coarseness for most purposes by the manufacturer.

The measurements of Dantzer and Roehrich (90) mentioned above for flax and hemp are believed to be finer than would have been obtained if they had used the same average qualities or the technique of fiber separation employed by Schiefer (170). It is extermely hard to arrive at an end point in dividing fiber bundles or splitting strands in soft fibers such as flax, hemp, and jute, and the results obtained with these fibers are only relative to the qualities tested and the technique employed. With hard fibers, fineness is more easily measured and duplication of measurements is more readily obtained because these fibers do not divide into as fine strands as the soft stem fibers.

Special attention should be directed to the fineness of pita floja (Aechmea magdalenae) and sansevieria which are leaf fibers of potential value in cordage. The measurements given above confirm the general belief that the pineapple and lily fibers to which these plants belong are finer than those of Agave and Musa species.

SWELLING

In between the crystalline cellulose molecular chains of the fiber lies some amorphous cellulose that is not crystallized. In swelling, water penetrates the amorphous structure more easily than it does the crystalline and produces an internal swelling of the fiber. If the water or wetting agent is sufficiently strong in chemical reaction and is permitted to remain in contact with the fiber long enough, ultimately the crystalline structure will itself swell by the penetration of the solution. The water in the amorphous swollen form acts somewhat as a lubricant in permitting the fibers to stretch. The swelling of the crystalline structure, however, and the subsequent removal of water through drying brings about a different physical arrangement of the chains of the crystals. This modifies the properties of the fibers, as happens in the mercerization process.

The amount of swelling in different fibers depends on the amount of amorphous material that they contain, on the size of the crystallites, and on the presence of polar groups. By refined methods of measuring swelling Preston and Nimkar (143) showed differences between various synthetic fibers, but they measured swelling in only three natural vegetable fibers. Their measurements showed that flax swelled more than jute or cotton, swelling in the latter two being approximately the same.

Some ropes swell so much when wet that they cannot be used in pulley blocks of normal size without binding. This sometimes occurs when a weaker substitute fiber is used and in order to increase the strength of the rope a larger size is employed. On swelling, this binds in the pulley block. A fiber that swells on account of absorption of water becomes heavy and sinks rapidly. Abaca is generally considered by practical men to be more buoyant than sisal. Table 15 shows the variations that occurred in sisal and abaca ropes of British manufacture when immersed in water for different periods of time.

The results in table 15 show that sisal increased in girth more than abaca but took up less water by weight. However, it is apparent from the chemical results that the low uptake of water might have resulted partly from the greater amounts of oils (matter extracted by petroleum ether) introduced in the course of manufacture. The difference is considerable and in respect to non-swelling, abaca rope appears to possess a decided advantage over sisal rope.

The British Admiralty (80) in a number of additional tests attempted to measure the swelling of cordage fibers. They reported an increase in girth of the 3- and 7-inch abaca and sisal ropes after soaking in water and a reduction in girth when they were allowed to dry in air. Sisal rope was found to absorb water very rapidly, the bulk in the first hour, after which the increase in weight was small. Abaca rope, on the other hand, absorbed water much more slowly, but after

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TABLE 15.--Variations in sisal and abaca ropes when soaked in water for different lengths of time (78)

Item	Sisal No. 1	Sisal No. 2	Abaca J
	Soaked in tap water for 48 hours		
	Percent	*Percent*	*Percent*
Decrease in length	6.25	5.58	5.95
Increase in girth	11.1	8.69	5.26
Increase in weight	38.91	47.37	52.89
	Pounds	*Pounds*	*Pounds*
Weight per foot dry	0.280	0.259	0.261
Weight per foot wet	.415	.404	.425
Alteration in twist	Nil	Nil	Nil
	Percent	*Percent*	*Percent*
Matter extracted by light petroleum	6.25	3.8	3.4
	Soaked in sea water for 4 months		
	Percent	*Percent*	*Percent*
Increase in girth	9.26	6.21	3.60

167 hours or more appeared to take up as much water as sisal, or more. Abaca swelled less than sisal in the early stages, but after 2 hours the swelling was about the same.

The rate of shrinkage on drying was also about the same, but on the average the sisal rope more nearly returned to its original girth than the abaca. The report did state that sisal rope was likely to unlay more than abaca rope when wetted for considerable periods and on drying this tendency was still noticeable, which may account to some extent for the statement that sisal does not recover its original girth.

BUOYANCY

The British Admiralty (80) in its study of the swelling of British ropes included tests on the buoyancy of small bundles of 6-inch lengths of fiber strands containing none of the oily matter that might be introduced in the manufacturing process. Their results, shown in table 16, demonstrate clearly the superior buoyancy of abaca over henequen and sisal. Henequen appears to be slightly superior to sisal.

TABLE 16.--Buoyancy of abaca, sisal, and henequen fiber

Fiber	Grade	100 fiber strands in bundle			Bundles of equal weight		
		Weight of bundle	Time to sink		Weight of bundle	Time to sink	
		Grams	*Min.*	*Sec.*	*Grams*	*Min.*	*Sec.*
Abaca	F	0.46	20	0	1.5	30	0
Do	G	1.32	6	0	1.5	11	0
Do	L1	2.43	4	0	1.5	6	0
Sisal (Java)	Kobla "A"	.64	0	25	1.5	0	45
Do	Sockamandi "X"	.43	0	30	1.5	1	10
Sisal (East African)	No. 1	.56	0	20	1.5	0	45
Do	No. 2	.40	0	30	1.5	1	20
Henequen (Mexican)	....	.85	1	0	1.5	1	30

The authors concluded that the buoyancy was not due to any great difference in chemical composition but rather to the readiness with which the fibers absorb moisture, and it seems not unlikely that this in turn is largely dependent on differences in the surface of the fibers which give rise to differences of surface tension in contact with water.

The Imperial Institute (82) reported that phormium is capable of withstanding the action of sea water over prolonged periods, though it is hardly up to the standard of abaca. Phormium was found to absorb water at a more rapid rate than abaca and to sink more rapidly. It also swelled more and remained swollen when dried.

STRENGTH LOSS DUE TO IMMERSION IN WATER

Long Period:

Deterioration of fiber resulting from long immersion in water is due largely to biological causes.

In July 1932 the Imperial Institute reported the results of four series of tests on abaca, sisal, and phormium in which ropes were exposed to the action of sea water in crates so that they were submerged and uncovered with changes of the tides. In the report on the fourth series of trials (81) it was stated that the results "confirm those of the previous series and demonstrate that ropes made of East African Sisal and New Zealand hemp [phormium] when exposed to sea-water are capable of retaining their strength to a similar extent to Manila ropes." A summary of the results, given in table 17, shows the percentage decreases in average strength for different periods.

The abaca ropes used in this fourth series had greater initial strength than the sisal or phormium ropes, but after four to nine months the percentage loss was approximately the same. The small differences are probably of no practical significance.

TABLE 17.--Percentage decrease in average strength of sisal, Manila hemp, and New Zealand hemp (phormium) ropes after different periods of immersion (81)

Months	Sisal hemp			Manila hemp			New Zealand hemp
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7
	African No. 1 Brushed	African No. 1 Unbrushed	Java	S. 3.	K	M. 1.	Fair
2 (Mar. 16-May 11)	21.3	25.2	24.3	8.1	17.7	11.2	15.2
4 (Mar. 16-July 14)	51.6	54.6	58.9	50.4	53.9	53.6	54.9
6 (Mar. 16-Sept. 17)	58.2	63.8	70.5	65.1	62.5	64.7	66.2
9 (Mar. 16-Dec. 16)	66.3	73.7	79.3	73.3	74.5	72.6	71.4

Short Period:

The action of water on the physical properties of the cordage fibers is more specific in short than in long immersion tests because in the short tests biological activity does not have an opportunity to influence the results. Instead of all fibers losing strength, some actually grow stronger when wet.

Table 18 contains data furnished through the courtesy of the United States Navy [102] that have a practical bearing on this question. The specimens were immersed in tap water at 70°F. to a foot depth and tested while wet. The breaking length was obtained by multiplying the breaking strength by the number of feet per pound. In general, abaca, cotton, sisal, ramie, and caroá increased in strength when wet, but American hemp unless tarred appeared to lose strength. Table 18 further illustrates the superior strength of abaca. The dry strength in order of decreasing importance in ropes of 1-1/2-inch circumference was: Abaca, henequen, hemp, sisal, ramie, and jute; with wet strength the order was: Abaca, ramie, henequen, sisal, jute, and hemp.

[102] HIMMELFARB, D., and LUTTS, C. G. PROPERTIES OF MANILA SUBSTITUTE FIBERS. 13 pp. Boston. June 1, 1943. (Navy Yard, Boston Materials Lab. Report 8001.) [Unpublished.]

TABLE 18.--Effect of wetting on the breaking strength (length) of cordage fibers[103]

Fiber	Size circumference	Strength		Strength ratio wet to dry
		Dry	Wet	
	Inches	*Pounds*	*Pounds*	
Abaca	1-1/2	2,870	3,000	1.04
Do	3	10,000	10,950	1.10
Do	3	11,300	11,850	1.05
Do	3	11,600	11,200	.97
Sisal	1-1/2	2,034	1,827	.90
Do	1-1/2	2,010	2,060	1.02
Do	3	6,680	6,740	1.01
Do	3	8,080	8,690	1.07
Do	3	7,950	7,200	.91
Henequen	1-1/2	2,410	2,000	.83
Jute	1-3/8 (tarred)	1,170	1,050	.90
Do	1-1/2	1,860	1,820	.98
Do	3	6,100	5,600	.92
Cotton	1/8	210	245	1.17
Do	1/4	600	810	1.35
Do	1/4	605	735	1.21
American hemp	1-1/2	2,080	1,210	.58
Do	1-1/2 (tarred)	1,550	1,480	.96
Do	1-3/4	4,100	2,350	.57
Do	1-3/4	3,700	2,550	.69
Do	1-3/4	3,660	3,650	1.00
Do	1-3/4	3,780	3,660	.97
Do	1-3/4	3,605	3,100	.86
Do	3	7,000	4,550	.65
Do	3 (tarred)	9,100	7,650	.84
Ramie	1-1/2 (Haitian)	2,030	2,520	1.24
Do	1-1/2 (Alabama)	1,820	3,070	1.69
Caroá	2-1/4	3,600	4,100	1.14

[103] See footnote 102.

The percentage decrease in strength of rope made of different fibers after exposure to sea water for different periods is shown in table 19. The results of the tests show that No. 1 Brushed Sisal rope was slightly but not materially inferior to Manila Streaky No. 3 in its resistance to sea water. Phormium losses were small at first, being similar to those of abaca, but the final loss was equal to that of sisal. Indian hemp (Crotalaria) was more resistant than Russian hemp (Cannabis), but both were inferior to abaca, sisal, and phormium.

RESISTANCE TO IMMERSION IF TARRED

The British Admiralty in cooperation with the Imperial Institute made a study of the value of Empire fibers as substitutes for abaca, and after some ten years of testing partially adopted for service ropes made of sisal and phormium. Continuing their investigations they tested sisal in tarred ropes for different periods of immersion (83).

While the results were on sisal rather than on abaca they are believed to be applicable to some extent to most cordage fibers. It was found in 9 months' tests that tarred sisal in ropes under normal storage conditions lost 6 percent strength, duplicate tarred samples submerged and exposed by sea tide lost 29 percent (untarred 76 percent), and triplicate samples exposed on a roof lost 11 percent (untarred 13 percent). The quantity of tar (Archangel) absorbed by the fiber was 12.87 percent in addition to about 4-1/2 percent batching compound.

TABLE 19.--Percentage decrease in strength of 3-inch ropes of different fibers exposed to sea water for different lengths of time (79)

Period	Sisal				Manila hemp (abaca)	Russian hemp	Indian hemp (sunn)	New Zealand hemp (phormium)					Sisal
Seawater exposure[a]	No. 1 brushed	No. 1 unbrushed	No. 2 brushed	No. 2 unbrushed	No. 3 streaky	Dressed siretz	Dressed	Fair	High point fair	Good fair[b]	High point fair[b]	High point fair[c]	Brushed[c]
Months:													
2...........	50.1	48.6	38.1	43.1	23.6	49.6	39.8	33.3	27.5	21.6	19.3	29.1	43.9
4...........	65.6	70.6	70.4	67.9	56.3	77.4	72.6	61.0	65.2	67.9	65.9	69.2	71.4
6...........	73.9	72.1	79.6	71.9	68.6	85.3	80.9	69.2	72.8	74.9	70.8	.....	....
9...........	74.7	80.4	78.9	81.0	70.0	88.6	82.6	69.6	75.5	75.8	74.7	.....	....

[a] Exposure began July 12.
[b] Exposure began in September.
[c] Exposure began in September with insufficient fiber to complete all tests.

RELATIVE STRENGTH OF ROPES OF DIFFERENT FIBERS

The Boston Navy Yard[104] has reported on the strength of ropes made from abaca and a number of abaca substitute fibers. The results show the unit strength of the ropes as measured by the breaking length, which is the value obtained by multiplying the breaking strength by the number of feet per pound. Table 20 shows the relative strength of ropes made from the more common cordage fibers. Hemp, ramie, and caroá were not discussed in relation to the other fibers, possibly because there were only two tests each. However, it is obvious that hemp and ramie fibers make strong rope even though not equal to abaca. The same report shows the comparative strength of ropes of the different fibers when wet and dry. The ropes for wetting were immersed in tap water at 70° F. to a depth of one foot and tested while wet. Notations in table 20 of the specific reaction of the ropes when wet are those of the present authors. They are based on averages of the tests performed, but whether the quality of a particular fiber as determined in one series of tests is representative of the fiber in general is open to question. The validity of the results with abaca, sisal, henequen, and jute is confirmed, however, by the work of Dewey and Whitlock (51), who reported on nearly 3,000 comparative tests of strength, uncorrected for slight variations in weight per foot and turn, as follows:

	Abaca	Sisal	Jute	Henequen
Number of samples	411	1,898	558	20
Average strength/abaca spec.	1.128	.942	.799	.649
Average strength/abaca	1.00	.83	.71	.58
Specified strength ratio	1.00	.70-.80	.60	.60

TABLE 20.--Breaking length (strength) of ropes made of different cordage fibers

Fiber	Min. breaking length			Strength (relative value)	Approximate loss or gain in strength when wet
	1-1/2" circ.	2-1/4" circ.	3" circ.		
	Feet	*Feet*	*Feet*		
Abaca	35,245	--	33,390	100	10% gain
Sisal	28,196	--	26,712	80	Gain less than abaca
Henequen	21,147	--	20,034	60	17% loss
Jute	21,147	--	20,034	60	6% loss
Cotton	19,575	--	17,850	55	25% gain
Hemp	33,517	--	--	--	20% loss
Ramie	32,063	--	--	--	24-69% gain
Caroá	--	22,500	--	--	15% gain

Leonard and Wexler (110) made a study of many natural and synthetic fibers used in ropes for mountain climbing. Because of the growing importance of synthetics in cordage a table showing their results is included here (table 21).

The findings on natural fibers are of the order: Abaca 100, hemp 90, flax 87, sisal 73, cotton 66, and jute 46. These are not greatly out of line with the earlier results reported. Cotton is a little high and jute is definitely low. However, for the specialty use to which this type of rope is put - one involving human life - it is not surprising that cotton should rank higher than in the Navy Yard tests, for only the best strength long staple cotton would probably be used in a cotton rope for mountain climbing. Nylon shows great strength both in the dry and wet condition.

Tests conducted by the National Bureau of Standards[105] show the relative strength of hemp (Cannabis sativa), sisal, and jute ropes. In no case did the addition of 33-1/3 percent or 50 percent of hemp fiber to sisal reduce the strength of ropes in dry tests, but in every case it caused a reduction in wet strength. The test relationship of these fibers in different ropes was as follows:

[104] See Footnote No. 102.

[105] U. S. NATIONAL BUREAU OF STANDARDS. ROPES MADE FROM SISAL, FROM AMERICAN HEMP AND SISAL IN MIXTURES, AND FROM JUTE. (Natl. Bur. Standards. Report Supplementary to the Bur. Aeronaut., Navy Dept. on tests of Feb. 5, 1945.) [Unpublished.]

TABLE 21.--Comparative performance of climbing rope with manila as standard

Test		Manila	Sisal	Mountain nylon	High elongation nylon	Clothesline nylon	Pre-set nylon	Monofil nylon	Braided nylon	Rayon	Saran	Cotton	Jute	Beale's Manila	Frost's Italian hemp	Frost's English flax
Tensile strength............	Dry	100	73	147	120	104	109	132	99	68	43	66	46	78	90	87
	Wet	100	68	115	94	84	100	100	78	32	45	--	--	--	--	--
Elongation at failure.......	Dry	100	103	458	608	368	308	418	344	--	215	125	107	130	74	133
	Wet	100	113	316	368	--	--	258	215	--	--	--	--	--	--	--
Strain energy...............	Dry	100	73	675	732	390	335	561	347	--	93	83	49	104	67	116
	Wet	100	75	362	333	--	--	258	168	--	--	--	--	--	--	--
Abrasion over rough bar.....	Dry	100	--	113	--	155	156	0	91	--	--	--	--	--	--	--
Abrasion over smooth bar....	Dry	100	--	1,982	--	--	--	--	--	--	--	--	--	--	--	--
Flexing over pulley.........	Dry	100	--	1,508	--	--	--	--	--	--	--	--	--	--	--	--
Carabiner strength..........	Dry	100	137	160	141	127	125	140	125	--	--	--	--	--	--	--
Square knot strength........	Dry	100	101	127	120	138	130	106	129	--	--	--	--	--	--	--
	Wet	100	105	120	100	--	--	98	--	--	--	--	--	--	--	--
Weathering..................	Dry	100	--	113	--	--	--	--	--	--	--	--	--	--	--	--
Resistance to wetting.......	Wet	100	--	197	--	132	316	--	121	--	--	--	--	--	--	--
Exposure to extreme heat....	Dry	100	134	149	--	--	--	--	--	--	--	--	--	--	--	--
Exposure to freezing water..	Wet	100	100	91	--	--	--	--	--	--	--	--	--	--	--	--
Exposure to subzero temperature.....................	Dry	100	105	102	--	--	--	--	--	--	--	--	--	--	--	--

Composition		Nominal diameter	Breaking strength		Ratio to sisal	
Sisal parts	Hemp parts		Dry	Wet	Dry	Wet
		Inch	*Pound*	*Pound*	*Percent*	*Percent*
ALL.........	--	1/2	2,450	2,400	100	100
1...........	1	1/2	2,670	2,220	+108.97	-108.10
All.........	--	9/16	2,910	2,880	100	100
2...........	1	9/16	3,202	2,310	+110.03	-124.67
All.........	--	9/16	2,844	2,728	100	100
2...........	1	9/16	2,920	2,390	+102.67	-118.32
2...........	1	9/16	2,970	2,592	+104.43	-105.24
All.........	--	1	8,410	8,420	100	100
1...........	1	1	8,830	7,560	+105.11	-111.37
All.........	--	1	7,640	7,070	100	100
2...........	1	1	8,470	6,440	+110.86	-109.78
All.........	--	1	7,385	7,240	100	100
2...........	1	1	8,140	6,280	+110.22	-115.28
Jute		1/2	1,647	1,614	-67.22	-48.69
"		1	6,486	6,310	-83.02	-83.27

Calculations made by the writers from the results presented by the Bureau of Standards show that the substitution of hemp to the extent of 33-1/3 to 50 percent increased the strength of sisal rope from 5 to 10 percent in the dry state, whereas in the wet state hemp in these proportions decreased the strength 10 to 20 percent. In the dry state sisal was approximately 20 to 50 percent stronger than jute.

It must be recognized that many factors influence the strength of ropes made of different fibers and the results of no one test can be used as criteria for rating the different fibers. However, the reader in reviewing the tests presented earlier in this monograph with raw fibers and ropes will readily recognize the similarity of results. By way of summary, table 22 has been compiled mainly from literature previously cited and is presented here to show the order in which various investigators have rated the more common cordage fibers for strength. The table brings out a few divergent results, principally the work of Braga (29) in Brazil. Why his results differ so widely from those of other workers is not clear. It can hardly be that he used an unusually weak sample of abaca, or the reverse - an unusually strong sample--as the standard. Table 22 brings out the great strength of abaca in comparison with other cordage fibers. It further shows that hemp, flax, ramie, and sansevieria are fibers that might well be given more consideration for use in cordage where strength is esteemed.

ROPE STRENGTH AS INFLUENCED BY WEATHERING AND PRESERVATIVE TREATMENTS

More experimental testing is now being conducted on the influence of weathering on the strength of rope and the effectiveness of different preservative treatments than on the basic differences inherent in the fibers. These tests have added greately to the knowledge of fibers in general, for the untreated checks normally included in the tests yield comparative data for the fibers in their natural state.

Navy Yard tests [111] on outdoor weathering for different periods of exposure, with and without specific treatments of abaca, sisal, jute, and cotton twines are presented in table 23. From these results it was concluded that the particular twines of abaca, sisal, and jute were practically equal in resistance to the sun-weather exposure while cotton was least resistant. To some extent treatments improved the resistance of sisal twine to sun weathering, copper naphthenate being the most effective in this respect. The effect of straight weathering was about equal at the two locations, Boston and New Orleans.

[111] HERBEIN, S. D., and QUINLAN, W. H. WEATHERING TESTS ON CORDAGE AT SOUTHERN REGIONAL LABORATORY, NEW ORLEANS. 5 pp. Boston. Feb. 17, 1949. (Navy Yard, Boston. Matérials Lab. Report 9671.) [Unpublished.]

TABLE 22.—Breaking strength of various raw cordage fibers and ropes made of some of the more important fibers as reported by different workers. Abaca rated as 100 percent is the standard for comparison

Research workers	Abaca	Hemp	Flax	Ramie	Sisal	Sansevieria	Henequen	Jute	Cotton	Sunn	Ambari	Phormium	Cantala	Paka	Cabuya	Zapupe	Kenaf retted	Palma
	Breaking strength of raw cordage fibers																	
Heim (88)	100	84	66	154	74	--	--	61	--	76	70	64	--	54	--	--	--	--
U. S. Dept. Agr.[106]	100	--	69	88	75	67	79	58	--	--	--	--	--	--	51	--	41	--
Schiefer (170)	100	56	--	--	78	--	56	55	--	--	50	--	--	--	--	--	--	--
Braga (29)	100	--	--	--	145	--	99	10	--	16	14	46	--	11	31	--	--	--
Botkins (27)	100	76	--	--	69	--	--	54	--	--	--	--	--	--	--	--	--	70
Dewey, L. H. (53)	100	--	--	--	65	--	48	--	--	--	--	54	28	--	58	62	--	--
Kaswell [107]	100	--	--	--	63	64	47	--	--	--	--	--	--	--	--	--	--	--
	Breaking strength of ropes																	
Boston Navy Yard[108]	100	95	--	91	80	--	60	60	55									
Dewey, G.I. (51)	100	--	--	--	83	--	58	71	--									
Leonard (110)	100	90	87	--	73	--	--	46	66									
Bureau of Standards[109]	100	95	--	--	80	--	--	52	--									
American Mfg. Co.[110]	100	--	--	--	80	84	--	--	--									

106 See Footnote No. 90.
107 See Footnote No. 94.
108 See Footnote No. 102.
109 See Footnote No. 105.
110 SEABOARD AIR LINE RAILWAY. AGRICULTURE DEPARTMENT. A PROPOSAL FOR THE PRODUCTION AND PROCESSING OF SANSEVIERIA FIBER IN FLORIDA AS A WAR EMERGENCY MEASURE TO REPLENISH STOCKS OF HARD FIBERS NOW FACING EXHAUSTION BECAUSE OF WAR CONDITIONS. 9 pp. Savannah, Ga. 1942. (Report to Off. Foreign Agr. Relat.) [Processed.]

TABLE 23.--Tensile strength results for 3-ply cordage exposed to weathering at New Orleans, La., and Boston, Mass.

Material	Strength, New Orleans					Strength, Boston			
	Original	Reduction after exposure				Original	Reduction after exposure		
		3 mos.	6 mos.	9 mos.	12 mos.		5 mos.	9 mos.	12 mos.
	Lbs.	%	%	%	%	*Lbs.*	%	%	%
Cotton..................	197	25.4	54.3	66.0	71.1	--	--	--	--
Jute....................	252	19.8	28.2	31.3	43.3	254	13.5	17.3	38.6
Abaca...................	420	12.6	32.1	32.6	40.2	445	20.0	23.4	40.5
Sisal...................	373	4.6	29.8	43.7	51.7	453	8.8	32.9	40.2
Treated sisal:									
Cu Napht. (0.2% cu) (asphalt, dilute)...	429	14.9	23.3	31.7	33.8	405	0.5	7.7	21.0
Cu Oleate (0.15% cu) Dowicide 7 (0.1%).....	438	18.7	26.0	28.3	38.1	--	--	--	--
Dowicide 7 (0.1%).....	402	10.2	27.4	32.6	42.3	--	--	--	--

Another Navy Yard test[112] reports work of a similar nature which included in addition to the outdoor weathering, comparisons of several other types of exposure. Specimens subjected to humid stowage were placed on wooden platforms, wetted from time to time with tap water, and covered with a paulin. The "sea and weather" was a tidal water coverage and exposure test and the soil burial was 2 inches coverage at 65 percent humidity and 80° F. Table 24 illustrates the results with untreated-preservative ropes. Several preservatives were added to sisal specimens. The results of these tests, which are presented in table 24, show that preservative treatments gave some improvement over no treatment and copper naphthenate was superior to the others tried.

TABLE 24.--Relative order of efficiency (strength) of untreated ropes subjected to different types of destructive agencies (ranging from good to poor)

Miami, Fla.			Duxbury, Mass.			
Humid stowage	Sea and weather	Weather	Humid stowage	Sea and weather	Soil burial	Consensus
Abaca	Jute	Abaca	Abaca	Abaca	Jute	Abaca
Sisal	Abaca	Sisal	Jute	Jute	Abaca	Jute
Jute	Sisal	Jute	Sisal	Sisal	Sisal	Sisal
Sisal-hemp	Sisal-hemp	Sisal-hemp	Sisal-hemp	Sisal-hemp	Sisal-hemp	Sisal-hemp
Hemp	Hemp	Hemp	Hemp	Hemp	Hemp	Hemp

DETERIORATION DUE TO HOT STACK GASES

While the results of studies showing the extent of deterioration in abaca brought about by exposure to hot gases are not available, the Bureau of Ships[113] of the United States Navy Department has supplied test data on the deterioration caused by hot stack gases in signal halliards made of flax. The test consisted in flexing 1-inch, Aczol-treated halliards around sheaves in an atmosphere of fumes of burning oil at 400° F. This temperature represents the charring point

[112] U. S. NAVY DEPARTMENT. INVESTIGATION OF CORDAGE PRESERVATIVES. 4 pp. Boston. July 15, 1946. (Navy Yard, Boston. Materials Lab. Report 8747B.) (Progress.) [Unpublished.]

[113] U. S. NAVY DEPARTMENT. HALLIARDS, RESISTANCE TO HOT STACK GASES. Boston. Nov. 1, 1948. (Navy Yard, Boston. Materials Lab. Report 9111.) [Unpublished.]

of vegetable fibers, and halliards in service are subjected to hot stack gases reaching this temperature. The halliards on the sheaths were subjected to 60 oscillations per minute. The following results were obtained:

Temperature, °F.	300	350	400	450	500
Oscillations to failure at a load of 5 lbs. (average)...	8,646	4,476	2,271	1,020	633
	Load in pounds at 400° F.				
	5	10	15		
Oscillations to failure (average 10 tests).............	2,271	840	492		

It will be noted that flexing durability (oscillations to failure) decreased from 8,646 at 300° F. to 633 at 500° F. and that it decreased from 2,271 under a load of 5 pounds to 492 under a load of 15 pounds.

While these tests do not show how the fiber is tendered when subjected to high temperatures and fumes, it does show the extent to which deterioration may occur. Fibers to be used where they would be subjected to high temperatures or fumes might be expected to respond somewhat similarly to those used in the tests described, the amount of deterioration varying with the severity of the temperatures and the stresses to which the fiber was subjected.

CORDAGE STANDARDS

Cordage standards are judged first in reference to their value in the raw condition in which they are offered in trade. The impression made by the fiber at this stage often determines its success in competition with other fibers, or in the case of a little known fiber, governs its acceptance in trade.

The classification of fibers in trade is only a further step in the assignment of quality rating. Classification begins in the production areas where such factors as variations in color and length and, to some extent, fineness, luster, and cleanliness are determined by quick visual observation. This field- and trade-inspection classification has proved practical. Nevertheless, the trade would like to be able to place more reliance on classification, and hence measures taken to improve the methods of classification are well received by manufacturers. Unfortunately segregation of fibers into grade groups in the production areas, which must be performed cheaply in man labor and as quickly as possible, does not allow much latitude for introducing refinements of mechanical, physical, and chemical instruments or techniques that would be of practical and economic value. Factors of strength, fineness, spinnability, softness, brittleness, suppleness, elasticity etc., all of which play a part in determining the final value of the cordage product, can hardly be measured accurately in a field classification system and must be determined mainly in the laboratory. Fortunately, however, the manufacturer knows from his own factory experience in spinning specific grades of definite origin that a certain grade of fiber has the properties that will result, when spun in his mill, in a product that can meet a market demand and competition.

A search of the literature has failed to reveal any single place in which descriptions of the cordage standards adopted by the various producing countries are available. For this reason the official grades of the common cordage fibers adopted by the countries of origin are brought together here. The classifications of the different fibers are recorded as of indicated dates. Changes in the classification system do occur from time to time and for one not familiar with the trade it would be well to check the up-to-dateness of data relating to a particular fiber and the country in which it originates. Table 25 shows the classification designations of the more common cordage fibers by country of origin. It should be understood that these grades are general rather than specific, for certain tolerances are permitted with which the trade is familiar.

ABACA, CANTON, AMOKID, AND PACOL

Philippines

As early as 1902 correspondence of the United States Department of Agriculture with the Governor of the Philippine Islands shows that American manufacturers favored an inspection under Philippine Islands Government supervision of the then existing abaca fiber qualities. An Act, No. 2380, of the Third Philippine Legislature, Special Session of 1914, directed the Director of Agriculture to establish, define, and designate standards to become the official standards. This order was followed by many others designating changes in the established standards up to the Fiber Inspection Adminis-

TABLE 25.--Grade designations of the more common cordage fibers by country of origin

		ABACA				SISAL						
		Philippines		Central America	Indo-nesia	Kenya, Tan-ganyika, and Uganda	Mozam-bique	Indo-nesia	Philip-pines	Comores	Haiti	Brazil
		Hand or Spindle	Deco									
	Excellent	TA AB			Superior	△1	Extra	A X	SR-1	P. Première	A	1
		TB CD							SR-2	A. Deuxième		
		TC E		Clear	Good	A	1	B Y	SR-3	B. Troisième	X	3
		TD F										
		TE S2			Fair	◇2	A	C Z			B	5
		S3										
Cleaning	Good	I	AD-1		Fair X	$\boxed{3L}$	2				Y	7
		J1	AD-2									
		G	AD-3			3	2SL		SR-Y		S	9
		H										
	Fair	J2		Streaky		UG	3L		SR-0			
		K										
		M1				SCWF	3					
	Coarse	L1										
		L2					R					
		M2										
	Very coarse	DL										
		DM	AD-4								Peas-ant	
		Y-1	AD-Y									
		Y-2							SR-T		T	
		Y-3									T-3	
		Y-4									T-4	
		0-1	AD-0									
		0-2										
		0-3										
		T-1	AD-T	Tow		Tow-1	Tow 1	D XX				
		T-2					Waste 1					
		T-3				Tow-2	Waste 2					
		Waste										

trative Order No. 4 (Revised) of December 1, 1939, effective date July 1, 1940, entitled, "Determinations and description of the official standards for the various commercial grades of certain Philippine fibers." The grades of Philippine abaca for tagal (fine textile fiber) and normal cordage are given below:

Tagal Grades

Letter Designation	Name of Grade
TA	Tagal Extra Prime
TB	Tagal Prime
TC	Tagal Superior
TD	Tagal Good
TE	Tagal Fair

TABLE 25.--Grade designations of the more common cordage fibers by country of origin--Continued

HENEQUEN		MAGUEY (cantala)	PHORMIUM					MAURITIUS		CAROÁ
Mexico	Cuba	Philip-pines	New Zealand	St.Helena	Chile	Argen-tine	Azores	Island of Mauritius	Brazil (pite-ira)	Brazil
A-A	A	MR-1	Superior	Prime	A or I	Hemp	Hemp	Superior	Tipo 1	Tipo 1
		MR-2	Fine	Tiger						
A		MR-3		J.D. &Co.	B or II			Prime	Tipo 3	Tipo 3
			Good-fair							
B	B				C or III			Very Good	Tipo 5	Tipo 5
			High-point fair							
B-1					D or IV			Good	Tipo 7	Tipo 7
			Fair							
C	C	MR-Y						Fair	Tipo 9	Tipo 9
			Common							
M		MR-0						Common		
M-1										
			Rejected					Raw		
								Hard		
	Tow	MR-T	Tow 1st	Tow 1		Tow	Tow			
			Tow 2nd	Tow 2						
			Tow 3rd							
			Stripper slips-1st							
			Stripper slips-2nd							

Normal Grades

(I) Grades of Excellent Cleaning

Letter Designation	Name of Grade
AB	Superior Current
CD	Good Current
E	Midway
F	25% Over Fair Current
S2	Streaky Two
S3	Streaky Three

(II) Grades of Good Cleaning

Letter Designation	Name of Grade
I	Fair Current
J1	Superior Seconds No. 1
G	Soft Seconds
H	Soft Brown

(III) Grades of Fair Cleaning

Letter Designation	Name of Grade
J2	Superior Seconds No. 2
K	Medium Seconds
M1	Medium Brown

(IV) Grades of Coarse Cleaning

Letter Designation	Name of Grade
L1	Coarse
L2	Coarse Seconds
M2	Coarse Brown

(V) Grades of Very Coarse Cleaning

Letter Designation	Name of Grade
DL	Daet Coarse
DM	Daet Coarse Brown

Residual Grades

Letter Designation	Name of Grade
Y1	Damaged One
Y2	Damaged Two
Y3	Damaged Three
Y4	Damaged Four
O1	Strings One
O2	Strings Two
O3	Strings Three
T1	Tow One
T2	Tow Two
T3	Tow Three

Waste Grade

W	Waste

Decorticated Grades

Letter Designation	Name of Grade
AD-1	Abaca Decorticated Superior
AD-2	Abaca Decorticated Good
AD-3	Abaca Decorticated Fair
AD-4	Abaca Decorticated Strips
AD-Y	Abaca Decorticated Damaged
AD-O	Abaca Decorticated Strings
AD-T	Abaca Decorticated Tow

Grades of Canton and Similar Fibers (including amokid, and other very light, weak and spurious fibers from similar plants of unknown origin - *Musa* sp.)

Letter Designation	Name of Grade
Can-1	Canton One
Can-2	Canton Two
Can-3	Canton Three
Can-X	Canton X

Grades of Pacol (*Musa* sp.)

Letter Designation	Name of Grade
Pcl-1	Pacol One
Pcl-2	Pacol Two
Pcl-X	Pacol X

Central America

As previously stated, the production of abaca in Central America is conducted in Panama, Costa Rica, Guatemala, and Honduras. Since 1943 it has been supervised by the United Fruit Company under an agreement with the Reconstruction Finance Corporation of the United States Government. The methods of production are very similar in all four countries and this permits a uniform system of grading for all countries. The grades have been established and approved by the United States Reconstruction Finance Corporation and the United Fruit Company. They represent government grades promulgated by the United States rather than government grades of the individual Latin American countries.

The grades as originally presented by the Office of Defense Supplies, R. F. C., July 1, 1946 were: Superior, Good, Streaky, Brown, and Tow. On December 17, 1948, the R. F. C. introduced a new grade between Superior and Good designated as Clear, and by February 7, 1949, Clear was designated to take the place of Superior and Good. As practically no Brown fiber has been produced the Central American grades are now only Clear, Streaky, and Tow.

Although the grades are determined on the basis of strength, cleaning, color, and length these factors are in reality minor in that unless the fiber is badly damaged it is passed as possessing average normal strength, the cleaning is all similar, and is considered good in that all nonfibrous material is normally removed. The grades are primarily based on color since Clear represents any fiber from light ocher through ivory to white and Streaky represents any with purple or red tinges. The minimum length of line fiber is 30 inches; fiber below this length is graded Tow.

Indonesia

There are no official government standards for abaca grades in Indonesia. The fiber is graded by the principal growers and marketers with the designations for long fiber as follows:

Superior: Excellent cleaning, color very light ivory white; length 3 to 4 feet.
Good: Excellent cleaning, color light cream or ivory white; length 3 to 4 1/2 feet.
Fair: Good cleaning, color predominantly cream with a few yellowish and purple streaks and amber spots; length 3 to 4 1/2 feet.
Fair X: Good cleaning, color light brownish, white with some purple and brown or amber streaks and a few black strips; length 3 to 4 1/2 feet.

SISAL

Kenya, Tanganyika, and Uganda

These countries follow the same classification system to a marked degree in marketing their sisal fiber. The prescribed grades have not been covered by any official government order, but it was expected that some action would be taken in 1950. The grades were introduced by the Kenya Sisal Growers Association and have been accepted by related trade organizations throughout the world. The Kenya Sisal Board furnished the following East African grading definitions in January 1950:

Kenya Sisal Grading Definitions	Bale marks
Length from 3 ft. with average of 3 ft., 6 ins. Free of defective decortication. Properly brushed. Free of tow, bunchy ends, knots and harshness. Color - creamy white to cream.	1
The same as Grade 1, but colour yellowish, sunburned, slightly spotted or slightly discolored.	A
Length from 2 ft., 6 ins. upwards. Free of defective decortication. Properly brushed. Free of tow, bunchy ends, knots and harshness. Color - creamy white to cream.	2
Length from 3 ft. upwards, consisting of brushed fiber that does not conform to Grades 1, A or 2; although minor defects in color and cleaning are allowable it must be free of barky or undecorticated fiber and knots.	3L
Same as No. 3L but length from 2 ft. upwards.	3
Fiber that does not conform to the above-mentioned grades as regards length, color and cleaning, but minimum length to be 2 ft.	UG
Length not less than 18 inches and not more than 24 inches, otherwise as No. 3.	SCWF

Note 1 All grades to be parallel packing, no ties or knots, free from dampness and excessive baling pressure.

Note 2 The word "harshness" included in the definitions of No. 1, A and 2 grades only refers to fiber from which the gum has not been sufficiently extracted by cleaning and does not apply to fiber which is coarse in texture due to soil or climatic conditions.

Sisal Tow	
Proper tow from the brushing machine. Free of line fibre and cuttings and reasonably free of dust but entirely free of sweepings and knots. Color - creamy white to cream.	Tow 1
Darker color allowed. Small percentage of line fiber, long white cuttings, and not entirely free of dust but entirely free of sweepings or knots.	Tow 2

Mozambique[114]

The fibre of sisal is classified in the following patterns, in accordance with official Portuguese Government standards.[115]

Sisal extra: Consisting of fibre whose length, texture, colour, grade of brush and packing are satisfactory to certain requisites between the producer and the buyer, for special purposes.

Sisal 1: Consisting of fibre with 90 centimetres (35.4 inches) or more in length, of white, ivory or slightly cream colour, resulting from the selection, decortication, washing, drying brushing, classification, handling and baling conducted correctly, without any tolerance of defects or of impurities.

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[114] Report 9 of Mar. 12, 1949 from American Consulate General, Lourenco Marques, Mozambique. [Unpublished.]
[115] Official Portuguese Government Standards as furnished by U. S. Importer, Mar. 10, 1949.

Sisal A: Consisting of fibre with 90 centimetres (35.4 inches) or more in length, slightly spotted or of a yellowish colour slightly burnt or discolored, without tolerance of other defects or of impurities.

Sisal 2: Consisting of fibre with 75 centimetres (29.5 inches) or more in length, of white, ivory or slightly cream colour, as a result of selection, decortication, washing, drying, brushing, classification, handling and baling conducted correctly, without tolerance of defects or of impurities.

Sisal 2 SL: Consisting of fibre with 60 centimetres (23.6 inches) or more in length, of white, ivory or slightly cream colour, resulting from selection, decortication, washing, drying, brushing, classification, handling and baling conducted correctly, without tolerance of defects or of impurities.

Sisal 3 L: Consisting of fibre with 90 centimetres (35.4 inches) or more in length, admitting the following tolerances of defects:
(a) Reduced percentage of fibre deficiently decorticated.
(b) Reduced percentage of spotted fibre or of fibre of spotted colour.
(c) Reduced percentage of fibre deficiently brushed.

Sisal 3: Consisting of fibre with 60 centimetres (23.6 inches) or more in length, admitting the following tolerances of defects:
(a) Reduced percentage of fibre deficiently decorticated.
(b) Reduced percentage of spotted fibre or of fibre of spotted colour.
(c) Reduced percentage of fibre deficiently brushed.

Sisal R: Consisting of fibre of 60 centimetres (23.6 inches) or more in length, admitting a considerable percentage of fibre imperfectly decorticated, spotted or of spotted colour, or deficiently brushed.

The special characteristics of the patterns of Sisal Extra must be communicated to the Export Control Board, in due time by the producers interested.

The tow of Sisal shall be classified in the following patterns:

Tow 1: Consisting of twisted fibre, of cream or yellowish colour, sufficiently clean, admitting the tolerance of a small percentage of straight fibre, but free from entanglements, knots, bark, pulp, dust or other impurities.

The waste of Sisal shall be classified in the following patterns:

Waste 1 or Clean Waste: Consisting of residues of cream fibre, fibre washed and brushed, without impurities.

Waste 2 or Dirty Waste: Consisting of residue of cream or spotted fibre, only washed, with impurities.

Indonesia

The present system of grading agave fibers in Indonesia was set up during the period of the Netherlands East Indies political administration. It was not a government system but one in which each producing company set up its own grades. The system in most common use is as follows:[116]

Grade A: White fiber--length more than 90 cm.
B: White fiber--length between 60 and 90 cm.
C: White fiber--length between 50 and 60 cm.
D: Waste and "tow" (Kawoel)

[116] FIBERS-NETHERLANDS INDIES. Report of Aug. 6, 1941 from American Embassy, Djakarta, Java. [Unpublished.]

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Certain estates, however, make the following classifications:

Grade A: White fiber--length more than 105 cm.
B: White fiber--length between 75 and 105 cm.
C: White fiber--length between 50 and 75 cm.
D: Waste and "tow" (Kawoel)

The estates of H. V. A. (Handelsveereniging Amsterdam), estimated to produce 65 percent of the sisal grown in Indonesia, use the first set of white fiber grades shown above and the following system for off colored grades:

Grade X: Off colored fiber--length more than 90 cm.
Y: Off colored fiber--length between 60 and 90 cm.
Z: Off colored fiber--length between 50 and 60 cm.
XX: Inferior grades

Philippines

The Commonwealth of the Philippines, Department of Agriculture and Commerce, Fiber Inspection Administrative Order No. 4 (Revised) of December 1, 1939, effective date July 1, 1940, designates the official grades of sisal.

Sisal--Retted and Decorticated Sisal, whether washed or not in sea or fresh water - Agave sisalana, Per.

Letter Designation	Name of Grade
SR-1	Sisal One
SR-2	Sisal Two
SR-3	Sisal Three
SR-Y	Sisal Damaged
SR-O	Sisal Strings
SR-T	Sisal Tow

Comore Islands

The grades of sisal as described for the Comore Islands in 1947 by Hébert (87) are:

P. Première quality well cleaned, white, over 90 cms. in length.
A. Deuxième quality some imperfections in cleaning, white, and over 70-75 cms. in length.
B. Troisième quality more imperfections in cleaning and over 50-65 cms. in length.

Haiti

Haiti was the only large producer of sisal in the Western Hemisphere in the years between World Wars I and II. Haitian sisal is considered an exceedingly high quality product and the maintenance of Haitian standards has been well adhered to. Haitian sisal was the only sisal fiber available from the Western Hemisphere countries for many years until the Brazilian sisal industry became established. The Brazilian industry has grown with surprising rapidity since the first fiber was produced in 1941. While individual private companies early adopted methods of classification, a Haitian Executive Order No. 262, dated April 8 and promulgated in Le Moniteur of April 12, 1943, established official export standards for grades of sisal processed in Haiti. The Standardization Committee took counsel in formulating these grades with the general managers of the two largest sisal plantations in Haiti. The order (translated) follows:

Article 1. Beginning the first of October, 1943, all processed sisal destined for export must be classified and declared in customs, following the description of one of the grades defined below, which it is understood must be clean and dry:

Grade A: Fibers more than 36 inches long, white or light in color.
Grade X: Fibers more than 36 inches long, white or greyish white in color, with some few yellow or brown stains;
Grade B: Fibers 24 to 36 inches long, white or light color;

Grade Y: Fibers 24 to 36 inches long, white or greyish white in color, with some few yellow or brown stains;
Grade S: Fibers 24 or more inches in length, greyish white slightly pulpy.
Grade T: Fiber waste (tow), white in color;
Grade T-3 Tow, pale cream in color;
Grade T-4 Tow, deeper cream than the preceding.

Article 2. The weight of the bales of each kind, or grade, shall be fixed by an announcement of the Department of Commerce and National Economy.

Article 3. Any bale which does not conform to the characteristics of the grade declared shall not be allowed for export.

Article 4. The present Arrete shall be published and carried out under the supervision of the Secretaries of State for Agriculture and Labor and for Finance, Commerce and National Economy.

Done at the National Palace at Port-au-Prince, the 8th day of April, 1943, in the 140 year of Independence.

Elie Lescot

By the President:
Secretary of State for Agriculture and Labor
Maurice Dartigue

Secretary of State for Finance, Commerce and National Economy
Abel Lacroix

Brazil

Beginning with a production of some 15 tons of sisal in 1941, Brazil produced an estimated 30,000 tons in 1949. With such a new and rapid expansion in production, the quality and practices of trade packaging have not been as well standardized as in some of the older production areas. Sisal like many other fibers in Brazil follows an official Brazilian classification system based on color, cleanliness, strength, and freedom from defects of processing. The designations are by odd numbers, namely, Tipo 1, 3, 5, 7, and 9. A decree, No. 14,269, promulgating these grades was made by the Ministerio da Agricultura, Rio de Janeiro, Brazil, December 15, 1943. The description follows:

Tipo 1.--Fibers cream-white color, normal strength, free of impurities or processing defects.

Tipo 3.--Fibers cream-white color, strong, free of impurities (pectic substances) and tangled fibers.

Tipo 5.--Fibers cream color, normal strength, and free of impurities.

Tipo 7.--Fibers coarse, yellowish, greenish, or gray color and normal strength.

Tipo 9.--Fibers of greater coarseness, yellowish, greenish, or gray color, but of normal strength.

HENEQUEN

Mexico

The Association Henequeneros de Yucatán and the government of the State of Yucatán, taking into account the existence and customs of the international market of fibers, have classified henequen into seven classes based on length, color, cleaning, and quantity of impurities, as shown in table 26 (120).

TABLE 26.--Grades of Mexican henequen adopted by Henequeneros de Yucatán

Class	Length	Color	Cleaning	Impurities
	Meters			*Percent*
A-A	1 or more	White	Brushed or washed	No more than 2
A	1 or more	White	Clean	No more than 2
B	75 cm. to 1 meter	White	Clean	No more than 3
B-1	75 cm. to 1 meter	White	--	3 percent or more
C	60 cm. to 75 cm.	White	Clean	No more than 3
M	75 cm. or more	Streaky and dark	Clean	No more than 3
M-1	60 cm. or less	--	--	No more than 5

Cuba

Cuba has no law or decree that establishes henequen grades. The growers acting more or less in cooperation have established the following grades:

A - Fiber 3 feet or longer, white and not spotted.

B - Fiber shorter than 3 feet, white and not spotted. Also fiber 3 feet or longer with some spotting.

C - All other line fiber.

All tow is of one grade and designated "tow".

MAGUEY

Philippines

The Commonwealth of the Philippines, Department of Agriculture and Commerce, Fiber Inspection Administrative Order No. 4 (Revised) of December 1, 1939, effective date July 1, 1940, designates the official grades of maguey.

Maguey--Retted and Decorticated Maguey, whether washed or not in sea or fresh water--Agave cantala, Roxb.

Letter Designation	Name of Grade
MR-1	Maguey One
MR-2	Maguey Two
MR-3	Maguey Three
MR-Y	Maguey Damaged
MR-O	Maguey Strings
MR-T	Maguey Tow

PHORMIUM

New Zealand

Standard compulsory government phormium grading regulations were introduced into New Zealand as early as 1901. The grades as designated and described (16) are:[117]

[117] GREAT BRITAIN. MINISTER OF SUPPLY. CONTROL OF HEMP ORDER, 1939. (Statutory Rules and Orders 1939 No. 1004, dated Sept. 1, 1939.)

Straight fiber:

		Scoring
A	Superior	90-100 points
B	Fine	80-89 "
C	Good-fair	70-79 "
DD	High-point fair	65-69 "
D	Fair	60-64 "
E	Common	50-59 "
F	Rejected	under 50 "

Tow:

1st
2nd
3rd
Condemned

Stripper-slips:

1st
2nd
Condemned

"Stripper-slips" is the term applied to waste fiber produced during stripping but not carded. Tow is waste fiber produced during scutching. The system of scoring is based on an allotment of 25 points each for stripping, scutching, color, and strength. The term "stripping" in phormium production refers to the usual fiber separation process. After the damp, fresh fiber is dried it may be reworked to soften and further clean it on another machine and this second process is called the scutching.

St. Helena, Azores, and Argentina

The British "Control of Hemp Order"[118] put into effect in 1939 at the beginning of World War II to govern the trade transactions in fibers, mentioned the following grades of phormium fiber from St. Helena, Azores, and Argentina:

St. Helena Prime	Azores Hemp	Argentine Hemp
St. Helena Tiger	Azores Tow	Argentine Tow
St. Helena J.D. & Co.		
St. Helena Tow No. 1		
St. Helena Tow No. 2		

As the same British executive order did not list all grades of abaca and Cannabis sativa, it is possible that there are additional recognizable grades of phormium fiber from these three sources.

Chile

Phormium in Chile is grown and manufactured primarily by a private corporation, the Sociedad Agricola e Industrial Formio Chileno. The plantation is at Mafil and the spinning mill at Valdivia. The system of fiber grading is based on the system of grading the leaves, as follows:

	Leaf length
Grade A or I	1.20 meters or longer
B or II	1 to 1.20 meters
C or III	.75 to 1 meter
D or IV	.50 to .75 cms.

[118] See Footnote No. 117.

MAURITIUS (FURCRAEA GIGANTEA)

Island of Mauritius

Mauritius fiber has been graded for many years for export according to standards controlled by the Mauritius Hemp Producers' Syndicate. (8) The grades are designated: Superior, Prime, Very good, Good, Fair, and Common. In some years small percentages are designated "raw" or "hard." These grades are based primarily on degree of cleaning.

Brazil

Piteira, the name by which *Furcraea gigantea* is known in Brazil, is graded for export according to standards set up under Federal decree No. 14, 269 of December 15, 1943. These are based on cleaning, strength, and defects of preparation. They are: Tipo 1, 3, 5, 7, and 9. The decree is the same as for Brazilian sisal and the description of the standards for the different grades are the same as described under Sisal.

CAROÁ

Brazil

The Ministerio da Agricultura, Rio de Janeiro, in "Decreto n. 6. 630, de 20 de dezembro de 1940" approved a classification of standard grades of caroá described as follows:

Tipo 1. Considered of first quality, shall be of fibers 0. 80 to 1. 70 meters in length of white or cream-white color, of normal softness and strength, free of pectin substances and without defects of preparation and absence of tangled fibers.

Tipo 3. Shall be of fibers 0. 80 to 1. 70 meters in length of white-cream or cream color and of normal softness and strength.

Tipo 5. (Description missing in decree.)

Tipo 7. Shall be of fibers 0. 80 to 1. 70 meters in length, of yellowish color, darkened or greenish, and normal strength.

Tipo 9. Considerable limitations. Shall be of fibers apparently 0. 80 to 1. 70 meters in length, of yellowish, greenish, or darkish color, and of normal strength.

PRODUCTION OF CORDAGE FIBERS BY GRADES

Frequently it is desirable to know the proportion of fiber of different grades marketed from different countries because the country of origin is an indication as to whether or not the fiber is mainly of high or low grade. The total fiber production of a country is seldom if ever distributed equally through the various grades. While the proportions of the total amount produced will vary in different years because of variations in environmental factors affecting growth, economic conditions, etc., trends of production obtained by using the figures of several years should prove of value in visualizing the production of future years unless some differences in methods of production or classification should occur that would affect the system of growth or marketing.

ABACA

The average yearly production of Philippine abaca by grades for a ten-year period is shown in table 27.

TABLE 27.--Abaca yearly production (by grades)

Year	AB	CD	E	F	I	S2	J1	S3	G
1925............	8,545	31,549	46,865	99,123	118,023	89,921	114,080	33,909	76,014
%.............	0.7	2.6	3.9	8.2	9.8	7.4	9.4	2.8	6.2
1926............	8,112	35,298	40,397	89,421	135,717	110,726	126,957	43,972	94,480
%.............	0.7	2.8	3.3	7.2	11.0	8.9	10.3	3.5	7.6
1927............	2,485	26,179	33,768	76,433	118,156	109,156	98,151	36,321	82,108
%.............	0.2	2.1	2.7	6.2	9.6	8.9	8.0	3.0	6.7
1928............	1,207	21,294	27,017	62,721	121,201	100,233	133,837	42,619	106,694
%.............	0.1	1.5	1.9	4.5	8.7	7.2	9.7	3.1	7.7
1929............	1,007	25,697	37,923	74,978	111,475	140,506	126,881	68,631	133,853
%.............	0.1	1.6	2.4	4.7	7.0	8.8	8.0	4.3	8.4
1930............	171	11,101	20,604	48,720	100,914	92,412	111,574	57,683	118,316
%.............	--	0.9	1.6	3.8	7.9	7.3	8.8	4.5	9.3
1931............	378	12,201	15,752	38,466	74,508	75,750	84,273	50,327	90,681
%.............	--	1.1	1.5	3.5	7.0	7.1	7.9	4.7	8.5
1932............	142	7,961	10,963	23,815	55,236	60,705	87,991	44,580	97,239
%.............	--	0.9	1.3	2.7	6.3	7.0	10.1	5.1	11.1
1933............	286	8,634	15,468	44,648	91,055	64,103	142,981	58,409	135,319
%.............	--	0.7	1.3	3.6	7.4	5.2	11.6	4.8	11.0
1934............	564	13,338	21,358	67,338	108,605	80,469	131,564	67,708	150,907
%.............	--	0.9	1.5	4.7	7.5	5.6	9.1	4.7	10.5

Year	J2	H	K	L1	L2	M1	M2	DL	DM
1925............	127,833	37,890	120,065		85,618		53,751	18,791	13,874
%.............	10.6	3.1	9.9		7.1		4.4	1.6	1.1
1926............	130,807	40,378	84,863	24,582	59,281	16,257	31,912	18,148	7,401
%.............	10.6	3.3	6.9	2.0	4.8	1.3	2.6	1.5	0.6
1927............	134,812	30,618	77,091	86,437	54,168	47,834	33,634	25,561	8,126
%.............	11.0	2.5	6.3	7.0	4.4	3.9	2.7	2.1	0.7
1928............	138,449	38,276	110,727	94,363	60,319	57,507	36,703	29,956	7,512
%.............	10.0	2.8	8.0	6.8	4.4	4.1	2.6	2.2	0.5
1929............	127,378	47,131	168,470	77,660	60,487	69,768	33,742	20,670	8,874
%.............	8.0	3.0	10.6	4.9	3.8	4.4	2.1	1.3	0.6
1930............	135,783	39,424	166,117	65,776	44,317	68,144	26,087	18,811	7,305
%.............	10.7	3.1	13.0	5.2	3.5	5.3	2.0	1.5	0.6
1931............	68,266	26,335	104,953	58,432	68,055	41,565	34,197	19,046	7,999
%.............	6.4	2.5	9.8	5.5	6.3	3.9	3.2	1.8	0.7
1932............	76,579	28,531	70,589	28,877	43,902	23,402	21,168	7,866	3,292
%.............	8.8	3.3	8.1	3.3	5.0	2.7	2.4	0.9	0.4
1933............	110,868	38,916	101,680	53,524	61,952	35,993	36,242	10,472	3,535
%.............	9.0	3.2	8.3	4.4	5.0	2.9	3.0	0.9	0.3
1934............	136,217	45,800	115,398	49,455	68,199	41,218	33,073	14,156	6,254
%.............	9.4	3.2	8.0	3.4	4.7	2.9	2.3	1.0	0.4

Philippine statistics of pressings bales of individual grades of abaca during 1948, reproduced below, may be helpful in estimating supplies and may explain why some grades may in some years be scarce or unobtainable (193):

Grade	Non-Davao	Davao	Total	Percent
AB	22	--	22	--
CD	4,591	23	4,614	3/4
E	8,867	1,552	10,419	1-3/4
F	21,423	13,327	34,750	6
I	24,452	38,939	63,391	11
S2	33,892	33,009	66,901	11-1/2
J1	51,489	38,260	89,749	15-1/2
S3	13,926	13,882	27,808	4-3/4
G	75,649	41,150	116,799	20-1/4
J2	31,299	4,200	35,499	6-1/4
H	20,085	7,916	28,001	5
K	42,750	4,302	47,052	8-1/4
L1	2,878	216	3,094	1/2
L2	2,479	63	2,542	3/8
M1	14,475	1,678	16,153	2-3/4
M2	982	39	1,021	1/4
DL	13	--	13	--
DM	--	--	--	--
Y1	195	1	196	--
Y2	4,461	684	5,145	7/8
Y3	4,606	253	4,859	3/4
Y4	160	--	160	--
O1	72	--	72	--
O2	1,594	993	2,587	3/8
O3	1,042	5	1,047	1/4
T1	1,088	--	1,088	1/4
T2	4,521	4,027	8,548	1-1/2
T3	3,187	2,037	5,224	1
W	498	212	710	1/8
Total	370,696	206,768	577,464	

SISAL

Table 28 shows the distribution by grades of sisal produced in British East Africa during the years 1943 to 1946, inclusive.

TABLE 28.--Percentages by grades in different years of total production of sisal in Kenya, Uganda, and Tanganyika[119]

Grades	1943	1944	1945	1946
Kenya and Uganda:				
1	23.20	26.02	19.23	14.82
A	14.98	10.62	11.18	11.06
2	19.65	19.65	18.37	19.14
3L	8.49	7.91	11.05	10.00
3	19.60	23.70	26.36	26.22
VG	4.27	3.45	5.06	9.15
Tow 1	4.66	4.16	4.08	4.45
Tow 2	1.57	1.69	1.33	1.48
F Tow	3.58	2.80	3.34	3.68
Tanganyika:				
1	41.64	41.15	38.46	30.41
A	12.61	13.51	13.65	15.89
2	13.07	13.38	13.41	12.37
3L	17.47	17.01	18.54	22.22
3	6.29	6.01	6.91	7.90
VG	2.35	2.02	2.32	3.84
Tow 1	5.90	5.58	5.33	5.49
Tow 2	.49	.72	.89	1.23
F Tow	.18	.62	.49	.65

[119] EAST AFRICAN SISAL INDUSTRY. ANNUAL REPORT. (Proceedings at the annual meeting in Tanga and Nairobi, 1947.)

An analysis of 258 lots of sisal (17,504,750 pounds) shipped from Haiti during the fourth quarter, 1949, shows the following distribution by grades:[120]

Grade	Percent of total
"A"	29.82
"X"	32.65
"Y"	5.38
"S"	4.85
White Tow	.37
Flume Tow	21.59
Other	5.34
Total	100.00

The proportion of sisal of the different grades as reported in 1947 for the Comore Islands by Hébert was as follows:

Grade	Percent of total
1st	50
2nd	45
3rd	5
Total	100

HENEQUEN

The proportions of henequen of different grades produced in Yucatán in the years 1942-46, inclusive, are shown in table 29.

[120] QUARTERLY FIBER REPORT - HAITI - SISAL AND KENAF WITH REVIEW OF THE YEAR 1949. 7 pp. Report 113 of Mar. 11, 1950 from American Embassy, Port-au-Prince, Haiti. [Unpublished.]

TABLE 29.--Percentages by grades in different years of total production of henequen in Yucatán (56) (12)

Grades	1942	1943	1944	1945	1946
A	40	40	46.4	48	48
B	31	27	24.5	25	26
B-1	8	9	7.1	6	7
C	8	9.5	8.6	7	9
M	13	14.5	13.5	6	4
M-1	--	--	--	8	6

Table 29 shows that practically 75 percent of the total production of long henequen fiber in Yucatán comes within the two highest grades and that the proportion of fiber in the lower grades is about the same from year to year. The table does not show the amount of cleaned bagasse produced in Yucatán, which seems to have been relatively insignificant in past years, as shown by export figures.

MAURITIUS

The president of the Mauritius Hemp Producers' Syndicate reporting for the year 1942 (8) presented the tonnage of Mauritius fiber classified by different grades for the period 1933-42, inclusive, as follows:

	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942
	%	%	%	%	%	%	%	%	%	%
Superior	1.25	3.39	--	--	.31	--	--	2.38	4.00	--
Prime	51.67	44.51	61.28	63.09	49.96	58.49	78.43	67.84	77.25	96.20
Very Good	23.61	35.44	27.12	25.19	27.88	38.70	11.59	23.09	15.05	3.00
Good	20.70	15.87	9.16	4.36	3.81	.85	8.15	6.46	2.79	.80
Fair	1.83	.78	1.18	.44	.78	--	--	.23	.85	--
Common	.38	.01	--	--	.06	--	--	--	--	--
Raw	--	--	1.26	6.92	17.20	1.96	1.83	--	--	--
Hard	--	--	--	--	--	--	--	--	--	--

During the period 1882-1946 the annual production ranged from 242 to 3,105 tons.[121]

BALE WEIGHTS, SIZES, AND STOWAGE FACTORS OF CORDAGE FIBERS

The weight and dimensions of bales of certain cordage fibers, together with the kind and weight of the covering and binding material of the bales, are given in table 30.

TRANSPORTATION OF CORDAGE FIBERS [123]

With the exception of cotton, hemp that is grown in Wisconsin and Kentucky, and some flax in Oregon, all of the vegetable fibers used in the United States in the production of cordage, rope, and twine are imported from foreign countries.

Fibers arrive in the United States by ship, usually at the port of entry nearest to the factory where they are to be converted into cordage. From the port of entry the fiber moves to the factory by railroad, truck, lighter, or in some cases by river steamer.

Some fibers, such as istle, Tampico sisal, and Sinaloa sisal, move from their Mexican points of origin by railroad cars across the Mexican border through to the cordage processors' factories, but these are the only exceptions to steamer arrivals.

[121] LOCK, G. W., and LEES, P. W. REPORTS ON THE MAURITIUS FIBRE INDUSTRY. Pub. 44, Colony of Mauritius, p. 45. 1947.

[123] This section was written for this monograph by an expert in the field of transportation, E. E. Bockstedt, Vice President in charge of traffic, Columbian Rope Company, Auburn, N. Y.

TABLE 30.--Bale weights, sizes, and stowage factors of specified fibers[122]

Fiber	Gross weight	Bale dimensions			Average cu. ft. per bale	Bale covers			Binding material			Net wt. per bale		Cu. ft. per long ton (gr. wt.)
		Width	Depth	Length		Kind	Weight		Kind	Weight				
	Lbs.	In.	In.	In.			Lbs.	Oz.		Lbs.	Oz.	Lbs.	Oz.	
Java Cantala:														
Sokarameh	764	26-2/3	32	39	19-3/10	None	--	--	Iron bands	10	14	753	2	56.59
Mento	561	21-1/2	27-1/4	40	13-3/10	None	--	--	Iron bands	8	9	552	7	53.09
Soekamandi	453	20-1/2	26	39-1/2	12-3/10	None	--	--	Iron bands	8	10	444	6	60.82
M. G. R.	449	21	24-1/4	39	11-8/10	Mats 2 sides	--	6	Iron bands	4	8	444	2	58.87
Java Sisal:														
H. V. A.	733	25	31	40	17-8/10	None	--	--	Iron bands	11	3	721	13	54.40
Kobla	467	22	24-1/2	40-1/2	12-7/10	None	--	--	Iron bands	8	11	458	5	60.92
Soekon	763	25	32-1/2	40-1/4	18-7/10	None	--	--	Iron bands	10	12	752	4	54.90
African Sisal:														
Kenya	234	14-1/2	18-1/2	48-1/4	7-3/10	None	--	--	Wire bands	3	5	230	11	69.88
Tanganyika	466	19-1/4	25-1/4	51-1/4	14-6/10	Burlap 1 side and both ends	1	3	Iron bands	8	5	456	8	70.18
Portuguese	571	21-1/4	25-1/4	51-1/2	16-3/10	Burlap 2 sides	--	12	Iron bands	8	7	561	13	63.94
Haitian Sisal:														
H. A. D. C.	573	26-1/8	32-1/2	53-3/4	26-2/10	None	--	--	Rope	5	4	567	12	102.42
Sumatra Abaca	610	24-1/4	30-1/2	38-1/4	17	None	--	--	Iron bands	11	1	598	15	62.43
Henequen:														
Mexican	413	27	32-1/4	47-1/2	24-1/10	None	--	--	Rope	5	--	408	--	130.71
Cuba	515	31-1/2	34-1/2	43-1/8	28-6/10	None	--	--	Rope	2	1	512	15	124.40

122 Furnished to Office of Cotton and Other Fiber Crops and Diseases, U. S. Bureau of Plant Industry, by Plymouth Cordage Company, Plymouth, Massachusetts, in 1942.

THE BROKER

There are no established exchanges in the United States for vegetable fibers other than cotton. As a result the independent broker plays an important role. Only in a few cases do the cordage manufacturers buy their fibers direct from the fiber plantations; usually they are obtained through brokers. Only one processor owns a plantation.

For years it has been the custom in the cordage industry to purchase supplies of fiber through brokers, usually located in Boston, New York, San Francisco, or London, England.

The broker generally has a direct connection with the plantation owner for the sale of the fiber that the plantation produces. The broker usually represents plantations or balers which produce, or bale, abacas, sisals, jutes, and flaxes all over the world so that he has constant offers coming into his office which he makes available to the cordage manufacturers by telephone or letter in the hope of making a sale.

It will be interesting to follow an offer through a broker's office to see the functions that he performs and the service that he renders not only to the foreign connection but also to the cordage manufacturers in this country.

A plantation in Haiti cables to its broker authorizing him to sell 25 tons of "A" quality and 25 tons of "X" quality, Haitian machine-dried sisal for example, 16¢ and 15-3/4¢ per pound landed New York, May-June shipment.

The broker makes his contacts and finally sells to a cordage processor in Bridesburg, Pa., and cables to his principal to make the shipment. When the shipment is made from Haiti the plantation cables the broker that the shipment has been made on the steamer Trajanus due New York June 10. The plantation mails the broker the ocean bills of lading and commercial invoices and usually draws a draft on the broker for 80 percent to 90 percent of the valuation of the shipment - balance to be paid when the details of the sale are finalized.

Here are a few details to show how the broker functions:

(1) Places Marine and War Risk Insurance.
(2) Receives the shipping papers and validates the draft to the consignee.
(3) Pays the ocean freight to the steamship company.
(4) Makes the customs entry and takes delivery from the steamship company.
(5) Arranges to have each bale weighed at the port of entry.
(6) Forwards the shipment to the cordage processor.
(7) Makes claim against the steamer if packages are damaged or lost.
(8) Invoices the cordage processor at the agreed price (which includes his fee) on the weights obtained at the port of entry.

OCEAN FREIGHT RATES ON FIBER

Ocean freight rates are generally predicated upon the space displaced in the ship, but in some cases the rate is expressed in cents per 100 pounds and in other cases a bale rate is expressed.

The schedule below shows the rates in 1950 with approximate conversion into cents per 100 pounds.

Fiber	From	To	Ocean rate	Conversion per 100 lbs.
Henequen......	Tampico, Mex.	New York	$14.50 per 1,000 kilos plus 2.2%	$0.70
Do........	Vera Cruz, Mex.	New York	14.50 per 1,000 kilos plus 2.2%	.70
Do........	Progreso, Mex.	New York	2.75 per bale of 400 lbs.	.70
Do........	Progreso, Mex.	New Orleans	2.10 per bale of 400 lbs.	.52
Do........	Havana	New York	.75 per 100	.75
Sisal.........	Haiti	New York	.75 per 100	.75
Do........	Haiti	New Orleans	.75 per 100	.75
Do........	Brazil	New York	30.50 per metric ton	1.50
Do........	Br. E. Africa ports	New York	20.00 per 40 cu. ft.	1.55
Do........	Port. E. Africa ports	New York	19.00 per 40 cu. ft.	1.50
Do........	Java ports	New York	21.30 per cu. meter	1.10
Abaca.........	Cen. America	New York	1.20 per 100	1.20
Do........	Cen. America	New Orleans	1.00 per 100	1.00
Do........	Philippines	New York	6.45 per bale of 275 lbs.	2.34
Do........	Philippines	Pacific ports	4.95 per bale of 275 lbs.	1.80
Jute..........	Calcutta	New York	17.00 for 40 cu. ft.	1.15
Do........	Chittagong	New York	17.00 for 40 cu. ft.	1.15

MARINE AND WAR RISK INSURANCE

It is the usual custom when making a shipment on an ocean carrier to cover the shipment for its full value at the port of shipment plus ocean freight and, in some cases, plus contemplated profit.

In some instances, when the market has advanced over the cost of the fiber, insurance is placed for replacement value of the fiber so that in the event of a loss the fiber could be repurchased.

Marine and War Risk Insurance rates vary depending upon the length of the voyage, harbor conditions, and hazards such as floating mines.

The attached schedule shows the difference in the rates from the various fiber-producing countries.

Schedule of Rates

As of November 21, 1949

	Marine Per $100 Value	War Per $100 Value
From Philippine Islands:		
Direct to Atlantic U. S. via Panama	.375	.10
Via inter-island steamer transshipped at Manila thence direct to U. S. Atlantic via Panama	.425	.10
Direct to U. S. Pacific	.30	.10
Via inter-island steamer transshipped at Manila direct to U. S. Pacific	.325	.10
Sisal from Haiti	.225	.05
Hemp from Central America via Panama:		
East Coast	.25	.05
West Coast	.30	

From	To		Marine	War
Yucatán	New York	Hemp & Sisal	.25	.05
Yucatán	New Orleans	" "	.25	.05
Cuba	New York	" "	.175	.05
British E. Africa	New York	" "	.475	.10
Portuguese E. Africa	New York	" "	.475	.10
Portuguese W. Africa	New York	" "	.475	.10
Tampico, Vera Cruz	New York	" "	.25	.05
Java, Sumatra	New York	" "	.525	.15
Calcutta	New York	Jute	.5125	.125

WEIGHING AND TARE ALLOWANCES

When the fibers arrive at the ports of entry the broker or importer usually arranges to have an official weigher weigh each bale, but in some cases factory weights are accepted by the seller.

Each bale is weighed and a typewritten copy of the weight notes is furnished by the broker to support the weight as shown on the invoice. The weighing charge is paid by the broker for the account of the seller and cost in 1950 about 7¢ per 100 pounds.

Where factory weights are accepted by the seller the factory furnishes the weights to the broker and the factory is then invoiced on this basis.

In selling jute where the bales are uniform in size only 10 percent of the shipment is weighed and these weights are used as average weights.

Where a foreign material is used as a band or a cover on the bale an allowance is made on the weight notes to cover the actual weight of the foreign material used for the band or cover.

Henequens from Mexico or Cuba are bound with henequen bands - no allowance.

Haitian sisal and in some cases African sisal is bound with sisal bands - no tare allowance.

Java sisal, Sumatra abaca, and some African sisal is bound with heavy iron bands, in some cases equal to 7 pounds per bale. In such cases the weigher makes actual tests of the weights of these iron bands and makes an allowance on the weight note.

Central American abaca is packed 300 pounds net per bale, baled with iron bands but no tare is allowed.

In some cases Philippine abaca is baled with palm leaf mats to cover the bale and rattan bands are used as bale ties. In such cases an allowance of 4 pounds per bale is made.

Jute is bound with a jute rope bale tie and in some cases an allowance is made.

PORT OR TERMINAL CHARGES ON FIBER IN UNITED STATES PORTS

The ocean freight rate on fiber from the country of origin includes discharge on the dock and in most cases delivery to the carrier which conveys it to the cordage factory.

From North Atlantic, South Atlantic, and Gulf ports the railroads have import railroad freight rates from the principal ports of entry to the cordage factories and these rates include the cost of loading the fiber in freight cars.

At the Pacific Coast ports this is not the case and only part of the loading and port charges are absorbed by the railroads. The balance, usually about 10¢ per net ton in 1950, is shown as advance charges incurred at the port of entry.

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