U. S. DEPARTMENT OF AGRICULTURE.

FIBER INVESTIGATIONS. REPORT NO. 5.

A REPORT

ON

THE LEAF FIBERS OF THE UNITED STATES,

DETAILING

RESULTS OF RECENT INVESTIGATIONS RELATING TO FLORIDA SISAL HEMP, THE FALSE SISAL HEMP PLANT OF FLORIDA, AND OTHER FIBER-PRODUCING AGAVES; BOWSTRING HEMP, PINEAPPLE FIBER, NEW ZEALAND FLAX, AND BEAR-GRASS.

BY

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SPECIAL AGENT.

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U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF THE ASSISTANT SECRETARY,
Washington, D. C., February 9, 1893.

SIR: I have the honor to transmit herewith, for your approval, a report on the leaf fibers of the United States, which has been prepared under my direction by Mr. Charles Richards Dodge, special agent in charge of the fiber investigations of this Department. The report contains the results of recent studies of sisal hemp culture in Florida, and experiments with the false sisal hemp plant and other fiber-producing Agaves of the subtropical region. In view of the continued interest in the subject, I take pleasure in recommending its early publication.

Very respectfully,

EDWIN WILLITS,
Assistant Secretary.

Hon. J. M. RUSK,
Secretary.

LETTER OF SUBMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
Washington, D. C., January 10, 1893.

SIR: I have the honor to submit herewith the manuscript of a report on the leaf fibers of the United States, being Bulletin No. 5, of the Fiber Investigations series. It is worthy of mention that we import leaf fibers to the extent of $7,000,000 to $8,000,000 annually, a large proportion of which should be grown in this country. And this is but a small part of the total sent out of the country each year for fibers, amounting in round numbers to $50,000,000. In this report I have given the results of my further investigations into sisal hemp culture in Florida, with a full description and history of the false sisal hemp plant, which was found to be a new species though allied to the plant from which the commercial fiber is obtained. In a third chapter I have described several species of fiber-producing Agaves that flourish in extreme southern portions of the United States, including that which furnishes the Ixtle, or Tampico hemp of commerce, of which we imported over $600,000 worth in 1892.

The results of the Department's experiments at Cocoanut Grove with pineapple fiber and bowstring hemp have furnished the material for the two chapters which follow. The pineapple industry in the United States is increasing each year, and it is thought that if the beautiful fiber contained in the leaves of the plant can be extracted at commercial cost after the fruit has been gathered, it will add largely to the profitableness of the pineapple industry. The interesting experiments with bowstring hemp, another superb fiber, warrant the belief that this culture may be made a profitable industry in Florida, and already some large plantations have been set out in the southern portion of the State.

The report concludes with chapters on New Zealand flax and beargrass fiber. Of the first named, which is already growing in California, we have exported recently as high as 76,000 bales in a single year. The latter is an indigenous species found covering large areas in the West and South, and suitable for the manufacture of binding twine and cotton bagging.

I have been aided in this work by Mr. R. M. Munroe, of Cocoanut Grove, Fla., who was appointed a special agent of the Department

after I left Florida last spring, and who carried on the work at the experimental factory under direction of the Department to the end of the season, which closed in June. Mr. Munroe's report on pineapple culture, with remarks on the production of the fiber, is interesting.

I wish also to call attention to the work of Dr. J. V. Harris, of Key West, who is growing the *Sansevieria*, or bowstring hemp plant, extensively as a private enterprise, though assisted to a limited extent by the Department. Dr. Harris's experience is also detailed in a special paper presented by him at my request. In connection with *Sansevieria* and pineapple fiber, I desire to thank Mr. W. T. Forbes, of Paterson, N. J., for further preparing and bleaching a series of samples for the Department collection.

I wish to acknowledge the aid of Mr. J. C. Todd, also of Paterson, N. J., who is assisting the Department in its experiments with beargrass fiber, and who kindly offered to clean the leaves supplied by the Department, and to manufacture the fiber, for the good of the industry. I also beg to make acknowledgments to Mr. Thomas A. Hine, of Newark, N. J., and to Mrs. J. D. Tuttle, of Miami, Fla., for courtesies and valuable assistance in connection with my work in Florida last winter. The accompanying illustrations were reproduced from negatives taken by me in the localities visited, and accurately represent the subjects illustrated.

I am, sir, very respectfully,

CHAS. RICHARDS DODGE,
Special Agent, in charge of Fiber Investigations.

Hon. EDWIN WILLITS,
Assistant Secretary.

LEAF FIBERS OF THE UNITED STATES.

SISAL HEMP INVESTIGATIONS.

Since the publication of my first report* on sisal hemp culture in Florida, a great deal of additional information has been secured, and some facts ascertained that have not hitherto been given to the public.

Early in the year (1892) I spent two months in extreme southern Florida, where explorations were made covering some 200 miles of the coast from Key West to New River on the east coast. Headquarters were established at Cocoanut Grove on Biscayne Bay, where an experimental cleaning factory was put in operation, machinery having been sent down by the Department for the purpose. The results of the season's work were in every way satisfactory, and a considerable quantity of valuable material, in the form of fiber products, was secured, which will enable the Department to test the fiber in manufacture and ascertain the facts regarding yield of fiber per ton, tensile strength, and commercial value.

With a fast-sailing vessel at my disposal I was able to collect plants and leaves from the principal tracts along the coast where sisal has been growing for forty years or more and to bring the latter to the cleaning mill in perfectly fresh condition. The chief sources of supply were as follows: Indian Key, two varieties from the original plantings by Dr. Perrine; the Metecombe's (upper and lower), more recent plantations from the first named; the Perrine grant, from plantings by Charles Howe, who was associated with Dr. Perrine; from Narre's Cut, opposite Miami, more recent, supposed to have been planted by a man named Braman, in the seventies, and from Jupiter, Fla., from plantations set out by Peter Stone at Jupiter Point about the close of the war. (Plate I.) Very small lots were also secured from Fort Dallas and other points along the coast, where small areas were found growing. A quantity of fiber from the false sisal was also obtained from leaves grown on Sands, Elliott's, and other keys, but which will be referred to in a special chapter on false sisal hemp.

In regard to the distribution of these two species of plants, however, it is appropriate to mention here that in all the territory covered by

* A report on sisal hemp culture in the United States, Bulletin No. 3, Fiber Investigations, 1891.

my explorations, plants of the true sisal hemp were always found in situations near to the habitations of man, or near the former sites of such habitations. On the contrary, on both mainland and keys, where the face of the country is yet in a state of nature, no plants of the true sisal were ever seen, though such situations were frequently found to be covered with dense growths of the false sisal, the species often being distinguishable from the water before the boat had made a landing.

Regarding the existing tracts of the true sisal hemp plant, *Agave rigida* var. *sisalana*, that upon Indian Key is the largest, as it circles the island, growing for the most part near the shore line, and not found in the center of this key, which is one of the smallest of the group. Here the greater quantity of leaves secured for the purpose of extracting the fiber were taken, the next largest lot coming from Capt. Addison's place on the Perrine grant. Only the lower leaves of a plant were cut, though as a rule fully one-half of all the leaves were taken off.

A study of the distribution of the true sisal hemp plant over the east and west coasts of the southern portion of Florida is most interesting because of its wide extent, while the plantations are often, at the same time, quite remote from each other. This might be taken as satisfactory proof that the original plants were set out by man, if no other proof existed. Fortunately it has been possible to trace the history of the principal plantations, the facts showing that at various times during the past forty or fifty years sisal enthusiasts have endeavored to carry out Dr. Perrine's work of establishing this industry in Florida.

Regarding the west coast, which I have but partially explored, it will be impossible to speak authoritatively. The northern limit of safe cultivation on the west coast was stated in my first report to reach only as far as latitude 27° 15′, which would place it a little below the center of Manatee County. The statement was made on the authority of a valued correspondent, Mr. Ranson, who says that this latitude marks the frost line. A writer in the Port Tampa Mail, commenting on the above states that there is no county in Florida where the henequen grows more rapidly and to greater perfection than in Hillsboro County, lying above Manatee, and he places the limit of safe cultivation on the west coast as far north as the Anclote River, practically the boundary line between Hernando and Hillsboro counties, or fully a degree higher than stated by Mr. Ranson. I have seen many thrifty plants in cultivation at Punta Gorda and around Tampa, and even in more northerly portions of the State, but have not regarded cultivation absolutely "safe" much above Charlotte Harbor, one year with another.* A frost even once in five years is once too often where sisal hemp is grown commercially. Dr. Washburn, of the subtropical experiment station at Fort Myers, informed me that there are marked climatic dif-

*I am aware of the fact that no portion of Florida is totally exempt from frost one year with another. By "safe" I mean comparatively safe for sisal hemp culture.

SISAL TRACT AT JUPITER POINT, FLA.

ferences between the two regions immediately bordering the Caloosahatchie River, that is north and south of this body of water. And in proof of this he referred to many tropical plants which grew luxuriantly immediately south of it which would not thrive on the other side of the river from Myers. Considering the east coast I made the following statement in the Annual Report of the Department for 1891:

> The first point of interest in my investigation in Florida was Titusville, where thrifty plants were seen in the gardens, grown chiefly for ornament. At Cape Canaveral, on the coast, Mr. Robert Ranson has a small plantation, which was doing well. This, I should say, was the northern limit of sisal culture, but in my opinion the best results will be obtained below Jupiter and the Lake Worth district.

I still adhere to this opinion, and while accepting the statements of our two east and west coast correspondents, which would fix the line above latitude 28°, I consider latitude 27°, running across the State, a safer limit for the establishment of plantations on a commercial scale. There is no doubt that the plants will grow and thrive in more northerly locations, and possibly give a crop, or several crops, of cuttings of leaves after maturity, but there is always a danger of injury by sudden changes of temperature, from which even the climate of Yucatan is not exempt. In 1888, in Yucatan, there was a loss of 90 per cent of plants from a fall of temperature in a single night, from 89° to 57°, following a storm of rain, hail, and wind. Such changes often occur in Florida; I have myself witnessed a sudden fall to 48° in twenty-four hours, on Biscayne Bay, which is in the extreme southern part of the State, with the Gulf Stream running within a few miles of the coast. On the gulf side, away from the influence of the Gulf Stream, the liability to sudden changes in the winter is much greater, for this reason. Therefore I consider that the region lying below latitude 27° is the safer for this culture.

There are several large tracts of the *sisalana* growing in the Charlotte Harbor region. That at Pine Island, belonging to Mr. William Batty of Cedar Keys, was planted some fifty years ago, or about the time of Dr. Perrine's death; and the plantations on Sanibel Island, the Ten Thousand Ialsnds, and at other points down to Cape Sable, from all I can learn, are descended from plantings made about the same period.

Regarding the tracts of sisal growing on the keys lying west of Bahia Hunda, I can say but little from personal observation. After leaving Key West the first tract of any importance is found on Boca Chica, where the sisal plantation of Mr. George H. Bier is located. In a recent communication from Mr. Bier, relating to his own plantation, some interesting statements are made, from which extracts are reproduced as follows:

> The plants on Boca Chica are all pure henequen, and it is the only place where it has been planted with any semblance of regularity as a sisal plantation, and I have plants enough to set out 500 acres at 600 plants to the acre. The next place upon which the pure plant is to be found in large numbers is upon the key adjacent to

Boca Chica, Big Coppitt, commonly called Santina, after an old pirate who first squatted upon it; here it is found to be pure. Then comes the following keys: Sugar Loaf, Big Cajues, Little and Big Torch, Summerland's, and Hine's. Upon all these keys sisal is growing to a great extent in patches, but more or less interspersed with false sisal, Spanish bayonet, and bamboo, and in some of them so closely are they mingled that an expert alone can distinguish them when in a young state. All the plants were originally furnished by Mr. Charles Howe, who was interested with Dr. Perrine, who imported them from Yucatan. After Dr. Perrine's death Mr. Howe continued, until his own death, to distribute these plants wherever he thought they would prosper. Many of these keys owe their plants to the heavy gales which were frequent at that time, and which carried the buds by wind and wave where they are now to be found.

I should call this the Key West group of islands where sisal tracts are growing. Then follows a break, as there are only a very few isolated patches growing on keys between Bahia Hunda and Upper Metecombe where the next large tract is to be found. This portion of the line of keys I have personally examined. Naturally Indian Key is the center of an extensive group of keys where the sisal hemp plant is growing more or less abundantly. Then follows another long break, there being no true sisal on the keys to the eastward of Upper Metecombe. The next point of attempted cultivation is at Capt. Addison's, on the Perrine grant, and from this point northward the plants are confined to the mainland. It is interesting to state in this connection that in localities upon the groups of keys which make up these "breaks" in the sisal hemp distribution, the false sisal abounds in dense thickets, and often amid equally dense growths of *Yucca aloifolia*. From Cape Florida northward to New River, with the exception of a small tract at Narre's Cut, opposite Miami, there is no sisal hemp growing. A few superb plants remain in the garden of the old Cape Florida light-house; and the Narre's Cut plantation, supposed to have been set out by Mr. Braman, is about 10 miles above this point. The land to the northward of this locality is, for the most part, in a state of nature.* At many points along this stretch of coast growths of sisal had been reported to me, and in many instances the locations of the tracts were easily fixed, as we sailed past, by the masts or blossom stalks which rose out of the tangle of scrub 15 to 20 feet in the air. Upon examination, however, the plants were found invariably to be the false and not the true sisal.

The next important point is at New River, where the Florida Fiber Company, of Jacksonville, have 1,300 acres of land which it is proposed to devote to this culture. A substantial beginning has already been made under the personal superintendence of Mr. J. R. Kuchler, of Jacksonville, and the work of planting is being rapidly pushed, the U. S. Department of Agriculture having encouraged the enterprise to the extent of 100,000 plants. I visited this tract in April, and was able to take a number of photographs illustrating the company's operations,

* The southern portion of the peninsula above Narre's Cut was planted in cocoanut trees about twelve years ago by Messrs. Field & Osborne and by Mr. Lum, who owns the Narre's Cut section.

NURSERY OF SISAL HEMP PLANTS AT NEW RIVER FLORIDA.

one of which is reproduced. (Plate II.) The plants being young and small, cuttings can not be made for several years to come, when some very interesting questions regarding the industry will be settled.

The large tract at Jupiter, to which reference has been made, was set out by one Peter Stone, during the few years immediately following the close of the war. I am informed that he was an eccentric character who rushed into a number of schemes for making a rapid fortune, thought at the time to be more or less chimerical, sisal culture being one of them. The tract now belongs to ex-Governor Gleason, of Eau Gallie, Fla.

Of the Indian River country I can not speak from personal investigation. Plants or leaves have been sent to me from various points on the river, in reply to correspondence, some of the specimens being false sisal, and some the true *sisalana*. Mr. C. T. McCarty, of Ankona, in St. Lucie Sound (Indian River), has supplied me with valuable information on the subject, accompanied by specimens of leaves. I append an extract from this correspondence:

I have perused your former report with care, pleasure, and profit. You make a long leap from Canaveral to Jupiter. We are on the west side of Indian River, about 10 miles south of Indian River Inlet, latitude 27° 20′. There are five places, within 3 miles south and 5 miles north of us, where Agaves of various kinds are growing in considerable quantities. At "Old St. Pierre," just south of the town of the same name, there are many thousands of them. They are of the varieties herewith, and are mixed. They probably were placed there twenty-five years ago.

FIG. 1.—Pole plants or slips (*Agave sisalana*).

Coming south 3 miles, where there was an old clearing, we find thousands more. Within one-half mile north and south of our house are two large groups, mainly of two varieties. There are thousands in those groups. There is a considerable group of the true sisal hemp growing on old St. Caperan, opposite Indian River Inlet. From the best sources of information accessible they were planted during the Seminole war, about 1840. They have become naturalized, and from here large quantities have been obtained for ornamental and decorative purposes.

Three miles south of us at the old Hevman Grove, settled in 1841, is a number of them also. Counting the pole plants as well as suckers, ten to twenty thousand or more can be found here. (See Fig. 1.) They are invariably found in our best hummocks on or near the river bank, probably because the clearings were made there. With us the *Agave rigida sisalana* sends up its pole at seven years on our best lands. The others are a little slower. So far as the plant is concerned the "poor land"

theory has no foundation in this locality. Our strongest and finest plants are on our best land.

So far as quality and quantity of fiber is concerned, that is a different question, and I await further light. You will doubtless determine that. I am thoroughly satisfied that plants of any of these varieties will succeed well here. The important questions relate to the machinery for extracting the fiber, and whether the industry can be made to pay without planting large areas.

The specimens submitted represented four forms of Agaves, the smooth and spined leaved varieties of sisal hemp, the false sisal, and a large-leaved bluish-green Agave somewhat resembling *Americana*, which was also found by me at many points to the southward from Jupiter. This species, which remains unidentified by me, will be referred to again in the chapter on Agaves.

In a recent communication from Mr. McCarty he says:

During this summer the seven-year plant, from which I sent you a leaf in April, poled. To satisfy my mind as to their rate of increase I saved the slips as they came to maturity, from 6 to 8 inches, and set them in nursery form. This one "pole" gave us 2,500 good slips, not a single one of which failed to grow. We planted them on new, rich land, and to-day after being planted two to three months, their removal shows that their roots have greedily penetrated the rich leaf mold. It would be impossible to give exact data as to the number of plants in this vicinity.

On my return from Florida I learned some interesting facts regarding the growths of sisal in the lake region of Polk County through Mr. Elonzo Cordery, of Fort Meade. As this is in the interior of the State, quite remote from tide water, it was most desirable to obtain specimens of plants or leaves and samples of the soil in which the plants were growing. These were sent by Mr. Cordery in reply to my request, the following being an extract from his letter accompanying the samples:

I immediately sent reliable parties out in the different sections where the plants are growing, and especially to the lake country of eastern Polk County (which is exempt from frost), to procure samples of leaves and soil to send you. I have sent by express to-day six leaves of different aged plants, all properly labeled; also two small boxes of soil marked, showing location from which same was drawn. These will give you a fair idea as to the rank growth made here and size of plants for each year, from two to five years, in what appears to me to be the poorest class of soil, with an entire absence of "coral rock" or limestone, to which you draw my attention as being requisite to the successful growth of the plant. Plants do certainly thrive here in this loose, porous soil, and it has been brought to my notice that the poorer the soil the richer the leaf in fiber, and the richer the soil the more succulent and pulpy the leaf. I regret that not more than two of the leaves sent are sufficiently mature to give you an idea of the quality or quantity of fiber to be obtained, the balance being sent to give you an idea of size only. You will be able to observe by chemical determination what is in the soil to produce such a growth, and whether, in your opinion, it would be suitable for starting the enterprise on a large scale, which, as I wrote you first, is contemplated by me if conditions are favorable. The soil sent you is underlain in some places with red clay found at from 3 to 4 feet from surface. In other places by sand rock, and again loose sand to the depth of 30 to 40 feet, as far as it has been penetrated by the digging of wells, etc.

If the soil of these lake lands is suitable (as the plants would certainly seem to indicate) for the culture of the plant, the working of the land would be slight in comparison with the Bahamas, and as to cost of same, not more than a fourth what

it is there. Here one man with a mule could (when plants were young) cultivate a very large acreage annually, there being no undergrowth or sprouts to contend with and no continual hoeing required to keep running vines, weeds, and sprouts down, as in the locality above alluded to.

Making due allowance for shrinkage of the pulp in transportation, these leaves seemed to be heavier for their size than the leaves met with on the keys and possibly would have produced a higher percentage of fiber. I had no means of reducing the fiber, however, so was unable to make the test. Mr. Cordery was asked to send a few leaves to the factory at Cocoanut Grove, but they were not received, and our operations on Biscayne Bay closed June 30.

The following notes on the growth of sisal hemp in Polk County, Fla., by Merrick Shaw, were sent with the above samples of surface and subsoil and leaves of 2, 3, 4 and 5 year-old plants, measuring respectively, 4 feet 1 inch, 4 feet 3½ inches, 4 feet 2 inches, 4 feet 4 inches, in length; also upper leaf of older plant 4 feet 9 inches:

The natives of this country have known of the plants being here for the past forty years; the cowboys have been in the habit of extracting the fiber to make crackers for their whips. The first plants are said to have been brought from the coast. There are two patches in this section where fields have been abandoned on which were a couple of these original plants, which have now spread themselves over one-fourth acre and formed an impenetrable thicket, unharmed by frost, fires, or any other cause.

Although there are one or more sisal plants in most of the gardens in this neighborhood, grown as ornamental shrubs, there has been great difficulty in obtaining the lower leaves to measure and weigh, as each year the outside leaves having been blackened by frost, the owners have trimmed them off as being unsightly, and left only the uninjured leaves.

The original plant growing on the soil of which sample is sent (Box 1) poled at 7 years old, twenty layers of leaves had been cut from this plant, and the lowest of those remaining measured 5 feet 9 inches in length by 5 inches in width at the broadest part. About a hundred suckers had been removed from this plant and planted elsewhere. Of one of these transplanted when about 4 inches in length, nine months ago, the lower leaves now measure 2 feet 2¼ inches by 3¼ inches greatest width. At the same place the measurements of a 5-year-old plant are: Lower leaves, 4 feet 4½ inches by 4⅜ inches greatest width; weight, per leaf, 1¾ pounds. The center leaves of this plant are longer, measuring 5 feet 8½ inches by 5 inches.

The lowest remaining leaves of another plant seen elsewhere in the neighborhood measured 4 feet 6 inches by 4¼ inches, but all the lowest leaves had been trimmed off. At this place a plant had also poled, but had been destroyed, and the suckers plowed under.

On the lakes the measurements of the lower leaves of a plant just 2 years old, transplanted when 9 inches in length, are 4 feet 1 inch by 4 inches. This plant was entirely unscathed by frost, though tropical plants in this vicinity, guavas, bananas, and pineappies had suffered. On another lake a 3-year-old plant bore leaves 4 feet 4 inches in length by 4½ inches greatest width. The land where we expect to make our experiments is entirely protected from frosts, being between several large lakes. There are bearing lemon and lime trees, gourd vines, beans, tomatoes, and other tender vegetation, which has never been injured. (Sample of subsoil from this section, Box 2, sent herewith.)

There is no question about the plant thriving in this soil, the vigorous growth of the specimens to be seen wholly uncared for, scattered through this country, giving

abundant proof, and having extracted by hand a portion of the fiber to test with samples of the Bahama fiber, which we have here, as far as we can judge, it will bear the same strain, but we can not clean the fiber satisfactorily without machinery or get it sufficiently clean to ascertain correctly the percentage contained in a certain amount of green leaf.

FIG. 2.—Sucker, poling (*Agave sisalana*).

A study of this wide distribution of the sisal hemp plant seems to confirm Mrs. Walker's statement, that when these plants (set out by her father) had multiplied to some extent the officers at Fort Dallas, at the mouth of the Miami River, were in the habit of gathering the young ones to send to other posts, where they were grown as ornamental plants. As a fact, the principal tracts of plants now growing in Florida are either in the neighborhood of former army posts or are located where Dr. Perrine, or his associates, set out plants at the time of his experiments.

Regarding the reproduction of the plants by suckers and pole plants there is nothing specially new to record, the ground having been fully covered in the former report. A singular abnormal habit of the plant, noticed on Indian Key and in other locations, is worth recording. The accompanying illustration (Fig. 2), made from a photograph, shows a sucker which, with leaves barely a foot long, had thrown up a slender pole to a height of 8 feet or more, crowned with fully formed blossoms, which in time would have given pole plants. I was informed by residents on Indian Key that this premature blossoming of a young plant or sucker while yet attached to the parent root is of not uncommon occurrence.

WORK AT THE DEPARTMENT'S EXPERIMENTAL FACTORY.

The Department was extremely fortunate in securing use of such portion of the plant of the Biscayne Bay Manufacturing Company, at Cocoanut Grove, as was necessary for its operations, this being the nearest available power to the sources of supply of the leaves, although

80 miles by sail from Indian Key. The Van Buren cleaning machine, previously purchased by the Department, was shipped to Florida and set up on my arrival. With ample space on the main floor of the building, and with a large loft in which to hang the cleaned fiber after it had been partially dried in the sun on the long factory wharf, the equipment was all that could be desired. Mr. Ralph M. Munroe, the superintendent of the Biscayne Bay Manufacturing Company, placed his schooner yacht *Micco* at the disposal of the Department, which enabled quick transportation of leaves, so essential to the success of the experiments. I may state that both the gathering of the leaves and the factory work were done under my personal supervision.

As to the manner of cutting or gathering the leaves, the plants being almost in a state of nature, and their lower leaves spreading out very near the surface of the ground, it was found impossible to use the Mexican *machete* employed in Yucatan for this purpose. The implement is in very common use in southern Florida, however, for cutting out the dense undergrowth in thickets, and was always carried with us. While the greater part of the leaves were cut with sheath knives, which the men always carry, the handiest implement used was a large pruning knife, having a blade nearly 4 inches long. The hook-like point of this knife often made it possible to sever a leaf with a single drawing cut, which could be accomplished more rapidly than a man could strike a blow with the *machete*, and the cutting was accomplished as rapidly. As fast as the leaves were cut they were bound in bundles of about fifty and thrown in piles, to be transported by small boat to the sailing vessel.

As to the quantity of leaves that one man would be able to cut in a day, while I have not the data to make positive statements, I should estimate that a ton and a half would be a fair day's work though this form of labor was new to our men and the plants so close together in the sisal thickets that the work was necessarily slow.

In my former report the average weight of a sisal hemp leaf was stated at a pound and three-quarters, the range being from a pound and a half to two pounds. To verify these figures, all the leaves cleaned at the experimental factory were sorted, and the bruised or discolored ones rejected, after which they were weighed out in 50-pound lots and counted. The countings of the first 2,000 pounds of leaves (*sisalana*) from Indian Key were recorded by 50-pound lots, as follows:

35	34	34	34	38
35	35	35	34	38
37	39	35	41	37
37	38	34	35	34
33	38	34	36	34
36	41	35	35	32
35	36	32	34	33
33	35	35	34	35

This shows an average weight of 1.41 pounds, or about 1 pound 6½ ounces to the leaf. This average is lower than would have been the

case had the cuttings been made invariably from old, mature plants. In some instances younger plants were cut, the difference in size not being readily distinguishable where the plants were growing in dense masses. Weighings of leaves of the spined form, also from Indian Key, fell below this average, and for the same reason: So few plants of the spined variety were found on this key it was necessary to cut some of the leaves from smaller plants to secure the quantity of fiber desired. Referring to the counts of individual bundles, the largest number of leaves in a 50-pound bundle was 41, and the smallest number 32, which makes the range from 1 pound $3\frac{3}{4}$ ounces to 1 pound 9 ounces. The second Indian Key lot (*sisalana*) cut about two weeks later, gave an average of 1.42 pounds to the leaf. (See Plate III—different forms.)

Several small lots of specially selected leaves from mammoth isolated plants, growing on the Metecombes, gave the following weights per leaf in pounds and fractions of pounds: First lot, 2.64; second, 2.08; third, 1.85, and fourth, 2.27. This shows a range from 1 pound $13\frac{1}{3}$ ounces to 2 pounds 10 ounces. Quite a difference was noted in the weights of the leaves from different portions of the same plant. The extreme bottom leaves, from Indian Key (rejecting those, of course, lying on the ground and partly decayed), when weighed and counted as above gave a weight of 1.2 pounds, or 1 pound 3 ounces and a fraction average per leaf. The weighings of lots from the Perrine grant gave similar results to those obtained from weighings of the first ton of Indian Key leaves, and detailed statements are not necessary. The lot from Jupiter Point, however, gave better results; 500 pounds of best leaves showed an average of 1 pound $8\frac{2}{3}$ ounces per leaf.

The effort was made to secure a quantity of leaves from Pine Island on the gulf side, but the remoteness of this tract from the factory, and the difficulty of securing a shipment before the hot weather had set in, prevented its accomplishment.

No attempt was made to estimate the cost of cleaning, the first object being to secure thoroughly well-cleaned fiber without regard to the time occupied in passing the leaves through the machine, and any figures based on the output per day of ten hours would have been very misleading. All fiber was carefully weighed after drying, and the waste of several lots washed out, dried, and weighed, so that a very fair estimate of the yield of Florida fiber per ton of leaves can be made.

REGARDING CULTIVATION.

The question of soil was fully discussed in the former report on sisal-hemp culture, and there is little of interest to add to the statements already published. That the plant thrives on the keys (Indian Key especially) upon the almost naked coral rock is evident from the luxuriant growth it makes in these situations. With a deeper soil, overlying shell, as at Jupiter, where vast shell mounds occur, the plant seems to do no better. I found soil on the peninsula, opposite Miami, so poor,

LEAVES OF TRUE AND FALSE SISAL HEMP PLANTS.

however, that a long row of plants set out ten years ago to form a boundary line had hardly made any growth, if they had more than held their own. This soil seemed to be mainly fine sand, with no trace of the underlying rock which always occurs on the mainland.

Mr. Cordery's sample of surface soil from Polk County, in the interior, has also the appearance of fine sand, but it is much darker in color than the Narre's Cut soil, and evidently contains some vegetable matter, as well as phosphate. A sample taken 18 inches below the surface, of a color somewhat resembling cayenne pepper, though lighter, contains fragments of rock, not analyzed, which is doubtless phosphate. These samples were taken in the "Sandhills" district, 5 miles east of Fort Meade, where old sisal plants are growing. Mr. C. G. Colbourn Wright sent from this locality (Fort Meade, Polk County) another sample of surface soil quite different from that sent by Mr. Cordery, as it is white, and, I should say without analysis, more deficient in elements of plant growth than the other samples submitted.

A writer living on the Gulf side states as the result of his observations that he believes the plant will grow almost anywhere and thrive; that it is indifferent to moisture, although it grows best in localities not too far from the sea; that it will thrive on scrub lands where nothing else but a scraggy growth of spruce and rosemary will grow—lands practically worthless at present in Florida. He considers that even these lands are better than the soil, rocky and sterile and almost without moisture, upon which the Yucatan fiber is produced, and states that while the plants make a heavier growth in rich soil, they will produce a far smaller proportion of fiber.

Regarding the soil of Yucatan, the following statement by Mr. E. Jerome Stuart, in the Kew Bulletin for November, 1892, is reproduced:

> The soil in the "fiber-producing district" of Yucatan is gravelly and stony, and varies in color, being black, brown, and red. There are large tracts of land in the district, similar to that on most of our islands, and known as "mixed land." The soil has an average depth of 8 inches, and is underlaid by soft limestone rock, similar to that of our (Bahamian) "Pine Barren" lands. The largest fiber fields in the State are to be found on this shallow, stony soil, and the yield of fiber is greater than on the deeper soil 30 miles farther inland.
>
> I could not, when looking at the fiber fields of Yucatan, doubt for a moment that the fiber fields of this colony are equally good, and if the growth of plants is any guaranty of the virtue contained in the soil in which they grow, I do not hesitate in saying that the soil of the Bahamas is equally as good as the soil of Yucatan.

Commenting on the last paragraph, I should say that from all I am able to learn there are thousands of acres of better sisal-hemp land in southern Florida than in the fiber-producing district of Yucatan.

Reference was made in my last report to the bad effect of shade upon the growing plants. My observations in Florida the past winter confirm all that was there stated. Plants growing in partially cleared land do very little better than when more completely shaded, as in the hummock, the leaves being thin and less rigid, and darker green in

color, and the growth will be much slower and the plants smaller at maturity. The clearing of the land is one of the largest expenses connected with establishing a sisal plantation, and when it is not properly done there will be a pretty good chance for failure.

In a communication from George H. Bier, of Key West, occurs the following statement bearing on this subject:

> Amongst the wild-growing sisal you will frequently find plants with small, thin leaves, shorter and fewer in number to the plant than the larger, more vigorous plants near them—in appearance and in every other respect they are like the true sisal, even in fiber, but the mast is short and slim and does not produce as large a number of buds. This failure to mature properly can be attributed to too much shade.

Mr. Stuart's recent report gives some interesting points regarding culture in Yucatan, from which a few paragraphs are reproduced:

> There are 200 henequen estates in Yucatan, varying from 500 to 28,000 acres in extent, having a total number of 105,000 acres under cultivation, employing 12,000 Indian laborers. The largest and best estates are on the rocky gravelly lands, and they are valued from $100,000 to $500,000 each. Each estate is managed by three principal men—the attorney, the manager, and assistant manager. The largest of them employ locomotives for hauling in the crop from the fields, others using tramway trucks or carts drawn by mules or oxen. Estates with less than 800 acres under cultivation erect one Raspador for every 100 acres. Those of 1,000 acres use the large automatic machines.
>
> The size of the cultivations on the estates range from 250 to 3,500 acres. They are laid out in fields or sections of 50 to 200 acres, and contain from 600 to 900 plants to the acre. When preparing the fields the land is cut during the dry season, is then allowed to spring up, after which it is "sprig weeded," and burnt after the first fall of rain. The stumps are cut close to the ground, so as to be out of the way of the leaves of the plants, and to facilitate the running of the line for planting and getting the rows straight.
>
> When planting, the laborers have a small line with the distances at which the plants are to be set out knotted on it, and a pole cut to the length that the rows are to be apart. A man and a boy are employed at each line. The boy drops the plants along the row at the distance marked on the line, and then removes the line to the next row, dropping the plants as before. The man does the planting, and is responsible for the rows being straight. When coming to a rock the planter does not turn aside, but goes on and places the plant in the row a little beyond.

NOTES CONCERNING SPECIES.

In speaking of the sisal hemp of Yucatan, of Cuba, the Bahamas, and Florida, it is natural to suppose that the same plant is cultivated in all these countries. But this is not so, as the Yucatan variety differs widely from that found so abundantly on the Florida Keys, being more stocky in habit, the leaves heavily armed with sharp spines, and the fiber coarser. Even the spined form found in Florida is a different variety from the spiny plant which produces the sisal hemp of commerce in Yucatan. It is, however, more closely allied to the *sisalana*, resembling it in every way, save that it has the rows of spines along the edges of the leaves. I found many leaves of the *sisalana*, which, normally, is without spines, save at the tip, that showed rudimentary

spines on either edge; and the finding of a leaf at Narre's Cut that was perfectly smooth on one side and fully spined on the other would seem to confirm the idea of a close relation between the two forms.

Mr. Bier thinks that the Florida spined variety and the smooth-leaved form are one and the same, the plants in time losing their spines through the influence of soil and climate. He says:

> The leaves of the sisal plant in this section of Florida will, I am satisfied, become in time as smooth as the majority are now found to be. I have not only seen buds, gathered from a full-spined plant, very irregular in their serrations, but some buds would have only one leaf serrated while the others were smooth, and others, again, with all their leaves serrated, while the leaves of others were entirely smooth leaved, and after a growth of one or two years the spines upon all would almost entirely disappear or become so slight that they were scarcely perceptible. This change and improvement in the plant I have always attributed to climatic influences and difference in soil.

I hardly think that this is the case, for small patches of mature plants of the spined form are to be found at various points along the coast. I found such on Indian Key, at Addison's, and at Jupiter Point. It is an interesting question, however, from the botanical standpoint, though of minor importance in relation to the fiber industry.

Mr. E. Jerome Stuart, in his report to Governor Shea, of the Bahamas, makes the following statements on the subject of varieties in a recent Kew bulletin:

> *The henequen.*—The kind of fiber plant growing in Yucatan, and known as the *Sacqui* or henequen, is a different agave from that of the Bahama hemp. The plant is hardy, and has, when cultivated, an average life of 18 years, and propagates itself by sending out "suckers" from its roots. The henequen (*Agave rigida* var. *elongata*) requires from five to eight years' growth to produce a marketable length (3 feet) of fiber. The leaf from which the fiber is extracted has a thorn at the point and spines on its edges, and averages 3¼ feet in length. The fiber of the plant is white, but being inferior to that of the Bahama hemp is rated in the market at from £6 to £8 per ton lower.
>
> *The Bahama hemp.*—The Bahama hemp (*Agave rigida* var. *sisalana*) differs from the henequen inasmuch as the leaves are without spines on their edges and the fiber is superior in texture. The plant matures from two to three years earlier than the henequen and has an average life of 12 years. Like the henequen it propagates itself from suckers, but is also capable of producing over 2,000 plants from the pole that grows from the center of the plant. The Bahama hemp is found both in Yucatan, where it is known as the *Yaxqui*, and in Cuba, but it is not largely cultivated, as it requires a more congenial climate than these countries afford. In this colony the plant luxuriates, the length of leaf being 4½ feet to 5 feet, weighing 1½ to 2 pounds. In Yucatan a leaf of the *Yaxqui* from a plant of the same age would measure 3¼ feet and weigh 11 ounces only.

If regard is had to strict accuracy, the name Florida hemp should be given to the smooth-leaved variety grown in the Bahamas (and also in Florida), as the larger proportion of the plants now growing on the Bahamian Islands was brought from Florida by the schooner load in very recent years.

I am aware of the fact that the sisal hemp plant has been growing in the Bahamas since 1845, at which time it was introduced into that

country from Yucatan by Mr. C. Nesbit, a former colonial secretary. Mr. Edwin Nesbit, a son of this gentleman, resident at San Antonio, Tex., has given the Department a long account of his father's efforts to introduce the industry into New Providence, the son being old enough at the time to remember many interesting details of the effort. This was about eight years after Dr. Perrine's similar effort to introduce the industry into Florida, and the selection of the smooth-leaved form of sisal hemp for introduction into two other countries by two persons about the same time has been regarded as a singular coincidence. As a very full Government report by Dr. Perrine was published in 1838, and the Bahamian introduction did not occur until 1845, it would not seem such a coincidence after all.

YIELD OF FIBER.

A study of the weighings of leaves, and the dried fiber obtained from these leaves, is interesting. But before making statements regarding the rates of yield of Florida sisal compared with the Yucatan and Bahamian, let me again refer to the fact that the variety grown in Yucatan is different from that grown in the Bahamas and Florida. In my former report it was stated that the *sisalana*, as grown in Florida, (Dr. Shott's *yaxci* form), produces less fiber, but excelling in softness, flexibility, and luster, and bringing a higher price in the market. The *sacci* form, cultivated throughout Yucatan, produces a far greater quantity of fiber than the preceeding, and furnishes the principal bulk of the sisal hemp of commerce.

In Mr. Stuart's recent report to the Bahamian Government on the sisal industry of Yucatan the yield of Mexican henequen is given as follows:

> The yield of fiber per acre is from 1,000 pounds to 1,470 pounds per annum. The number of plants usually set out in an acre is 650, giving an average of thirty-three leaves from each plant, and from 50 to 70 pounds of clean fiber to the 1,000 leaves. Making an average calculation of 650 plants to the acre, thirty-three leaves from each plant, yielding 60 pounds of fiber to the 1,000 leaves, the return would be as follows: $33 \times 650 = 21{,}450$ leaves, yielding $60 \times 21\frac{450}{1000} = 1{,}287$ pounds clean fiber per annum. The planters never speak doubtfully of their returns, as experience shows them that their crops can be relied on with almost complete certainty.

The average weight of a leaf of the Mexican form of plant is 1 pound 10 ounces, according to reliable authorities. A calculation based on the above figures places the yield of dried fiber from 2,240 pounds of leaves at 82 pounds and a fraction. The actual product of a long ton of Indian Key (Florida) leaves, from the *sisalana* form was a very little short of 79 pounds. The machine made a very considerable waste, which after being carefully washed and dried gave a weight of $22\frac{1}{2}$ pounds from the ton of leaves. This gives a total of very nearly 102 pounds of straight fiber and waste from a ton of leaves. Regarding the waste made by the raspador in Mexico, I have no authoritative

information, but I know it is not 20 per cent of the total weight of fiber in a ton of leaves, which is enormous.

Mr. T. J. McLain, United States consul at Nassau, informs me that the average yield of 2,000 pounds of sisal leaves in the Bahamas is 75 pounds, equivalent to 83 pounds to the long ton, or about four pounds more than the yield of Indian Key fiber from the Department's experiments. This difference is more than accounted for in the excessive waste made at the Florida experimental factory, due probably to a slight defect in the individual machine used by the Department for cleaning the fiber. It should be noted that Mr. Van Buren claims a loss of not over 5 per cent for his machine when in perfect running order.

The statement has been made in connection with the question of soil that the better the soil and the larger and heavier the leaf the less percentage of fiber to the ton of such leaves. It has been stated that the Jupiter Point leaves cleaned by me weighed on the average about 1 pound 9 ounces, against 1 pound 6½ ounces for the Indian Key lot. The results from weighings of dry fiber from the two sources show that a long ton of the heavier leaves from Jupiter Point yielded at the rate of 71 pounds of dried fiber, against the 79 pounds, actual, from Indian Key, the percentage of waste being about the same in each lot.

Leaves from the spined variety grown on Indian Key yielded at the rate of 72 pounds of fiber to the ton. As less than quarter of a ton could be secured, however, owing to scarcity of the plants of this variety, this estimated quantity can not be stated as absolute.

THE MACHINE QUESTION.

In my last report the principal machines in use for cleaning sisal hemp were mentioned, and several of them figured. The two classes or types of machines into which these devices are divided were also stated. The only new machine for cleaning sisal hemp leaves that has been brought to my attention since the publication of that report is the device patented in 1892 by J. L. Acosta, and manufactured by Joseph C. Todd, Paterson, N. J.

The claims of the inventor are set forth as follows:

In Fig. 3 is shown clearly the arrangement of the machine for cleaning henequen leaves without the use of crushing cylinders. The operator seats himself before the table and lays the leaves on the feeding chains. Care should be taken to lay the thick ends of the leaves to the right side, with something more than half of the length of the leaf hanging down. The chains will then carry the leaves to the holding belts, by which they will be presented to the first scraping wheel. The leaves having been cleaned for the greater part of their length by the first wheel, a device placed between the two scraping wheels transfers the clean portion of the fiber to the second holding belt, and the remainder is cleaned by the second wheel, having no uncleaned or partially cleaned portions in the middle, as is usual in other machines. The leaves of the Pita plant need to be crushed by finely corrugated cylinders in order to separate the fine fibers of the back of a leaf. They should be

crushed and scraped while still green and fresh, so that the cleaning may be assisted by the juices of the leaves. Knives or scrapers and brushes in alternation around the wheels are indispensable. It is also desirable to have a pump to furnish water to two small tanks fixed above the upper belts of both wheels. The water flows from these tanks to spread the leaves on the surface of the shoes and to clean and wash the fibers. Otherwise the fibers may be cleaned and washed after being scraped if it is desirable to avoid the expense of the pump and tanks. With a single man to put the leaves on the feeding chain and a boy to take away the clean fiber from the end of the machine, it is capable of cleaning thoroughly 50,000 to 60,000 leaves in a day.

I have not seen this machine running on sisal hemp leaves, but witnessed its work on the leaves of bear-grass furnished by the Department, the cleaning being accomplished in a thorough manner.

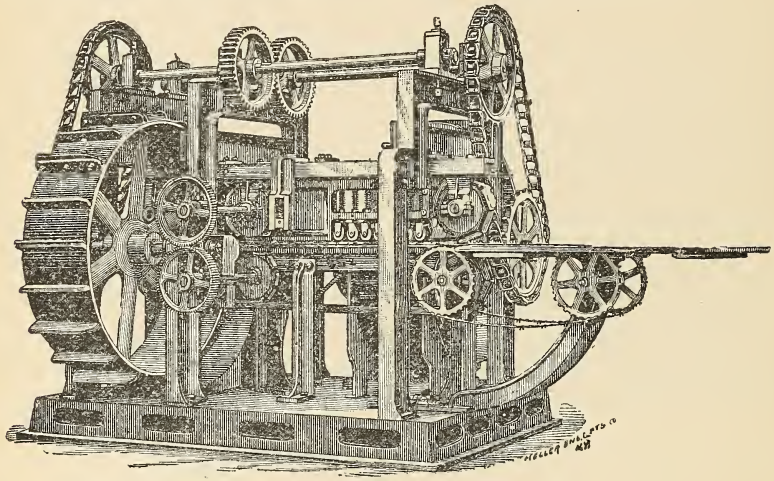


FIG. 3.—The J. C. Todd fiber machine.

As I have stated, the machine used by the Department in Florida is known as the Van Buren, this individual piece of machinery having been used by Mr. Van Buren at the various exhibitions which he attended. As far as relating to the quality of fiber turned out its work is very satisfactory, though its capacity is limited. I am informed by Consul McLain at Nassau that the Van Buren machine is extensively employed in the Bahamas for extracting sisal hemp, its capacity being about 150 to 200 pounds of dry fiber per day of ten hours.

In Mr. Stuart's recent Yucatan report there is quite a chapter on this subject, from which the following extracts have been made:

There are several kinds of machinery used for extracting the fiber on the diffrent estates. Those cleaning less than 75,000 leaves per day use the large common wheels, the Raspador and Barraclough; and those cleaning from 80,000 to 120,000 per day use the larger and more complicated machines, the Prieto, Villamore, Weicher, Death and Ellwood, etc. The planters, if using one of the large machines, keep several of the Raspadors in reserve for use in case of accidents; for should the large machine break down or get out of order, leaving 70,000 or 80,000 leaves on hand, and there be no means of cleaning them, it would involve a loss of over 4,000 pounds of fiber.

The Raspador is a 54-inch "wheel," said to be invented and manufactured in Mexico. It requires a 2-horse power engine to run it at a steady rate of 200 revolutions per minute, at which speed the best results are obtained. Capacity, 500 pounds dry fiber per day of ten hours; requires the services of two men.

The Barraclough, constructed by T. Barraclough & Co., Manchester, England, is similar to the Raspador, but of superior make. Capacity, 500 to 600 pounds dry fiber daily.

The Prieto machine is manufactured by Ping & Negre, Barcelona, Spain; requires a 16-horse power engine and the services of two men and a boy. Capacity, 7,000 pounds dry fiber per day of ten hours; cost, $4,500.

The Villamore machine, made by Krajewski & Pesant, 35 Broadway, New York, requires a 15-horse power engine and the services of two men and a boy. Capacity 6,000 pounds fiber per day of ten hours. Frame made of wood; cost, $500.

The Weicher machine, constructed by J. J. Weicher, 108 Liberty street, New York, is fitted with a service pipe for throwing a stream of water on the fiber as it is being cleaned, and is claimed by the inventor to lose but 1½ per cent only, as the leaves are fed into the machine endwise. Requires 12-horse power engine and services of three men. Capacity, 2,500 pounds dry fiber per day of ten hours.

The Death and Elwood machine, constructed by W. E. Death, of Brixton, England, requires a 3-horse power engine to drive it at a velocity of 400 revolutions per minute, and washes the fiber when cleaning. Like the Weicher, the leaves are fed into the machine endwise. Capacity 250 pounds (?) of dry fiber per day of ten hours.

With the exception of the Raspador and Barraclough, all the other machines are automatic; they rasp the pulp from the fiber on the same principle as the Raspador Their wheels being smaller require a velocity of 500 revolutions to the minute to give good results. Beyond cleaning a greater number of leaves they do not appear to do better work, as the percentage of loss is as great in the one as the other, and the fiber is equally as clean.

Engines and boilers.—The engines used were from 6 to 80 horse power, manufactured by Marshall & Son, London; Appleby Bros., London; Fawcett & Preston, Liverpool; Watts, Campbell & Co., Newark, N. J.; H. M. Sciple, corner Third and Arch street, Philadelphia.

The estates running 60 to 80 horse power engines have two boilers, using them alternately every fifteen days.

Presses.—Most of the small estates use small screw presses, baling from 3 to 8 bales daily. The large estates, baling from 16 to 30 bales daily, use hydraulic presses, construbted by Appleby Bros., London, and Fawcett & Preston, Liverpool.

Cars, tramways rails, etc.—The locomotive cars are made of wood, 20 feet by 4 feet. The rails are of iron with gauge 3 feet, and sleepers of wood 2 feet apart. Tramway trucks are of iron or wood; they are 12 feet by 3 feet. Rails and sleepers of iron with gauge 2 feet 4 inches, and sleepers 2 feet apart.

FALSE SISAL HEMP.

Agave decipiens Baker.

So many references have been made to this plant, which is so intimately connected with the recent history of the true sisal hemp plant, as found in south Florida, that it is a matter of congratulation that all doubts concerning its identity are now cleared up, On my return from Florida I was able to send specimens of the living plants, with fresh leaves, and both fresh and dried flowers, to Dr. Morris, assistant director of the Royal Kew Gardens, England, and which arrived in good condition. They were accompanied, also, by samples of the fiber, and with considerable photographic and descriptive material, relating to the habits of growth. The whole series was referred to the botanist, Dr. Baker, who is an eminent authority on this important family of plants, and who decided the species to be new. Dr. Baker's description of the plant, reproduced from the Kew Bulletin for July and August, 1892 (pages 183–184), is appended at the close of this chapter.

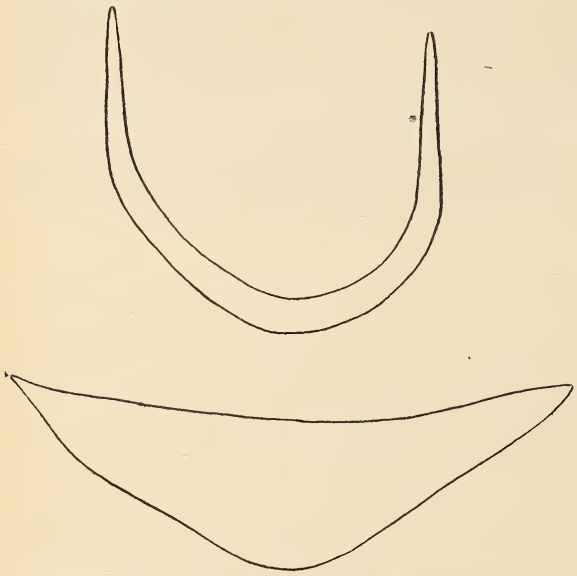


FIG. 4.—Section of false sisal hemp leaf (*Agave decipiens*).

It is a matter of surprise to me that this plant has so long been confounded with the true sisal, when the two forms differ so greatly in habit and in general appearance. The men who accompanied me in my investigation work along the keys and up the coast, on the mainland, so soon learned the difference in the appearance of the two forms that they were often able to state by means of the ship's glass as we sailed by whether plants growing on the shore were the true or the false species. Throwing out its mass of leaves from the top of a footstalk sometimes 6 feet high, which is the habit of the mature plant, the leaves

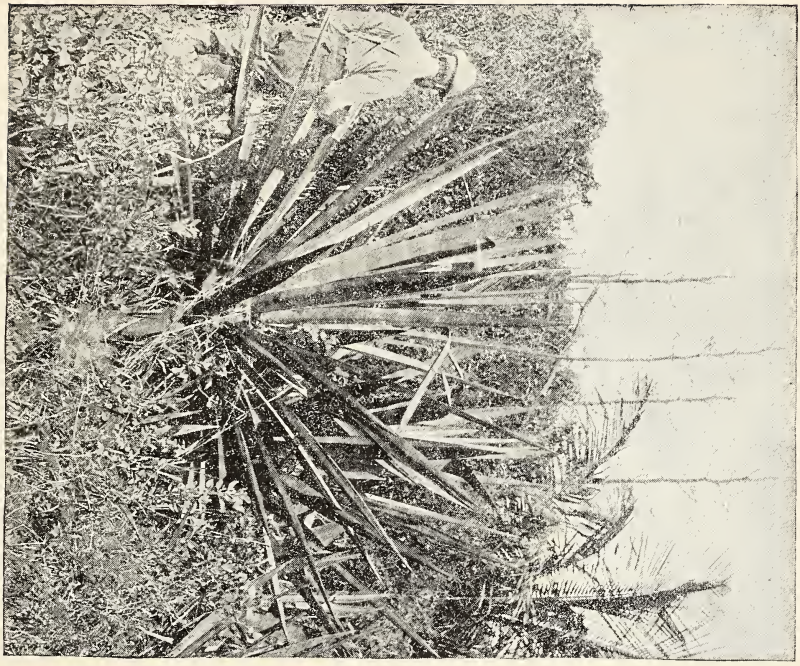


FIG. 1. TRUE SISAL HEMP PLANT.

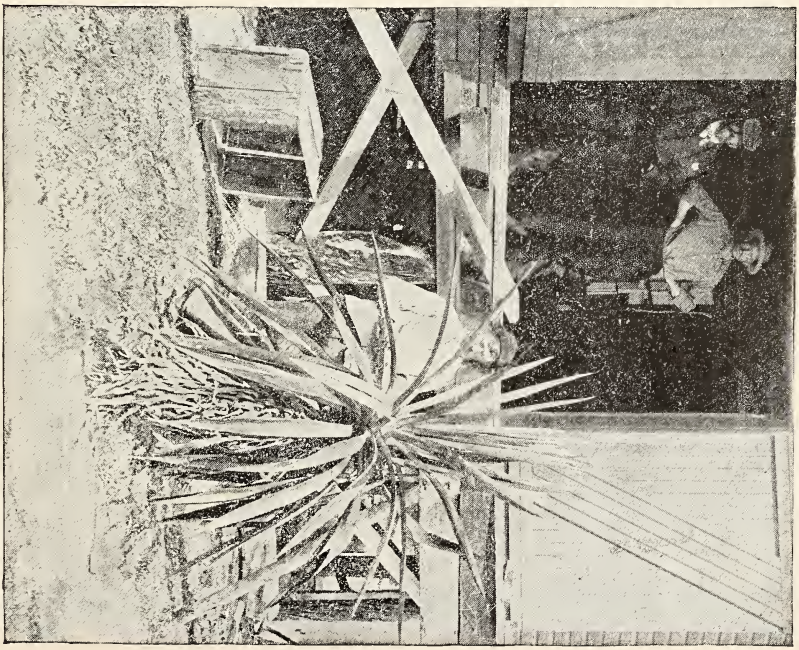


FIG. 2. FALSE SISAL HEMP PLANT.

seem to radiate from a common center like a many-pointed star, while the color is always in strong contrast to the surrounding vegetation. The true sisal plant, on the contrary, sends up its mass of leaves from the surface of the ground, though sometimes with a very short footstalk, this difference alone rendering identification easy, for before the lower leaves of *sisalana* have been cut, as in cultivation, the plant never shows this habit. (See Plate IV.) Other marked differences are: the shorter, narrower leaf in *decipiens* nearly always (on the keys) rolled in at the sides so that a cross section appears like the letter **U**. (See Fig. 4.) In color it is a brighter, more livid green. Its spines, which are very thickly set along the edges, are strongly recurved, and so sharp that it is impossible to go about among the plants without lacerating the flesh or tearing the clothing. (See Fig. 5.) Even the young plants, which have not acquired their footstalks, differ so greatly from the young plants of *sisalana*, that no one should mistake them after having had the differences once pointed out. The young *sisalana* grows very erect, the leaves being flatter and of a dark green, and without spines. The *decipiens* throws out its leaves with a more spreading habit, the lower series usually bent (recumbent) to the ground, the leaves themselves being short, stocky, and with the edges more or less turned up. The color, even in the young plants, is a brighter green than *sisalana*, the *tout ensemble* presenting a particularly marked form of plant. In their manner of poling we find the only similarity between the two and this doubtless has caused the expensive mistakes so often made by those collecting sisal plants, and through which shiploads have been taken from Florida to the Bahamas in past time. Dr. Baker even says: "I can not make out any material difference between the flowers of the two species." The poling is not only similar, but the young pole plants are similar, though I soon learned to detect a difference in the stockier appearance of the *decipiens*. But when once fixed in the soil the identity of the species is soon brought out in a marked manner.

Coming to the fiber, we find the strongest mark of difference between the two forms of fiber plants. In *decipiens* it is whiter, finer, softer, and greatly deficient in strength, though it approaches nearer the appearance of the true sisal fiber than that of any of the allied agaves not varieties of the *A. rigida* known commercially.

I found *A. decipiens* growing all along the coast and keys, from Jupiter almost down to Key West, always most abundant in the wilds where *Agave sisalana* was never found. It is a singular fact, however, that in the Lake Worth region it changes its form somewhat, the leaves being longer,

FIG. 5.—Edge of false sisal hemp leaf, showing spines.

often more flattened (sometimes perfectly flat) but always provided with the footstalk and with the terrible spines.

The leaves of *decipiens* used for fiber were collected, chiefly, from Sands Key, one of the line of keys forming the southern boundary of Biscayne Bay, though a few specimen lots were secured from other points. This key is uninhabited, and the plants were found in masses so dense (and so mixed with the prickly pear) that we were only able to secure leaves from the outside plants. The work of cutting the leaves, even from these isolated plants, was in the nature of an ordeal. Every member of the party took a knife and attacked the thicket, no one escaping the experience of bleeding hands and arms and of more or less injured clothing. If there is any place where strong language is halfway excusable it is in a thicket of *Agave decipiens*.

FIG. 6.—Blossom of false sisal hemp plant.

Some of the plants of this species growing on Sands Key are magnificent specimens. Radiating in all directions from the top of an immense footstalk, clothed to its very base with the dead leaves of former years of growth, its mass of leaves often reach an expanse of 7 or 8 feet, the topmost tips being 12 feet from the ground, while rising out of this dense cluster of leaves is a huge mast often reaching a height of 20 feet more, the branchlets thickly set with pole plants. (Fig. 6.) I have seen masts on Sands Key 4 inches in diameter, though 3 inches is the normal measurement. If *A. sisalana* does not thrive in the shade this species will grow in the densest tangles of saw palmetto and low, shrub-like vegetation, thrusting up its head defiantly, in lusty vigor, from the dense undergrowth. Sometimes it is

A TANGLE OF WILD GROWTH ON SANDS KEY, FLA.

covered with rank growths of wild vines, whose tendrils bind firmly together whole bunches of leaves. I saw one plant so bound in this manner that the larger part of its leaves were tied closely together at the tips, yet it grew and put forth new leaves as though free like its fellows.

Plate v illustrates fully the appearance of the vegetation upon these uninhabited keys, where everything grows in wildest luxuriance and forms tangles so dense as to be impenetrable save as the explorer cuts his way in with blows of the *machete*. It is in such places that the false sisal, the Spanish bayonet, and cactus or prickly pear are found in perfection.

The experiences of my first day on and around Sands Key, where this view was taken, will long be remembered; although in February the air was as balmy as spring. Donning a pair of rubber boots reaching to the hips, and in company with Mr. Jo Curry, we put off from the yacht early in the morning in a small boat to make the round of this interesting isle, lying a mile or more from our anchorage. For the first half mile the boat glided smoothly through the green waters, that showed an average depth of 4 to 6 feet, the coral bottom clearly visible, covered with sponges, sea plumes, and the many-colored seaweeds, or marine life. Shoaling suddenly the rowing was often impeded, and at length, when within a quarter of a mile of the key, it became necessary to disembark and draw the boat after us. It was impossible to find a landing place on the bay side among the dense growths of mangrove with their network of interlacing roots, and for a mile or more we tramped, or floundered, over the shoals until the eastern end of the key was reached. Here the tide was running swiftly, forming eddies between the jagged masses of outcropping coral, and at this point the first picture was taken, the camera having been set up in 2 feet of water. Turning westward, the shoaling of the bottom necessitated taking a course considerable distance southward from the shore, where we rowed or drew the boat after us by turns, surprising the fish that were sunning themselves in the deeper pockets, frightening the gulls or clumsy pelicans, and once coming suddenly upon a half-grown shark stranded by the outflowing tide.

I made a "landing," finally, alone, Curry remaining an eighth of a mile seaward with the boat. The silence, the solitude, the wild grandeur of this bit of sea-girt wilderness was most impressive. The sparkling waters, the glistening sands, the beach drift, and the harmonious blending of color in the rich, rank vegetation, made a picture not soon to be forgotten.

When entering the thickets the false sisal and the cactus are naturally the plants most to be dreaded, owing to the needle-like spines, which it is almost impossible to avoid. I do not think the spines of *decipiens* poison the flesh like those of the prickly pear, although the juice extracted from the leaves by the machine was found so acrid that handling the pulp caused the hands to smart in a very few minutes.

In my first report I called the false sisal plant *Agave mexicana*, on the authority of a gentleman who has brought together in his collection many species of Agaves, his examples of the plant being so named. The correction should be made in the pages of the former report.

In Bulletin 3 allusion was made to a correspondence with the Bahamian authorities, in which this statement occurs:

> We do not approve of the fiber plants secured from Florida, which are very inferior in product, both in quality and quantity, to what we get from the indigenous plant.

I do not think now there can be any doubt concerning the identity of the "fiber plant" alluded to in the above. We know that the Bahamians carried off, by purchase or otherwise, schooner loads of the false sisal. The true sisal hemp plant of Florida, as I have shown, produces an equal quantity of fiber to the Bahamian, and of a superior quality, as far as I have been able to make comparisons with the Bahamian product. The fiber from *decipiens*, on the contrary, has been found "very inferior in product, both in quality and quantity." The species should be carefully avoided, therefore, by those collecting plants to start plantations.

DESCRIPTION OF THE FALSE SISAL PLANT OF FLORIDA.

By J. G. Baker, *Kew, England.*

In the Kew Bulletin for February last (pp. 21-40) a general account was given of the sisal hemp industry, and particulars were given of the distribution of sisal hemp plants in nearly every part of the world. In the description of the plants found in Florida it was pointed out that the bulk of these consisted of the best sort for fiber (*Agara rigida* var. *sisalana*), in every respect similar to the plants now being so largely planted in the Bahamas, Turks Islands, Jamaica, and elsewhere. Amongst the Florida plants Mr. Charles Richards Dodge, an officer of the U. S. Department of Agriculture, found here and there some plants which were evidently not true sisal. For instance, "at Juno, about 10 miles further south (from Jupiter), at the head of Lake Worth, I found another fine nursery of perhaps 100,000 plants, the property of Mr. A. M. Fields, who is quite enthusiastic on the subject. Fully 50 per cent of his plants are not *Agave sisalana*, however, but a species which was subsequently met with at many points along the east and west coast, as well as on the Keys, doubtless *Agave mexicana*." At the time this was quoted in the Kew Bulletin (p. 26) it was stated that probably this determination would require to be verified. Since that time abundant material has been received at Kew from Florida from Mr. Dodge, and there is no doubt that the plant which he had provisionally taken to be *Agave mexicana*, and mentioned in his report under the name of "False sisal," was an entirely new species. In a letter dated April 27, 1892, forwarding specimens, Mr. Dodge, of the U. S. Department of Agriculture, under date April 27, 1892, states:

"I have just received from Biscayne Bay, southern Florida, some blossoms of my so-called 'false sisal,' accompanied by mature leaves taken from the same plant. One of these I send you by mail to-day, the others being in a semidecayed condition and unfit to send. This is the normal length of the leaves found throughout the Biscayne Bay region and along the line of keys. Those at Lake Worth, which is very near to Jupiter, I found with leaves at least a foot longer, in rare instances 2 feet longer, though preserving the same characteristics. I send you with this a few blossoms, together with a sample of true sisal hemp, and another of false sisal for

comparison with it. As you will see, one is a strong, good fiber, the other is not more than half as strong, and of different appearance."

These and other specimens have enabled Mr. J. G. Baker, F. R. S., the keeper of the herbarium at Kew, to draw up the following description of the plant:

AGAVE (EUAGAVE) DECIPIENS Baker.

Caudice demum 3 to 4-pedali, foliis dense rosulatis ensiformibus rigidis demum 4-pedalibus utrinque levissimis viridibus infra medium ad apicem sensim angustatis, facie sæpissime concavis, spina terminali pungente breviter decurrente, aculeis marginalibus parvis atro-castaneis deltoideo-cuspidatis, floribus in paniculam amplam thyrsoideam dispositis, ovario oblongo, perianthii tubo brevi late infundibulari, lobis tubo duplo longioribus, staminibus longe exsertis, stylo staminibus demum æquilongo.

Hab.: Florida: Biscayne Bay and Lake Worth. For all the material from which the plant is described we are indebted to C. R. Dodge, esq., the special agent for fiber investigations of the United States Department of Agriculture. It is the plant supposed to be *A. mexicana*, figured on Plates 7 and 8 of his report, No. 3, issued May, 1891.

Caudex reaching a length of 3 to 4 feet, whilst *A. sisalana*, over the same area, remains nearly acaulescent. *Leaves* densely rosulate, very rigid, ensiform, reaching a length of 4 feet, broadest a little below the middle, where they reach 3½ to 4 inches, narrowed very gradually to the horny brown pungent point, which is one-half to three-fourths inch long, and decurrent as a narrow brown-black line along the edge of the leaf for 3 to 4 inches, narrowed also to a point above the diluted base, where they are 2½ inches broad, very smooth, and apple green on both surfaces, not distinctly glaucous even when young, usually very concave all down the face and convex on the the back, rarely flat; marginal prickles moderately close, deltoid, cuspidate, brown-black, not more than a line long.

Peduncle with panicle about five times as long as the leaves. Panicle 8 to 10 feet long, with a rather flexuose axis, and usually single dense clusters of flowers terminating the laxly disposed simple arcuate branches.

Flowers arranged in dense clusters. Ovary oblong, finally 2 inches long, three-fourths inch diameter. *Perianth* greenish-yellow, an inch long; tube broadly funnel-shaped; lobes complicate lanceolate from a dilated base, twice as long as the tube. *Stamens* 18 to 21 lines long, inserted at the middle of the perianth tube; antlers linear, one-half inch long. *Style* finally reaching to the top of the stamens.

Belongs to the section *Rigidæ* and nearly allied to *A. rigida* var. *A. elongata* Jacobi, from which it differs by its longer caudex and concave-faced leaves, which are very smooth on both sides, and not at all glaucous even when young, broadest below the middle, and narrowed very gradually to the hard point, which is decurrent for a short distance as a narrow brown-black border. The fiber which it yields is very inferior in tenacity to that of *A. sisalana*. I can not make out any material difference between the flowers of the two species. The name *decipiens* refers to the plant being confused so easily with the forms of *A. rigida*, of which the fiber is so much more valuable that it would lead to loss and disappointment if it were cultivated for economic use.

OTHER FIBER-PRODUCING AGAVES.

In tropical America there are over one hundred and fifty species of Agaves, many of which yield valuable fiber that is used to a greater or less extent commercially, or by the natives in the countries where produced. While the varieties yielding sisal hemp are the most largely used commercially there are others which, in Mexico and Central America, form considerable industries. As far as I can learn, however, none of these are produced commercially in the United States, though several useful species are growing in the extreme southern portion of the United States, near the Mexican border. The most valuable of these species, the *Agave heterocantha*, produces the well-known Tampico fiber or Ixtle, which is used chiefly in brush manufactures, although the fiber is obtained from several species. The *Agave americana* or Maguay, another species of commercial value, is better known, however, as the plant producing the *pulque* than as a fiber plant. During the past two years I have extracted fiber from twenty or more species of Agave, and these species will form the subject of the present chapter.

FIG. 7.—*Agave americana.*

THE MAGUAY (*Agave americana*).

A description of this plant is hardly necessary, as there is hardly a conservatory at the North or a garden at the South that does not contain one or more examples. It may be briefly described, however, as having leaves 3 to 6 feet in length, thick and fleshy, and formed of hard, pulpy matter, intermixed with the fibers. (Fig. 7.) In color they are very light green, covered with a whitish bloom (save in the variegated variety), and armed at tips and along the edge with spines.

The species is found in many parts of the world. In America it is known as the century plant and as the American aloe. *Carata* and *Pita** are names given to it in Spanish-American countries, the last name also being given to the fiber. It is known in India as *Cutthaler nar*, and as *Bans-Keora* in Hindostan. The Indians of Mexico and Arizona use it for saddlecloths and cordage. The "saddlecloths" are not woven, but are merely masses of fiber of regular thickness, tacked with thread at regular distances in the same manner that mattresses are secured and the hair kept in place. In the West Indies it is employed by the negroes for making cordage, hammocks, and fishing-lines, and in Mexico is utilized in the manufacture of ropes for use in the mines, and in some cases for the rigging of ships. In South America it has even been used for large cables.

The name *Pita* follows it to Spain and Sicily, where it is used for cordage and mats. It is also made into paper in Mexico, a sample of "Maguay paper" in the Museum attesting its value as a paper stuff. The sample is clear and white and of fine texture. In New South Wales "it produces such an excellent fiber, of such strong and durable quality," it is recommended for cultivation for its fiber alone, particularly as "it will grow in almost any situation, and so freely that under favorable circumstances it will flower in from seven to eight years." An allied form, known as the bitter aloe, is employed by the peasant women of Fayal in the manufacture of the celebrated "Fayal lace," which has brought such high prices in Paris, where the greater portion of this delicate fabric is sold.

Among other uses of this Agave it is employed in portions of southern Europe as a hedge plant, the spiny leaves particularly adapting it for the purpose. Soap is also manufactured from the juice, and the fresh leaves cut in slices are occasionally used as food for cattle. The most important product, however, is the sap, which forms an intoxicating liquor known as *pulque*.

Dr. Forbes Royle states that the India *Pita* has been found superior in strength to either coir, jute, or sunn hemp. In a trial of strength near Calcutta, the tests were made with ropes 1 fathom long and 3 inches in circumference, with the following results: The Agave or pita broke in a strain of 2,519½ pounds; coir, 2,175 pounds; jute, 2,456½ pounds, and sunn hemp, 2,269½ pounds. In an experiment with Russian hemp and pita, the first named broke with 160 pounds' weight, and the latter with 270 pounds. These experiments show the great strength of the fiber, which is worthy of more extended cultivation and employment in the arts.

When the fiber is extracted by hand the leaves are crushed and macerated in water, and the fiber separated from the parenchyma by beating. The fiber is contained in roots as well as leaves. Another plan in vogue is to lay the long leaves upon a board, and with a square iron

* *Bromelia sylvestris* and other species are also called *Pita* by some authors, though the name properly belongs to *Agave americana*.

bar held in both hands they are scraped until all the juice and pulp are pressed out, leaving the fiber ready to be cleaned.

The fiber has been described as composed of quite large filaments, white, brilliant, stiff, and light in weight. Vetillart states that, viewed under the microscope, the isolated fibers are short, with slender walls and very large central cavity. They are swollen in the middle and terminate in a point, the most frequent form of which is that of a spatula blade. They are sometimes lobed or bifurcated, and the thickness of the walls varies in the same fiber. It is very irregular, the exterior profile undulated or toothed to the extremity.

This would imply a very coarse, harsh fiber, but such is not the case. A number of samples in the Department collection, including not only those extracted by myself, but samples extracted by Mr. T. Albee Smith, of Baltimore, show a fine, soft, white fiber, of more or less brilliancy, a distinctive characteristic being a wavy or crinkled appearance which prevents the bundles of fibers in mass from lying closely parallel, as is the case with sisal hemp and similar straight fibers. Another marked peculiarity is its elasticity, which is so great, with its fineness, that I believe it could be used to advantage in the manufacture of hawsers, particularly for towing moderately large vessels. In towing disabled ships upon the ocean the danger of snapping a hawser under the severe strain caused by the lurching of the two vessels is very great and rupture often occurs. With such an elastic fiber I think the strain would be met and overcome, as this fiber, under ordinary conditions, is quite strong.

During the past two or three years quite a mass of data regarding this species has accumulated through correspondence, showing that, while the value of the fiber is appreciated, the plant is not grown commercially within our borders, save to small extent for the manufacture of *pulque*, and this mainly in Arizona. While referring to this use of the plant it may be stated that the plants producing *pulque* and *mescal* are said to be quite different, the latter beverage being extracted from another species.

Agave americana is not found in Florida, save in conservatories or gardens, though an allied form was met with at various localities, and which will be referred to later. Some magnificent cultivated examples were observed in Fernandina, near the hotel, and others were noticed in St. Augustine, their leaves so large and fleshy that no ordinary machine could work them without first cutting them into strips. The plants come to maturity in three years, though they do not flower for eight, and sometimes twenty years.

I can not learn that any attempt has been made in this country either to cultivate the species or to use the leaves of growing plants for fiber. Mr. R. W. Paton, representing a California industrial company, which owns extensive lands in southern California, some time ago wrote several letters to the Department in relation to the *Agave americana*,

and it was proposed at one time to try to utilize the fiber. The want of a good machine, however, was the principal obstacle met with in the endeavor to start the industry. A quantity of leaves were at that time sent to Mr. Van Buren, of Jacksonville, Fla., to be extracted by his machine, but this inventor found the leaves too thick and wide to go through the machine as at that time constructed. Mr. T. Albee Smith, however, has cleaned the leaves successfully on his machine, figured on page 39 of Bulletin 3, issued by the Department a year ago. (See page 41.) Mr. Smith's material was received from Mexico. In Spon's Encyclopedia of the Industrial Arts, Manufactures, and Commercial Products (Part III, p. 912), a powerful machine is described for crushing the leaves of the plant and extracting the fiber, this authority stating that the species is now naturalized in southern Europe, Mauritius, Algeria, throughout India, and the Pacific Islands. I will close this account of the plant with a few brief extracts from the above authority:

The plant requires about three years to come to perfection, but it is exceedingly hardy, easy of propagation, very prolific, and grows in arid wastes where scarcely any other plant can live. It perishes after inflorescence, which does not occur until the eighth to twentieth year, but it then sends up numerous shoots. In Mexico, 5,000 to 6,000 plants may be found on an acre. The average number of leaves is forty, each measuring 8 to 10 feet long and 1 foot wide, and yielding 6 to 10 per cent by weight of fiber. The culture of the plant is being extended in America, but not in the proportion which its value deserves. In India it is all but neglected; it grows wild in many parts, and is sometimes cultivated as a hedge plant, but its fiber, seldom and badly prepared, is harsh and brittle, though of good color. Care would effect great improvements.

The native methods of preparing the fiber are very primitive: (1) The leaves are cut, and steeped in water; then beaten with sticks, and rubbed with stones or scraped with shells or wooden blades, to remove the nonfibrous portion; and finally washed, and bleached in the sun. This plan causes stains, and a tendency to rot, and thus reduces the value of the fiber. (2) The leaves are cut, and deprived of about 6 inches of the pointed end; then well beaten or bruised with wooden mallets on a smooth surface of stone or wood, tied in bundles of four leaves, and laid in heaps to ferment. The beating removes much of the sap; and the fermentation helps to loosen the fiber without damaging it. When the heat has subsided, the bundles are thrown into water and steeped for about a fortnight; after washing, the fiber appears clean and white. It is then dried, shaken, and packed.

Its uses are various. In its native countries it is applied to the manufacture of ropes, twine, fishing nets, hammocks, etc. It is exported for admixture with manila hemp (*Musa textilis*) for all kinds of cordage. Bleached and dyed it is made into matting and imitation horse-hair cloth, with good effect. The short fiber separated by the processes described above may also be carded and spun; while the waste is an excellent material for strong wrapping and envelope paper. The fiber, exposed for two hours to steam at 2 atmospheres, boiled in water for three hours, and again steamed for four hours, lost 5.55 per cent of its weight; as compared with manila hemp, 6.87; *Phormium*, 6.14; hemp, 6.18-8.44. Some slips of sized paper, weighing 39 grams, made from this fiber, bore an average weight of 89 pounds, as against Bank of England note pulp, 47 pounds. It is the most highly approved of all paper fibers, making a strong, tough, smooth paper, which feels like oiled paper, and, even while unsized, may be written on without the ink running. Its price is governed by that of manila hemp, being generally £7 to £10 a ton less than the latter. With proper care in the preparation, this difference should be much reduced. The fiber prepared in India is harsh and brittle, though of good color; it is not met with in commerce.

ANOTHER FLORIDA AGAVE (UNIDENTIFIED.)

A species of Agave allied to *A. americana*, but which I have not yet been able to identify, was found in many portions of southern Florida. Fine specimens of the leaves have been sent from the Indian River region by Mr. McCarty, who informs me that the plant is common in that section. I have myself seen it growing at Jupiter, at Lake Worth, and at other points on the mainland to the southward as far as the Perrine Grant, but I do not recall a specimen on any of the Keys. There is a superb plant at Cocoanut Grove, on the grounds of Mr. Kirk Munroe, from a photograph of which the accompanying illustration (Fig. 8) was made. The mature leaves measure 5 feet or more in length,

FIG. 8.—Agave (species unidentified).

8 to 10 inches in breadth, and will weigh 8 pounds or more. The serrations on the edges are very fine and close-set, the terminal spine being present. The color of the leaf is a light bluish green.

A quantity of small leaves of this species were run through the machine at Cocoanut Grove, but owing to the thickness of the butts it was necessary to split each leaf into four pieces and crush the butts with a mallet. The fiber is similar to that of *Agava americana* in every respect, crinkly, and elastic, and very white. A sufficient quantity of the fiber was secured for exhibition purposes, but not enough for test in manufacture. Specimens of the living plants were forwarded to the Department, and are now in a flourishing condition in the Department conservatory.

IXTLE OR TAMPICO (*Agave heterocantha.*)

Until recently there has been considerable doubt as to the identity of the species of Agave from which the Ixtle of commerce is produced. The common name of the plant is Lechuguilla, (or "lechigilla"), and

writers upon the subject usually refer to it under this name. In the report of the Mexican Boundary Survey the name *Agave lechuguilla* appears as the botanical designation of a plant producing a coarse fiber employed in the manufacture of cordage and bagging. Specimens of this fiber, and brushes made from it, were sent to the Kew Garden Museum fourteen years ago by the late Dr. C. C. Parry, formerly botanist of this Department, and from this and other material the identity of the plant, or plants, producing "Tampico hemp" has been established.

In Appendix XXI, Report of the Chief of Ordnance for 1883, there is a report on brush material and the manufacture of brushes, by Capt. A. L. Vaney, in which appears an account of this fiber, with rude figures. This writer, misled by Squer in his work on Tropical Fibers, makes Ixtle the product of *Bromelia sylvestris*. He also reproduces a letter from Hon. J. McLeod Murphy to the Department of Agriculture, who states that the average length of the leaf is 6 feet. This would indicate that Mr. Murphy has also been mistaken in the identity of the plant, and doubtless, likewise, has referred it to *Bromelia sylvestris*.

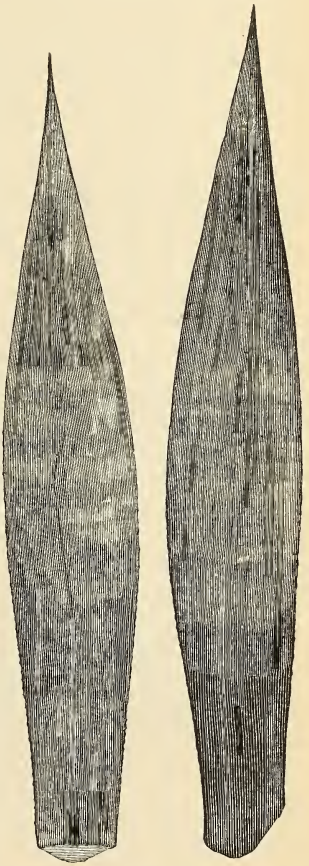


FIG. 9.—Leaves of Agave (species unidentified). (See page 38.)

Specimens of the true Ixtle plant have been sent to the Department from different sources in the past two years, and I have also had opportunity to examine the leaves in quantity at Mr. T. Albee Smith's establishment in Baltimore at the time I examined his fiber machine, and I have never seen the leaves over 18 inches in length. It should be stated that Mr. Smith has produced this fiber in quantity in Mexico, and is thoroughly posted as to the identity of the plant known as *A. lechuguilla*. The leaves brought from Baltimore, on my return, were compared with the plants in the large collection of Agaves in the Botanic Gardens in Washington, and proved to be the *Agave heterocantha*. At the same time there is no doubt that several other allied species of Agave (having harsh, bristle-like fiber) are also employed in obtaining the commercial supply of Ixtle. Mr. T. Albee Smith informs me, however, that fully 90 per cent of the fiber made in Mexico is from the species represented by the leaves shown by him in Baltimore.

The authorities of the Kew Garden, England, have extracted the fiber from *A. heterocantha* Zucc.; *A. xylacantha* Salmdyck; *A. horrida* Lemaire; *A. kerchovei* Lemaire; *A. lophantha* Scheide; *A. univittata* Haw.; and *A. multilineata* Baker, and state that—

all of these yield a coarse and somewhat rigid fiber, but the fiber of *A. heterocantha*, allowing for the age of the plant, comes nearest the commercial fiber known in London as Mexicana fiber or Istle.

All these species, it may be mentioned, belong to a distinct set of Agaves, the leaves of which are characterized by a continuous horny margin, and hence placed together by Baker under the group Marginatæ, of which the distinctive characters are, "Edge of the leaf furnished all the way down from the top to the bottom with a distinct horny border, of the same texture as the teeth."

I will mention two other species, *A. inghamii* and *A. stenophylla*, which I have cleaned on the Van Buren machine, the first named, especially, producing a very coarse rigid fiber. I shall refer to these, however, later on in this report.

Spon's Encyclopædia complicates the botanical synonomy of the plant by attributing ixtle to be the product of *Nidularium* (*Bromelia*) *karatas*, "Mexican fiber," "silk grass," "ixtle," etc., stating that the leaves vary in size from 6 to 8 feet in length, and from one-half to 4 inches in width. A saving clause is appended to the history of the species as follows:

It is very likely that this fiber contributes in no small degree to the large shipments of so-called "Mexican fiber," now extensively used in lieu of bristles for brush-making, and valued at £45 to £55 (and even £100) a ton.

The Kew Bulletin for December, 1887, has an article with an important bearing on the subject:

There is little doubt, therefore, that Mexican fiber or ixtle is derived from a group of Agaves with short leaves, and from the material available at Kew the evidence is strongly in favor of *Agave heterocantha* Zucc., being the species chiefly concerned. Indeed, the specimens contributed by Dr. Parry to Kew in 1879 afford direct proof on this point. Since the above remarks were written we have been favored by Dr. Newberry with a reprint of an article of his in the Popular Science Monthly for November, 1887, entitled "Food and Fiber Plants of the North American Indians." At page 10 we find he identifies the "lechuguilla" of the Indians with *Agave heterocantha*, and attention is particularly drawn to the size of the leaves, about a foot to 18 inches in length, and to the very strong character of the fiber contained in them.

Dr. Newberry's observations are given as follows:

Another less known but scarcely less valuable plant belonging to the same genus (*Agave*) is the "lechuguilla" (*Agave heteracantha*) of Chihuahua and the surrounding country. Of this, the leaves are from a foot to 18 inches in length, and grow in a tuft like those of a century plant (*Agave americana*). Though separated with some difficulty from the parenchyma in which they are enveloped, the fibers that traverse the leaves are numerous and very strong, and are largely used by the Mexicans for the manufacture of ropes, sacking, etc.

The ixtle plant is not cultivated, but grows wild, the fields lying in desolate barrenness along the table-lands of the States of Tamaulipas and San Luis Potosi, the most extensive tracts being near the towns of

Tula and Yanmare. Mr. T. Albee Smith, in correspondence with the department concerning the "*lecuguilla*," says:

The plant to which this coarse fiber is properly accredited is never cultivated, and grows in the dry, arid plains and on rocky cliffs in the mountains where little else can find sufficient moisture to exist. The maguey plant, *A. americana*, does not grow on arid and rocky sands, but its greatest luxuriance is attained on the great plains of Opam, which has a very rich soil.

The leaves are elongated, thick and fleshy, though tapering, and are armed along the sides with a row of terrible hooked spines, or thorns, the edge of the leaf thickened into a kind of brownish epidermis to which the spines are attached, and which can be readily stripped off with the thorns intact. It is claimed to give fully 25 per cent of fiber to the weight of the leaf.

The fiber in late years has been cleaned to a considerable extent by means of machinery, the fiber machine figured on this page (Fig. 10)

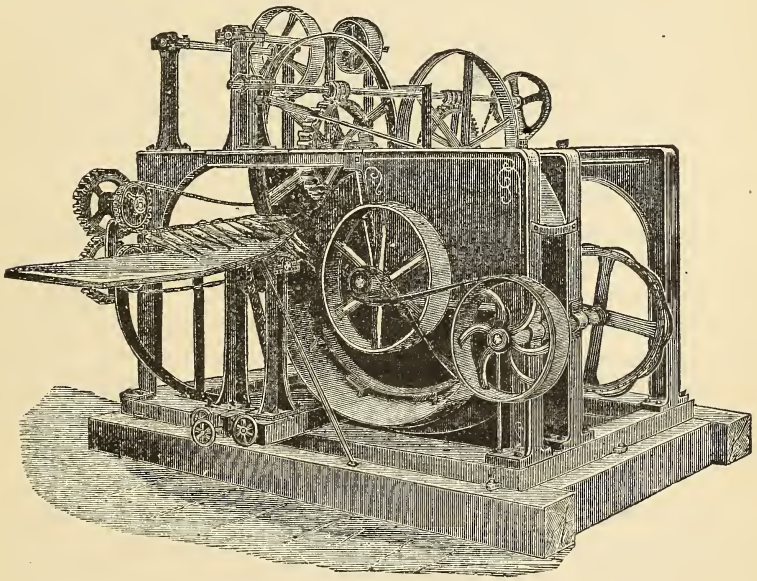


FIG. 10.—The T. Albee Smith machine.

being especially adapted to the purpose. The native method of hand cleaning is very primitive. The appliances used for the purpose may be described as consisting simply of a—

triangular, smooth-edged piece of iron, measuring about 16 inches long and 2 inches on each face, with one end terminating in clasp form and the other as a handle. A board of hard wood is laid at the foot of a tree, and over it, crosswise, is placed the aforesaid iron or presser, its clasp end hooking one of the roots of the tree and the handle end resting in the operator's right hand, with which he strongly presses the leaf against the board, while with the left hand he draws it its full length, repeating the operation until the leaf is completely purged of its aqueous matter. An Indian cleans an average of 20 pounds of ixtle per day in this manner. The cutting and

curing of the leaves have no special season. These operations are performed while the plants ripen, and this happens during the whole year.

While the commercial supply of fiber is wholly derived from Mexico, the plant nevertheless is found to a limited extent in extreme southern portions of the western United States. Mr. Samuel M. Jarvis, a correspondent of the Department living in Webb County, Texas, states that the plant not only grows very abundantly in Mexico, but is common in different portions of Webb County, Texas. He sends samples, which are referred to as "*lechuguilla*," and adds in his letter: "It is a wild plant, and has never been cultivated here nor in Mexico." The samples were the true Ixtle.

Consul Stone, of Nogales, Ariz., just across the border from Sonora, Mexico, in reply to questions relating to this species and to *Agave americana*, says:

> I have recently been to a ranch north of this point where the *lechuguilla* grows in abundance, and where I found two patches of maguey. It is probable that this maguey was once cultivated by the Indians. A carload of the maguey could be had here, and the *lechuguilla* in unlimited quantity. The place is 30 miles from Willcox, on the Southern Pacific Railroad. In the foothills the plants grow without water, and where nothing else can be grown. In the valley they could be cultivated, and by irrigation grown much more rapidly and larger. Plenty of water is to be had a few feet below the surface in the valley.

Ide and Christie, the London fiber brokers, quote this fiber as worth 22*s.* to 28*s.* per hundredweight in the London market (circular of November 15, 1892), equal to 4½ to 7 cents per pound. The fiber is very stout and harsh, of a yellowish white color, thickest at the end representing the base of the leaf. Consul Cassard states that it varies in length from 1 to 3 feet, according to localities where grown. The fiber known as "tula" measures on an average 24 inches, though other forms will reach 30 inches in length.

A FEW CONSERVATORY SPECIES.

In June, 1891, I extracted the fiber from some twenty species of Agaves, the leaves having been supplied the Department by Mr. W R. Smith, of the U. S. Botanical Gardens, Washington. The fiber was extracted on the Van Buren machine, on the grounds of the Department. Only small museum samples were secured.

A. inghamii.—A coarse, harsh fiber, the filaments smooth and polished, and of such stiffness that the material would make a superior brush fiber, possibly rivaling the Tampico of commerce derived from *A. heteracantha*. Under repeated tests three filaments stood an average strain of 10 pounds.

A. stenophylla.—Similar to the preceding, though not so coarse, but of sufficient stiffness to produce a good brush fiber. The fiber, if washed when extracted, would have come out very white. Three filaments bore an average strain of 7 pounds. These two species yielded about 5 per cent of pure bristle fiber.

A. rigida var. *sisalana* (greenhouse plants).—Fiber appeared to be finer than that from Florida plants, and not quite so strong.

A. rigida var. *elongata.*—Similar to the preceding, the fiber not distinguishable from it in appearance or strength.

A. rigida var. *longifolia.*—The fiber from this example was much finer than the *sisalana* (above) and quite deficient in strength. In appearance it resembles the fiber from *A. americana* rather than *sisalana*, though differing from either.

A. kerchovei.—A harsher fiber than that obtained from the *rigida* group, as above, but apparently having less strength. Somewhat resembles Tampico.

A. salmiana.—Almost as fine as the fiber from *americana;* not straight; very little strength.

A. jacquiniana.—Very fine, white fiber, but possessing no strength.

A. brauniana.—Similar to the preceding; a weak fiber.

A. cuspidata.—A very fine fiber; not straight, approaching in strength that of *A. sisalana.*

A. americana.—Previously described. Fiber as strong as *sisalana* from greenhouse plants, but quite inferior to the Florida-grown fiber.

A. variegata.—Very white, crinkly, and elastic. Stronger than the preceding, but inferior to good sisal hemp.

A. caribæa.—Similar to the above in color and general appearance, but finer and showing less strength than *A. americana.*

A. corderoyi.—Fiber straight, fine, white, of average strength.

A. decipiens, *A. coccinea* (3 varieties), *A. lateverens*, and *A. kellockii*—worthless.

Out of sixteen species other than *A. rigida* (varieties) but two species can take rank with *A. rigida* var. *sisalana* in strength, *A. inghamii* and *stenophlylla.* In the next grade I would place *A. cuspidata*, *A. americana*, *A. kerchovei*, and possibly *A. corderoyi*, while the other species are either not half the strength of *sisalana*, or are worthless. *A. lateverens* went all to pieces in the machine, coming out in short, pulpy fragments.

It would be interesting to secure fiber from these species as grown in the open air of the tropics. No doubt several of the better species would give fiber of fair strength, though inferior to sisal hemp grown under the same conditions.

An interesting collection of agave fiber, from different species, was obtained from the Mexican exhibit at Paris (1889), but it was found impossible to identify the larger number specifically. We know, however, that several species of Mexican agaves, not recognized commercially, produce strong, valuable, fiber, which is utilized in various ways in their native country.

PINEAPPLE FIBER.

Ananassa sativa.

The pineapple, which is now cultivated largely in southern Florida, the Bahamas, and to the southward, is supposed to be a native of Brazil, and from that country introduced into both the East and West Indies, from whence it spread to many portions of the New and Old World where it has so established itself that it has been thought to be indigenous. It flourishes on the west coast of Africa and in India. In the Rungpore district of India the fiber is much used by the local shoemakers for twine, though the plant is cultivated principally for its fruit-bearing qualities, the fiber being little appreciated. In the Philippine Islands it grows in great abundance, and is valued on account of the fineness of the fiber, from which is woven the celebrated pineapple cloth of the Philippines. M. Perrouttel, however, considered this a distant species, and named it *Bromelia pigna.*

The fiber of *A. sativa* is very fine and soft, the filaments being quite flexible and very resistant. They yield readily to treatment in the alkaline bath and are easily subdivided, especially when subjected to trituration.

The isolated fibers are very fine, of a tolerably regular diameter from one end to the other, but of very different size. The interior canal, which is very perceptible in the largest, is not so in the smaller ones. They are very flexible, curling and crisping readily under mechanism. The points are rarely sharp, and gradually become slender. They are rounded at the end, or, rather, blunt.

It is claimed for pineapple fiber that constant immersion in water does not in the least injure it, and the natives of the East Indies increase this property by tanning it, though it is probably at the expense of strength. In tests of strength pineapple fiber exhibits superior tenacity. The fiber from Singapore bore a strain of 350 pounds against 260 pounds for New Zealand flax. This last named has been proved equal, and in some experiments superior, to best English hemp. In the Journal of the Agricultural Society of India (vol. III, p. 182), there is a record of a rope of pineapple fiber, $3\frac{1}{4}$ inches in circumference, standing a strain of 5,700 pounds before breaking.

When preparing the fiber of the pineapple, the leaves must be manipulated in the green state, as nothing can be done with them when dry. The native method of hand preparation is to lay the leaves

FIG. 1. PINEAPPLE PLANT WITH FRUIT.

FIG. 2. PINEAPPLE FIELD, ELLIOTT'S KEY, FLORIDA.

upon a board, the epidermis being removed with a broad knife. When the epidermis is scraped away the fibers are seen lying upon the lower and denser epidermis, running in a longitudinal direction. Although very fine, the process of bleaching, by destroying the adhesion between the bundles of fibers, renders it so much finer that it can be spun like flax. In the East Indies, where the pineapple was introduced as early as 1600, the fiber is extensively used in the manufacture of the delicate fabric called *pina*, as well as for cordage. *Pina* is considered to be more delicate in texture than any other known to the vegetable kingdom. It is woven from the untwisted fibers of the Ananassa leaf, after they have been reduced to extreme fineness, and after the ends have been glued together to form a continuous thread.

When the plant is grown for fiber, as in the Philippine Islands, it is customary to take off the fruit before maturity, that the leaves may be more fully developed.

According to Spon, the Chinese method of cleaning the fiber is as follows:

> The first step is the removal of the fleshy sides of the leaf, a man sitting astride a narrow stool extends on it in front of him a single leaf, one end of which is held beneath him. He then, with a kind of two-handled bamboo plane, removes the succulent matter. Another man receives the leaves as they are planed, and with his thumb nail loosens the fibers about the middle of the leaf, gathers them in his hand, and by one effort detaches them from the outer skin. The fibers are next steeped in water, washed, and laid out to dry and bleach on rude frames of split bamboo. The processes of steeping, washing, and exposing to the sun are repeated until the fibers are considered properly bleached. In the Philippines the blunt end of a pot-sherd is used, and the fiber is carefully combed and sorted into four classes.

Naturally such tedious processes could never be employed were the industry established commercially. Machinery has been employed to produce the fiber, there being several inventions for the purpose. The authority above quoted gives a description, with illustrations, of a Sanford Mallory machine, which is claimed to clean 6,000 to 8,000 leaves in a day.

THE PINEAPPLE IN THE UNITED STATES.

In our own country the pineapple is cultivated wholly for its fruit, and chiefly in Florida. The principal plantations on the Keys are found at Elliott's and Key Largo (see Plate VI), though plantations are found to the southward of these for many miles. On the mainland there are more or less extensive plantations from the extreme southern portions of the State northward on the west coast to Charlotte Harbor, and on the east along the Indian River to the Lake Worth and Jupiter region.

In the spring of 1890 Dr. Harris, of Key West, wrote to the Department concerning this fiber as follows:

> I send a small specimen of the pineapple fiber. It is said that the cloth called pineapple silk is manufactured from this substance. It certainly furnishes a fiber which for fineness and strength will rival any in existence.

I have been more or less engaged in the culture of pineapples for twenty years and have demonstrated the fact that good pineapples can be grown with success anywhere south of the Caloosahatchee River, down as far as Naples, upon ordinary poor pine land, without fertilization. The pineapple, when it reaches maturity and fruits, has about 40 leaves, measuring about 1½ inches broad and about 2 feet long, and as it takes from eight to ten thousand plants to cover an acre, and it is one of the very easiest cultivated crops we have, the possibilities of this crop with a machine to clean the fiber from the leaves of the plants after the fruit is gathered are simply immense. It takes a crop of pineapples one year to fruit, if planted from the suckers, and eighteen months if planted from the slips; but after the first year there is a continuous crop every year until it is deemed advisable to replant.

Considerable quantities of the leaves were treated by me at the experimental factory at Cocoanut Grove, the experiments being continued after my return north under the direction of the Department by Special Agent R. M. Munroe. The fiber was extracted with the Van Buren machine, which, while it turned out a superb product, would be wholly inadequate for the work from the commercial standpoint, as only two or three leaves could be fed in at a time. As the object of the experiment, however, was to secure fiber for future test and obtain it in the best possible condition, the question of cost of production was not considered.

The Florida fiber, when simply plunged into cold water for a few moments after coming from the machine and then dried in the sun, came out almost white, with a fineness and softness unequaled by any other leaf fiber that I have extracted. The fiber will be further prepared and, if possible, spun.

REPORT OF SPECIAL AGENT R. M. MUNROE.

At the close of Special Agent Munroe's work the following report on the culture of the pineapple and extraction of the fiber was submitted by him:

It is claimed that pineapple cultivation was first successfully carried on in this part of the world by a native of the Bahamas, Capt. Ben Baker, who established himself at the lower end of Key Largo about the year 1866, undoubtedly the result of the depression in shipping at that period and the consequent decrease in the number of wrecks which in previous years had been the principal if not only *harvest* gathered in South Florida. Later on the industry received a further stimulus by the opening throughout the country of the large deposits of iron, coal, and copper, and introduction of improved processes for working the same, thus reducing the value of old metal to the extent of making entirely profitless the dismembering of old hulks along the reef and consequent extension of the pineapple fields to the northward as far as Sands Key, some 37 miles, and southward 18 miles to Indian Key, making almost a continuous line of plantations for a distance of 55 miles. The available land on these keys barely averages half a mile in width and consists of the honeycomed coral rock of an old reef, the interstices of which, from successive vegetable growths and deposits, have become filled with a rich leaf mold, soon exhausted and apparently unsusceptible of renovation except by natural methods. With the aid of a pointed stick the young pine slips are planted, generally 12,000 to the acre, the fruit coming to maturity in eighteen months, though producing suckers in less time. Three crops are usual from one planting, after which the land is

turned over to the weeds or to various less exhaustive semitropical productions. The writer has literally quarried many messes of fine sweet potatoes from these fields with the aid of a heavy crowbar, which, notwithstanding the excellence of the potato, has its drawbacks.

The first commercially successful plantation of any magnitude on the mainland seems to have been made by a Mr. Richards, at Eden, on the Indian River, about the year 1881, and at the Biscayne Bay region, by Mr. Fuzzard, of Cutler, in 1886, the latter thoroughly demonstrating that the hitherto supposed useless pine land could, with judicious fertilizing, be made to produce pineapples at a profit almost if not as great as the more fertile but less cultivated land of the Keys. These successes have led to a boom in the industry, which, like other similar movements, bids fair to overstep the mark and entail loss to many enthusiastic but inexperienced people who have not carefully considered all the points of the enterprise. Undoubtedly there is a large and permanent field open in this section for the intelligent and progressive planter of semitropical and some purely tropical fruits, for several reasons. A very possible superiority over fruit from lower latitudes in flavor and texture from its being grown at its most northern limit is a theory with many horticulturists, but one that has few facts to demonstrate it. Systematic and scientific fertilizing and care by a people who are not apt to stop much short of perfection in practice has probably had more to do with the point of superiority; and lastly, the assured fact that with few exceptions fruit ripened in the field is superior to that picked half green and sweated in the hold of a vessel, which must be the case with the products of our foreign neighbors in the Bahamas and West Indies. Rail transportation from this section will place properly ripened fruit on the table of the consumer with the field aroma still clinging to it, and which no degree of cheapness can entirely offset.

There are a few discouraging features of this new industry which time and experience will very likely overcome. The mainland, like the Keys, has for its foundation an old coral reef, but with much greater elevation, age, and extent. The outcropping rocks at first sight are anything but pleasing, but close inspection reveals the fact that disintegration has taken place to a great extent and that comparatively little labor will complete the reduction, and, while not wholly adapted to the making of tennis lawns, will produce land eminently suitable for the fruit farmer, inasmuch as the rock contains more or less phosphoric acid and is a good holder of other fertilizers and moisture. Expensive labor is another drawback common to most new localities, and though generally regulating itself in the course of time it is disastrous to the beginner with small means. And another drawback is the want of reliable transportation—an average of three days by small sailing vessel to Key West, and, if lucky in making connections, three to four days more to Northern ports, but, as is often the case, a total loss from failure to connect. Much of the Key produce is shipped in sailing vessels directly North, but this entails serious loss occasionally from failure of wind and weather. A good anchorage exists back of Fowey Rocks for vessels of 18 feet draft, where lightering can be carried on in all weathers, hurricanes excepted. Vessels of 9-foot draft can come into a harbor at Cape Florida, and, with a little dredging, into Biscayne Bay proper, which certainly insures steam-vessel service when the demand is sufficient.

The variety of pineapple mostly grown on the Keys and main land has been the Red Spanish. This selection is due to its good shipping qualities as compared with the other finer kinds common to the West Indies, and also to the fact that but few of the early planters had the knowledge of and the means to procure the finer kinds from more distant localities. A few of the farms have small patches of Sugar-loaf and Puerto Ricos for local consumption only. The American planter of the main has and is securing the tropical earth and in a few years it will indeed be a rare variety that is not represented in Florida soil.

Regarding the fiber side of the industry, it has long been known that the leaves of many varieties of pineapple contain a more or less valuable fiber. With the idea

that the leaves from the common variety grown in this country might be of commercial value in this respect and thus prove an extra source of profit to the planter, the Department began its present investigations in this direction. Although in the end it may prove more advantageous to plant special fruitless varieties for fiber production, the only object at present has been to add, if possible, as extra source of profit to pineapple farming in the shape of ready sale for the leaves after their usefulness to the plant has passed and the fruit has been cut. The practice has been to let the leaves decay under the plant and afford possible nourishment to the young suckers. The general opinion on this point is in favor of cutting the leaves, but experiments covering several seasons will be necessary to properly decide this point. Owing to the practice on the Keys of planting very close it was found that a very large proportion of the leaves were injured by chafing one on another, and also from being crushed under foot in weeding and cutting the fruit. This condition seems to be almost entirely obviated by spacing the plants at least 2 feet, as has been done on the mainland. Another defect was found in the withered condition of several inches of the tip or end, not noticeable in the younger leaves. This, however, may be due to the excessive drought of the past season. It does not occasion much loss of fiber, it is true, but adds to the cost of extraction, the decayed parts having to be cut off. At this date there are but few farms on the mainland with any considerable acreage in fruit, so that any statistics from these would be of little value as regards the supply of leaves, for a year or so to come. Judging from the amount of land taken up for this special purpose, the cleanings already made, and slips engaged for planting, the mainland leaves will exceed by far those on the Keys and continue to increase in the same proportion. The approximate acreage actually in pineapples on Keys Metacomba, Largo, and Elliott's is 930, and the number of apples shipped this season (1892) about 1,916,400, which does not include many thousand marketed after the close of the season. The average yield of good leaves from the Red Spanish for this year (which has been very unfavorable) is about 10 out of the average 25 of each plant, and the weight 1 pound, making the total for fruited plants in round numbers 958 tons. Adding the leaves to be gotten after close of season, and from abandoned fields, the quantity might be raised to 1,000 or 1,100 tons. I inclose with this the memorandum of work at the factory under my supervision, with weight of leaves, and other data.

In going over the details of the work of Mr. Munroe, the results in the different lots of leaves are found to be so similar that statements will be confined to lots Nos. 1 and 5, leaves from Elliott's Key and from the mainland. Lot No. 1 was 1,022 pounds of Red Spanish leaves from Elliott's Key, cut a day after the fruit had been gathered, the leaves being much injured by chafing and bruising; 202 pounds of this lot were assorted, and 10 pounds of the selected leaves numbered 89 by count. The weather was very favorable for drying the extracted fiber. The product from this 1,022 pounds when thoroughly dry weighed 25 pounds, or a fraction less than 55 pounds to the ton of leaves.

Lot No. 5 was from Fuzzard's plantation, near the Perrine Grant, 1,000 pounds of leaves, tips cut off. The leaves averaged ten to the pound. Good drying weather. Dry fiber from this 1,000 pounds weighed 18 pounds 2 ounces, or a little over 40 pounds to the ton of leaves.

Another lot from the mainland gave fiber at the rate of 42 pounds to the ton of leaves, the tips of the leaves having been cut off.

Allowing for excessive waste, this experiment shows that the yield of fiber from freshly cut pineapple leaves will range from 45 to 60 pounds

from a ton of 2,240 pounds of leaves, which is a good showing. An important point to be noted in studying the weights of the different lots of leaves run through the machine in these experiments is the proven fact that selected leaves, as to size, do not give as high a yield of fiber as average leaves. Lot No. 1 was 820 pounds of average leaves and 202 pounds of selected. While the total 1,022 pounds of leaves gave 25 pounds of fiber, the 820 pounds gave 21 pounds of fiber against a yield of 4 pounds from 202 pounds of leaves. Reduced to equivalents the average leaves yielded at the rate of 57½ pounds to the ton, while the selected leaves yielded less than 44½ pounds of fiber to the ton.

As to the value of pineapple fiber no figures can be given, as it is not yet a commercial product. There is no doubt that if the fiber could be produced in quantity at economical cost, manufacturers would soon find a use for it and would know what price they could afford to pay for it. The market price would then be fixed by the demand and supply. The machine question enters largely into the problem, however, and as the leaves are small a quantity would need to be cleaned, at one feeding of the machine, to make it pay. Estimating 10 leaves to the pound, there would be over 22,000 leaves to the ton, which, as we have seen, would produce from 50 to 60 pounds of fiber. The Sanford and Mallory machine referred to on a former page, and capable of cleaning 5,000 to 8,000 leaves per day, would at this rate clean only 12 to 18 pounds of fiber in a day, which would make the product somewhat high-priced. Were the fiber used in the manufacture of delicate fabrics, there is no doubt that it would command a price considerably higher than the product of the other leaf fibers described in this report. The Department will carry its experiments with this fiber further, and give manufacturers opportunity to examine it.

Dr. D. Morris, assistant director of the Royal Kew Gardens, publishes the following notes on pineapple fiber, which are sufficiently interesting to reproduce entire:

Although not at present in commercial use, this fiber has a future of considerable importance before it. It is finer and stronger than that yielded by any other plant, and in the Philippines, where the West Indian Ananas has become thoroughly naturalized, a beautiful fabric known as "pina cloth" is made from it. A rope of pineapple fiber, 3¼ inches in circumference, bore a strain, at Calcutta, of 57 cwt.

There are several samples of fiber of a wild pineapple (*Bromelia sylvestris* Willd.) from the West Indies and Central America at Kew, but there is no record of their commercial value. A sample supposed to be from this plant was lately sent from Trinidad, upon which the brokers reported as follows: "Not yet in commercial use, but destined, we think, to a successful future; fine, soft, supple fiber, strong, and good color, ample length; say £30 per ton and upwards."

The fiber of the *Jamaica pinguin* (*Bromelia pinguin* L.) would appear not to be of high value. The plant covers hundreds of acres in the plains and lowlands of Jamaica, and an effort was made some time ago to prepare the fiber for commercial purposes. The report of brokers upon a sample of 90 pounds was as follows: "A long, towzelled, weak fiber, of bad color, coarse, no strength, and only fit for breaking up. Similar to St. Helena hemp tow, but not so good. We should think £12

to £10 per ton the utmost value." Several samples of this penguin fiber, from Jamaica and elsewhere, cleaned both by hand and by machine, are to be seen in the Kew Museum, No. 2.

If the leaves of this plant were cut up, roughly dried, and placed in compressed bales, they might prove of value for paper-making. To establish this point it would be necessary to forward to England about half a ton of dried leaves in compressed bales, in order that paper-makers might be able to test them on sufficiently large scale.

WILD PINEAPPLE FIBER.

This fiber is extracted from the *Bromelia sylvestris*, and while it is fine and silky, and very white in color when properly prepared, it is not as good a fiber as the preceding. For many years it was confounded with the Ixtle or "*lechuguilla*" of Mexico, and the writer fell into the same error in the statements made concerning this fiber in the Report of 1879, though the details of the description given refer to wild pineapple fiber and not to Ixtle.

This species is found abundantly throughout the tropics, and there are no collections that do not contain superb samples of its fiber. Specimens brought by me from Paris, presented by the Mexican commissioner-general, are among the finest I have seen, averaging 4 feet in length, the fiber being soft, white and brilliant.

The wild pineapple abounds on the rocky hills of the West Indies, and particularly Jamaica, where the plants are used as hedges and fences. Its leaves are steeped in water by the natives, and, after beating with a wooden mallet, yield a strong fiber. It is in common use for cordage on the island of San Domingo, and is favorably mentioned by Dr. Parry in his report.

The leaves from which the fiber is obtained are from 1½ to 3 inches in width and 5 to 8 feet long. They are quite thin and are lined with a fine, tough fiber, which some authorities consider a superior substitute for flax. In portions of Mexico the *Bromelia* is cultivated for its fiber, which is described as very fine, from 6 to 8 feet in length, and from its fineness and toughness commonly used in belt-making works. It also finds application in the manufacture of many articles, such as bagging for baling cotton, wagon sheets, carpets, etc., besides forming a valuable material for making cordage, nets, hammocks, and similar articles of common use. In Mexico the leaves were formerly subjected to the slow and laborious process of hand scraping, but, I am now informed, are cleaned by machinery as there is a considerable demand for the product.

On the Isthmus of Tehuantepec it is used by the natives in the fabrication of thread, cordage, mats, bagging, clothing, and for hammocks, and the fiber is sometimes made into paper. It is also manufactured into cloth by the Spaniards for hammocks. Specimens of *Bromelia* fiber from British Honduras were brought to the notice of the Royal Society of Arts in 1857, and from examinations then made it was ascer-

tained that each fiber contained from five to twelve or more filaments, held together by gummy matter capable of being dissolved by proper processes. Specimens had been passed over the comb or hackle of a flax mill, and had been pronounced by the most experienced flax spinners (of England) to be greatly superior to Russian flax, and approaching the best description of Belgian in capability of application to the finest textile fabrics.

It is said that the more mature the plant the coarser and longer the fiber, so with this knowledge it is an easy matter to select just the quality of fiber desired. The plants are armed with spines or thorns—used by the natives for needles and pins—though these disappear in cultivation.

Squier has quite a chapter on this fiber in his work on Tropical Fibers, though he confounds it with the Istle, as referred to on a former page, and gives it as his opinion that the fiber is probably more valuable in every sense than that of any other tropical plant, and would seem to be produced more readily than that of *Agave sisalana.*

Microscopically the fibers of *Bromelia* differ from those of *Ananassa sativa.*

The interior canal is much more apparent and the walls thinner. The fibers often present great inequalities in the diameter of the same specimen as well as in the thickness of the walls.

I did not find this species growing in Florida, though it doubtless abounds along the southern borders of the United States adjacent to Mexico. There are no samples of the fiber in the Department collection that are known to have been produced from plants grown in our own country.

BOWSTRING HEMP.

Sansevieria div. sp.

Early in 1890 beautiful samples of this fiber were sent to the Department from Trinidad by T. J. St. Hill, accompanied by specimens of living plants. The plant had been frequently met with in conservatories, and upon inquiry I learned that it also grew out of doors in Florida, particularly in southern portions of the State, and considerable correspondence was received on the subject. There are three species of *Sansevieria* to which the name bowstring hemp is usually given, though there are a dozen species in the genus. The three species are *S. guineensis*, *S. zeylanica*, and *S. latifolia*, the first named being known as African bowstring hemp. *S. zeylanica* is the best known, however, and is common on the Ceylon coast, from which it takes its name. The plant has been known and prized in India from remote antiquity under the name of *Murva*. In the catalogue of Indian fibers (Exhibition 1862) it is called *Moorga*, *Mazool*, and *Moorgavee*, or *Moorgahvee*. It is at present known under the vernacular name of *Murgavi*, *Murga*, and *Mazool*. Its Sanskrit synonym is *Goni*. The genus *Sansevieria* abounds on the coast of Guinea, around Ceylon, and along the Bay of Bengal, extending to Java and the coasts of China. They are stemless, perennial plants, throwing out runners, and having only root leaves, which are thick and fleshy, and usually sword or lance shaped, with sheathing bases. They flower from January to May, and the plants grow wild in the jungles. They are easily propagated on most

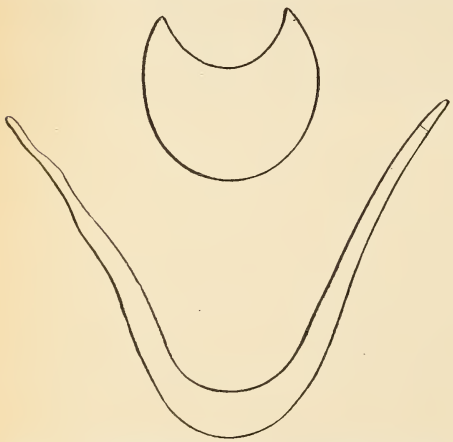


FIG. 11.—Cross-section of leaves of bowstring hemp.

every soil from the slips which issue in great abundance from the roots, requiring little or no care, and not requiring to be renewed often, if at all.

Dr. Buchanan found this plant employed in the manufacture of cordage at Bangalore, and bowstrings are still made of it in the Sircars and along the coast of Bengal. In the interior of Bengal it is equally common and wild, but not so largely used for fiber. The leaves are stated by most authorities to be from 3 to 4 feet in length, though I have cleaned leaves for their fiber in Florida that measured nearly 7 feet, and 100 pounds of selected leaves in one lot, cleaned, averaged over 6 feet. One species, native to tropical Africa, is said to produce leaves 9 feet in length. (Fig. 11 shows cross-section of Florida leaf.)

Among other species I may mention *S. Roxburghiana*, which is considered by English authorities as a distinct species common to the Bengal coast, and larger than *zeylanica*, though Royle does not admit it. *S. lanaginosa* is probably a distinct species; it is called *Katu-Kapet*, and found on the Malabar coast. This plant, upon experiment, has produced fiber as fine and soft as human hair, and possessing extraordinary strength and tenacity. Very superior examples have been likened to raw silk, and the firmness of the fiber "induced the Rev. J. Garrow to have it woven into cloth, which he declared was as fine a piece of cloth as he had ever seen." *Sansevieria* fiber was formerly considered a valuable paper stock at Trichinopoly, where the tow was used, while the fiber served as packing for steam engines.

Considered microscopically, "the fibers are fine, and constitute a white, brilliant filament, possessing a stiffness that does not disappear with friction. The fibers are hollow, straight, and smooth, with walls of uniform thickness. The central cavity is large. The points are sharp and slender." In *S. latifolia* the bundles are large, and are slightly refined by friction. It corresponds in general appearance with *S. zeylanica*, given above. The commercial fiber is described as hair-like and silky, and closely resembling the fiber of the pineapple. It is claimed to take dyes readily.

In the Kew Bulletin for April, 1887, it is stated that plants of this genus require a rich, moist soil and a comparatively humid climate, and that being essentially tropical plants they do not thrive in a temperature less than 60° F.

Under such conditions they grow rapidly and establish themselves permanently by means of their large spreading rhizomes or underground stems. It is true they will grow in comparatively dry districts, and even in soils strongly impregnated with salt, but their growth under such circumstances is very slow and the leaves are seldom large enough to produce marketable fiber. The plants are already abundant. In a wild or semicultivated state in most tropical countries they are capable of being propagated very readily. Usually the underground stem or rhizome is divided and planted, but plants may also be raised from seed, or from the leaves, which latter, planted whole or cut into small pieces, readily take root in moist situations.

The fiber of *S. guineensis*, which sometimes appears in the markets of Europe, has been thought by some to be superior to New Zealand flax. The strength of its fiber, as tested in the Agri-Horticultural Society of India, was found sufficient for hawsers and cables, while their fineness and tenacity are attested by their being used by jewelers for thread upon which to string pearls. It is too valuable and too fine a fiber, however, for cordage, in view of the fact that Manila, sisal, and common hemp are to be obtained abundantly, and are sufficiently strong for marine and other kinds of cordage.

Royle states that the untwisted bowstring hemp fiber will bear a strain of 280 pounds, compared with Agave, which bore 270 pounds, though Dr. Wight's experiments gave 362 pounds for *Agave* to 316 pounds for the *Sansevieria*. Dr. Roxburgh ascertained that a line of *Moorga* fiber 4 feet long bore a weight of 120 pounds, when a cord of the same size, made of Russian hemp, bore a weight of but 105 pounds. After remaining in water one hundred and sixteen days, the former bore a weight of 30 pounds while the latter was entirely rotten. It is not considered equal to Manila hemp.

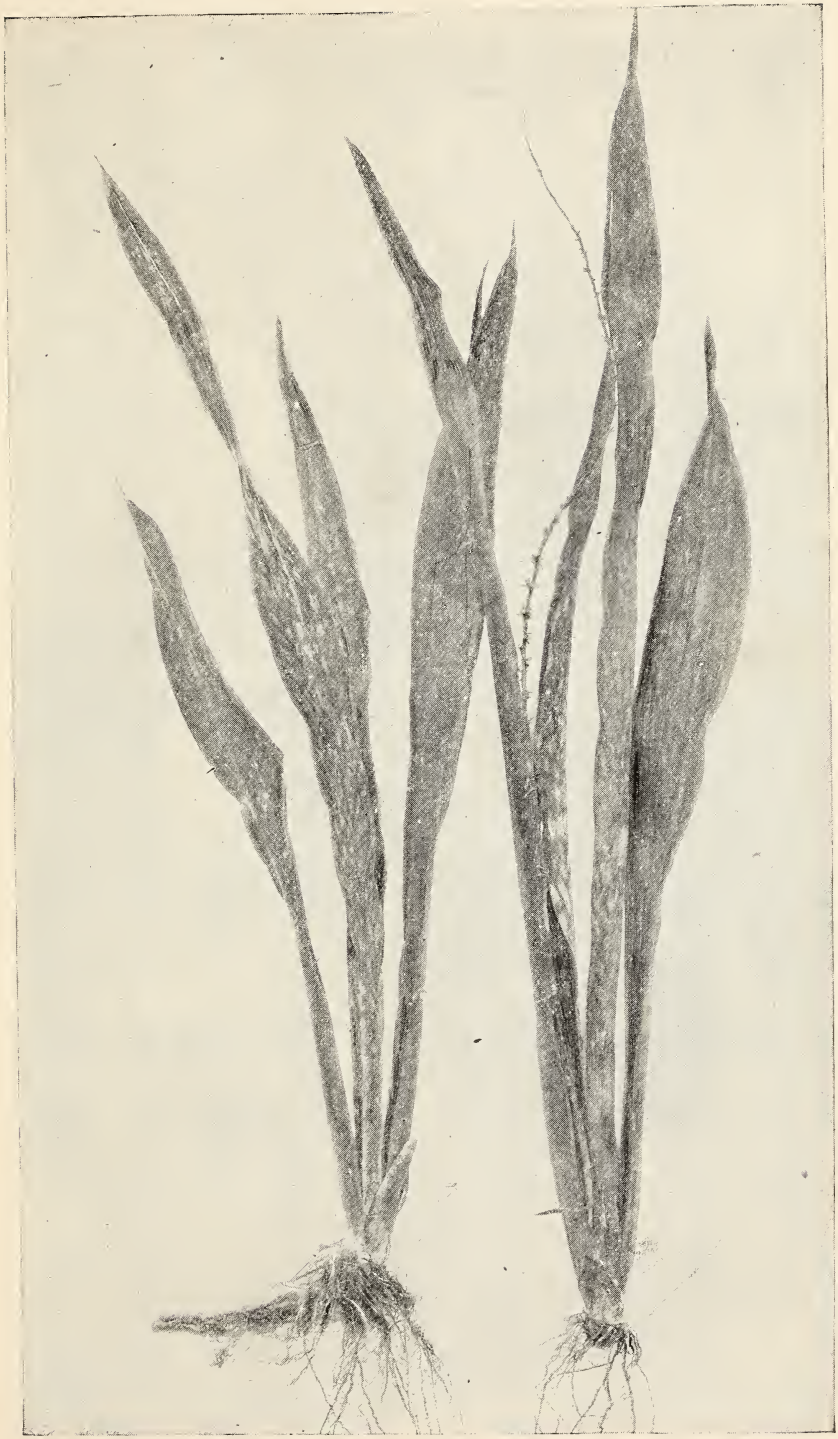
The native method of preparing this fiber is to place the leaves "upon a smooth board, then press one end of the leaf down with one of the great toes, and with a thin bit of hard stick held between the two hands they scrape the leaf from them and very quickly remove every part of the pulp." This is also accomplished by steeping the leaves in water until the pulpy portion decays, when the fiber is washed and cleaned, though in some cases steeping dissolves the fiber. The authorities state that 40 pounds of fresh leaves, 3½ or 4 feet in length, will yield a pound of cleaned fiber, or over 1,600 pounds of cleaned fiber per acre, at a gathering; with a favorable season, two such gatherings may be assured annually.

SANSEVIERIA GUINEENSIS Willd.

This is the best known form of plant producing bowstring hemp, and is one of the oldest species. Specimens of leaves and flowerless plants grown in Florida, and sent by the Department to Dr. Morris of the Kew Gardens, were thought, in the absence of the flowers, to be examples of this species. Dr. Morris's letter is as follows:

ROYAL KEW GARDENS,
June 27, 1892.

DEAR MR. DODGE: We have received the plant of *sansevieria* from Florida. The leaves alone do not enable us to speak quite decidedly in the matter. It is very probable that it is *Sansevieria guineensis*, a broad-leaved form of which comes very near to *Sansevieria longiflora*. The flowers would tell exactly which the species is. These are borne on a long peduncle. In *S. guineensis* the single tubular flowers are only about 1¾ inches long. Sometimes they may be 2 inches long. In *S. longiflora*, on the other hand, the single flowers are much longer and attain a length of about 3 to 4 inches. This is a very good characteristic. There is no possibility of the plant being *Z. zeylanica*. It has no resemblance whatever. Possibly you may be able to



SANSEVIERIA GUINEENSIS.

decide from your own observations which species it is. In any case, if one of your correspondents were to send us a few flowers—not the whole spike—we should be able to say at once what the Florida plant is.

With all good wishes, very sincerely yours,

D. MORRIS.

CHAS. RICHARDS DODGE, Esq.

The following descriptive matter, from the Kew Bulletin for April, 1887, is also reproduced:

S. guineensis was first figured and described, long before the days of Linnæus, in the year 1701, by Commelinus, in his "Horti Medici Amstelodamensis Rariorum Plantarum Descriptio," (tab. 20), under the name of "Aloe guineënsis radice geniculata foliis ex viridi et atro undulatim variegatis." Linnæus classified it under the genus *Aletris*, and so did Jacquin, who figured and carefully described it in 1770, in his Hortus Vindobonensis (vol. I, p. 67, t. 84). It has horny, erect, lanceolate leaves, 3 or 4 feet long, 3 inches broad at the middle, narrowed gradually to an acute apex, not distinctly bordered with red, copiously mottled on both surfaces with broad irregular bands of white. The flowers are in a lax, simple spike, which rises to the same height as the leaves, in clusters of three to six, with a whitish perianth about 2 inches long, of which the six segments are about as long as the cylindrical tube. It is a native of Guinea, from which we have wild specimens gathered by Barter and others. We have it from Central Africa, collected by Schweinfurth and Grant, and Abyssinia by Beccari, and, what is most likely, the same from the Zambesi country, gathered by Sir John Kirk in 1860; the latter accompanied by a sketch made on the spot, when he was botanist to the Livingstone expedition. On the Zambesi *S. guineensis* appears to be called "Konje," and Sir John Kirk speaks of it as "yielding a valuable fiber similar to Manila hemp." It is described as growing in great abundance in many places keeping to the shade of woods. (Plate VII.)

Mr. Horne, director of the Botanic Garden, Pamplemousses, states, in regard to this species, that the plant thrives well in Mauritius in damp marshy places in the lowlands, and that in his opinion it would do as well in the uplands.

Regarding culture and treatment the following information was furnished the Kew authorities by the late director of the botanical department, Jamaica:

In the first instance plants may be put out at 3 feet by 3 feet, which, allowing for roads and paths, would give about 3,000 to the acre. If the soil is kept well broken and moist, these plants by the extension of root suckers, will spread in all directions, so that ultimately the whole ground, with the exception of certain paths, which should be kept permanently opened, will be covered with plants. As regards the time which must elapse between planting out and the first yield of leaves suitable for fiber, there would appear to be a great difference of opinion. Plants which I saw at St. Thomas at three years old were only just ready to be cut; and Baron Eggers, who had planted them and kept them under close observation during the whole of that time, was of opinion that *sansevieria* plants could not be depended upon to yield a crop before three or three and a half years.

My own experience coincides with this, but necessarily much must depend upon the nature of the plants when first put out, the character of the soil, the amount of moisture received, as well as on the system of cultivation pursued.

From actual trial tests in India, where one-third of an acre was cultivated with *Sansevieria zeylanica*, it appears that full-grown leaves of 3 to 3½ feet long (their actual age is not mentioned) yielded about 1 pound of clean fiber for every 40 pounds of fresh leaves—that is, the weight of clean dry fiber was at the rate of 2½ per cent

of the fresh leaves. Dr. Roxburgh calculated that 1 acre would yield 1,613 pounds of clean fiber at a gathering, two of which may be reckoned on yearly "in a good soil and a favorable season, after the plants are of a proper age."

This would be at the rate of 1½ tons of fiber per acre per annum at the end of three or three and a half years, of the gross value (at the rate of £30 per ton) of £45. Whether this return can be depended upon for the West Indies on an extensive area I am unable to say.

THE BOWSTRING HEMP PLANT IN FLORIDA.

During my investigations in Florida in the winter of 1890–'91 I found this plant growing at several points, principally at Key West, on Boca Chica Key, and at Miami on the east coast. Nothing was accomplished, however, further than to demonstrate that it would thrive out of doors in southern Florida, though a brief mention was given to the plant in Bulletin No. 3 on sisal hemp culture, and a reference made to the value of the Florida-grown fiber, several samples having been secured.

This brief mention of the plant brought a letter from Dr. J. V. Harris, of Key West, with interesting statements, and asking for further information, as follows:

MYERS, LEE COUNTY, FLA.,
October 8, 1891.

DEAR SIR: In your exceedingly able and exhaustive report of 1st of May, by the Department of Agriculture, on "Sisal hemp culture in the United States,"* you make a casual mention in a brief paragraph on page 47 of the *Sansevieria zeylanica.* Inclosed is a specimen of the fiber of this plant extracted yesterday from a single leaf without any particular care or labor. This leaf was about 7 months old and yielded 3 per cent of dry fiber to its green weight. This, of course, is a considerably smaller percentage than that yielded by the henequen, but against this can be placed several advantages over the latter plant, which should, I think, entitle the *Sansevieria* to more respectful attention than has heretofore been accorded it. These advantages are:

(1) It yields a crop the first year. Henequen takes three to four years.

(2) Is readily propagated by cuttings from the roots in small pieces.

(3) Has no thorns or sharp edges about it.

(4) Spreads rapidly by sending up plants from its roots in every direction, as I am assured by a friend, who has grown it in his garden for years as an ornamental plant, that if the roots (small pieces covered with "eyes") were set out at a distance of 4 feet every way in suitable ground, he is confident that in two years the whole ground would be occupied by the plants, "for all the world like a bed of lilies in a pond." He says, "There is no getting rid of the stuff."

(5) The facility with which the mature leaves can be gathered. A smart jerk will detach them below the surface of the ground. In fact, a small boy could pluck them with great rapidity, many thousands per diem.

(6) In my opinion (and I have extracted sisal fiber by Van Buren's machine) the "fecula" can be removed from this leaf much more easily than it can be from the much thicker and more fleshy henequen.

(7) The finer texture, whiter color, superior gloss as compared with sisal hemp. I have not compared the tensile strength, but judge it to be at least equal to that of sisal hemp, having regard to its caliber. Possibly it may be stronger.

Like sisal hemp, the leaves can be (and ought to be) gathered as fast as they mature. I find the average weight of the leaf at 3 feet is 4 ounces avoirdupois (of

*Bulletin No. 3: A Report on Sisal Hemp Culture in the United States.

434¼ grains), yielding, as before stated, 3 per cent of dry fiber. To cut the entire plant down, mow it with a scythe, as suggested in your report (*vide* page 47), should only be resorted to when frost is apprehended, because, unless checked by frost, which cuts the plant down to the ground, the leaves and young plants of all sizes are growing mixed in with the mature leaves, and it would obviously be a mistake to shear them all off, since they would be useless for fiber, and, moreover, would cost money to sort out from the larger leaves. Should frost be apprehended, the scythe may perhaps be used with advantage, since the frost could destroy the whole of the leaves anyhow, and some of them (the larger ones) would be saved if cut and housed expeditiously. The frost, such as we get south of latitude 28°, in Florida at any rate, hurts the roots of this plant. My friend before quoted maintains that when the top is cut down by frost the roots push out beneath the surface with extra vigor, and when the cold weather is gone the result is a larger and better bed of leaves than would have occurred had there been no frost. *Quien sabe?* I am not able to say, for although I had known the *sansevieria* for years, it was only upon reading your report that I remembered it to be a fiber plant and took any notice of it. Now, in the face of what I have written it must be clear to your mind that this plant is capable of yielding in one year from the start three or four times the weight of dry fiber per acre that can be obtained from the henequen at the end of three years. Concede this as a fact, and the only remaining question is, "What is the comparative market value of the *sansevieria* fiber as against sisal?" If this question can be answered satisfactorily the Department of Agriculture will undoubtedly be affording an additional *raison d'etre* by making an exhaustive inquiry into this plant, as has been done in the case of sisal.

If you will take the trouble to ascertain and post me on the following points I shall feel grateful to you, as a collaborator in the same field:

(1) To what natural order does the *sansevieria* belong?

(2) Is it a variety of the *Phormium tenax* (New Zealand Flax)?

(3) If so, in what respect does the fiber differ from the New Zealand flax?

(4) Is there any market for the fiber in America or Europe? If so, to what extent?

(5) If so, what is the stuff worth per pound in New York and London?

(6) For what purpose is this fiber applicable?

(7) In what class of soil (wet or dry, rich or poor) does this plant make the best fiber?

(8) What is the best machine for extracting fiber, sisal and sanseviera, respectively, within your knowledge up to this date?

(9.) Any other point which may occur to you.

I am, dear sir, yours, faithfully,

J. V. Harris, M. D.

Chas. Richards Dodge, Esq.,
Special Agent, U. S. Department of Agriculture.

The following reply was sent to Dr. Harris from the office of Fiber Investigations:

Dear Sir: Your letter of October 8 was duly received. First, let me thank you for your kind words in regard to the sisal hemp report as well as for the beautiful sample from the *Sanserieria zeylanica.** I was extremely interested in reading your remarks about this plant, and shall file the matter for future reference, as I shall treat the *sansevieria* in some future fiber bulletin. By the way, do you know whether this plant grows in large or small quantities on any portion of the east coast below Jupiter? We have a Van Buren machine, which will be taken to Biscayne

*At the time this letter was written I had not examined into the identity of the plant, which was thought to be *S. zeylanica.* See letter of Dr. Morris on a previous page.

Bay this winter for the purpose of getting out a quantity of fiber from different species of fiber-producing plants in Florida for experiment. I am very anxious to get several hundred pounds of this fiber if possible for manufacture. So little is known about the fiber in a commercial sense that it will be difficult to answer your questions. You ask, first: To what natural order does the *Sansevieria zeylanica* belong?

(1) *Sansevieria* belongs to the order *Hæmodoraceæ*, the next order following *Bromeliaceæ*, another important group of fiber plants.

(2) It is not a variety of the *Phormium tenax* or New Zealand flax, but belongs to an extensive genus of plants furnishing a fiber known as bowstring hemp.

(3) *Sansevieria* is very much finer than the most of the New Zealand flax which comes to market. I would call it a superior textile.

(4) I can not learn that the fiber has ever been cultivated on a commercial scale in Europe, and certainly not in this country.

(5) There are no quotations as to price that I can at present refer you to.

(6) The fiber has only been employed by natives in Africa and the East for the manufacture of bowstrings and in the manufacture of cordage. If it was grown in this country it would be necessary to create a market for it, which I do not think would be difficult, if its cultivation is established and the supply regular and in sufficient amount to make it advantageous for manufacturers to use it.

(7) The British authorities state that the plant is found in abundance along the coast of Ceylon, the Bay of Bengal, and along the coasts of Japan and China. The *Sansevieria guineensis* is, I think, a native of Africa. It frequents the jungly salt seashores. It is easily propagated, and will thrive in almost any soil, requiring little or no care, and seldom needing to be renewed. I think it would grow admirably in many portions of the southern peninsula of Florida. It has been estimated that 1,600 pounds of clean fiber could be produced on a single acre from one harvest.

(8) It will he impossible to answer your question in regard to the best machine for extracting the fiber. Perhaps the sisal machine might prove too rough for it and a modification would be found necessary. The fiber is very soft, as you know, almost as fine as human hair, and of great strength and tenacity. It is really too good for cordage purposes, and doubtless, if properly introduced to the attention of manufacturers, could be manufactured into some kinds of textile fabrics. It certainly is a good field for experiment, although I would not advise one to go into it extensively, for the purpose of making money out of it, without due experiment at the outset.

Shall be glad to give you any further information you may require, and in turn will ask you to keep the Department posted as to anything you may learn from experience or through conversation with others regarding the plant as it grows in Florida. I remain,

Very truly, yours,

CHAS. RICHARDS DODGE,
Special Agent.

As early as the spring of 1890 several letters were received relating to this plant, one of the first being from Dr. Harris, who spoke highly of the value of the plant for fiber cultivation. Letters were also received from Mr. George H. Bier, of Key West, upon the subject, from which brief extracts are reproduced. Under date of May 12, 1890, he says:

A comparison of the fiber of the "*sansevieria*" you received from Trinidad with that which I sent you might enable you to determine to which of the *Sansevierias* it belongs. I am under the impression that it is the *Sansevieria zeylanica*, judging from the characteristics of the plant we have here. This plant was imported into England from New Zealand in 1735. It was then sent to the English West India Islands for propagation. It found its way to Cuba as an ornamental plant, and in 1866 was brought as an ornamental plant from Cuba to this Key. The people, though

ignorant of its value as a fiber plant, becoming alarmed at its fruitfulness, endeavored to eradicate it. It is superior in many respects to the sisal plant. Its fiber, though not quite so long, is as strong and much finer. Its yield of fiber is greater, although it does not produce as many leaves to the plant, for it grows closer and can be regularly cut every year, each succeeding year producing a larger crop from the same roots. It will produce twice the amount of fiber in the same space of ground as the sisal will do, and where the sisal takes from three to five years to mature or attain its greatest growth this plant will produce in eighteen months a leaf nearly 5 feet long.

Under date of April 14, 1890, he writes again:

I inclose the sample of lily with this. It evidently belongs to the same family as the sisal, as the fiber will show. It is a very vigorous plant, and when once established in the soil is hard to eradicate. It does not seed, but is propagated by means of its roots and leaves, which are cut into small pieces, each piece producing a plant. Its leaves are almost as long as those of the heniquen, each plant never producing more than from three to five leaves. From the center of this plant grows a stalk, about 5 feet high, covered, when flowering, with small lilies for one-half its length. These lilies are 1 inch long and white as mother of pearl, emitting a most delightful perfume. This plant, from the fact that it is spotted with a darker green than the color of the leaf itself, has been given the name in the English West India Islands of the "Spotted lily;" in the island of Cuba the "Cow lily." It adapts itself to any soil, rich or poor, but thrives best in moist ground.

Its fiber, as you will notice, is finer and softer than that of the sisal. It has never been extensively known and recognized as a valuable fiber plant, and millions have been dug up here, and thrown into the garbage carts, as a nuisance.

Through Mr. Bier the Department was able last season to secure almost a ton of leaves of the *sansevieria*, which were shipped to the Department's experimental fiber factory at Biscayne Bay. These were cleaned on the Van Buren machine, and a quantity of superb fiber secured. The leaves varied in length from 2½ feet to 7 feet in length, and it was possible to select over 100 pounds of leaves that averaged 6½ feet, and which gave fiber averaging over 6 feet in length.

Careful estimates based on the quality of *sansevieria* fiber produced in our experiments would fix the yield at about 40 pounds of fiber to the ton of leaves. It has been explained in a former chapter that the machine made too large a percentage of waste. The *sansevieria* waste was not weighed, but it is very safe to state that with only reasonable wastage (cut fiber and fiber drawn out with the pulp) the yield of fiber per ton would come nearer to 50 pounds. Even if this is considerably lower than the yield of sisal hemp, the quick growth of the plant, ease with which it can be harvested, and the higher price of the fiber will probably more than make up for the difference in yield of cleaned fiber.

The material is too good for cordage in the usual acceptance of the term. It is so much finer and better than the cordage fibers, so called, that it would doubtless find a use in the manufacture of fine twines, and I think with proper preparation could be made into a fair spinning fiber, and possibly be employed on some new form of manufacture. The fiber is fine, white, and lustrous, the leaves yielding readily to treatment in the machine in the fresh state. The Department fiber will be further prepared and tested.

Dr. Harris has so much confidence in the value of the bowstring hemp industry that he has planted out many acres of the young plants, propagated by himself, by subdivision of roots and by leaf cuttings. When in Key West in February, 1892, I visited his place, and was able to take photographs showing the manner in which the plant is propagated, and exhibiting the appearance of the rooted cuttings. These are reproduced on Plate IX.

At my request, Dr. Harris, of Key West, Florida, has prepared recently some brief statements relating to his experience with the plant, which are here reproduced:

THE FLORIDA SANSEVIERIA.

This plant, which is commonly known as bowstring hemp, is a native of tropical Africa and the East Indies. The following description from the Dictionary of Gardening, edited by George Nicholson, A. L. S., curator, Royal Botanic Gardens, Kew, I have verified in every particular, viz: Flora, perianth whitish, tinged with greenish brown, 2 inches long, the segments equaling the tube; raceme simple, 1½ feet to 2 feet long, 3 inches broad when expanded; scape 1 foot to 1½ feet high; glaucus, purplish green, with three or four deltoid bracts. September 1, suberect, oblanceolate, cartilaginous, 3 feet to 4 feet high, 2½ inches to 5 inches broad above the middle, whitish, or obscurely reddish on the marhins, white spotted, cuspidate.

The *sansevieria* has long been known as an ornamental plant, but, although one of the most valuable fiber-producing plants in existence, it has never, so far as I am aware, been utilized for commercial purposes. My attention was attracted to it about twenty years ago. Whilst examining it as an ornamental plant, I discovered that it afforded a large amount of fine, strong fiber. I immediately began making experiments with its culture, and was only prevented from going into the cultivation of it for the purpose of introducing it by the want of proper machinery for cleaning it. Since that time, however, many machines have been placed upon the market for cleaning sisal hemp, many of which clean the *sansevieria* in a very perfect manner, notably among these are the Death and Elwood and the Van Buren. I am convinced that the time has arrived to call attention to the valuable properties possessed by this hitherto commonplace plant.

In propagating the plant, for convenience the leaves are cut into sections about 4 inches long, and inserted into boxes of earth to the depth of about 2 inches; the soil must be moderately dry, as too much moisture will cause the leaves to rot; the boxes must be placed in a moderately shady place, and in a few weeks' time will put out numerous fibrous roots, which will soon be followed by suckers. The plant can also readily be propagated by sections of its rhizomes, or roots, which grow without any difficulty. (See Plates VIII and IX.)

Sansevieria requires good rich soil to succeed well, and will, under favorable circumstances, acquire its full growth in about twelve months' time; ordinarily, however, it will not acquire its full growth until some time in the second year.

When once the land is stocked with its growth, it will always, when cut, give a full growth from the roots inside of twelve months, so that it is perfectly safe after the second year to count on a full crop every year, the growth each year becoming denser, and in a few years becoming so thick that it would appear to be impossible to cultivate it, which, however, appears to be needless, as when once fully established it takes entire possession of the soil, entirely eradicating everything else; it does not appear to materially exhaust the soil, as it will grow for a number of years in the same place, and continue to make vigorous growth.

Sansevieria is essentially a tropical plant, but will stand a slight frost. It will grow luxuriantly upon the rich lands south of the latitude of the Caloosahatchee River upon the west coast and of Lake Worth upon the east coast. It will, after reaching maturity,

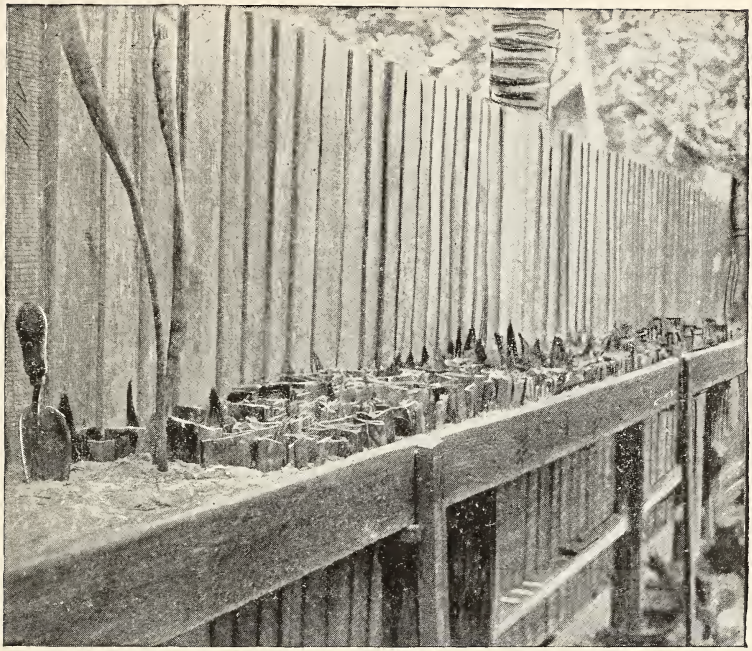


FIG. 1. SANSEVIERIA CUTTINGS IN PROPAGATING BED.

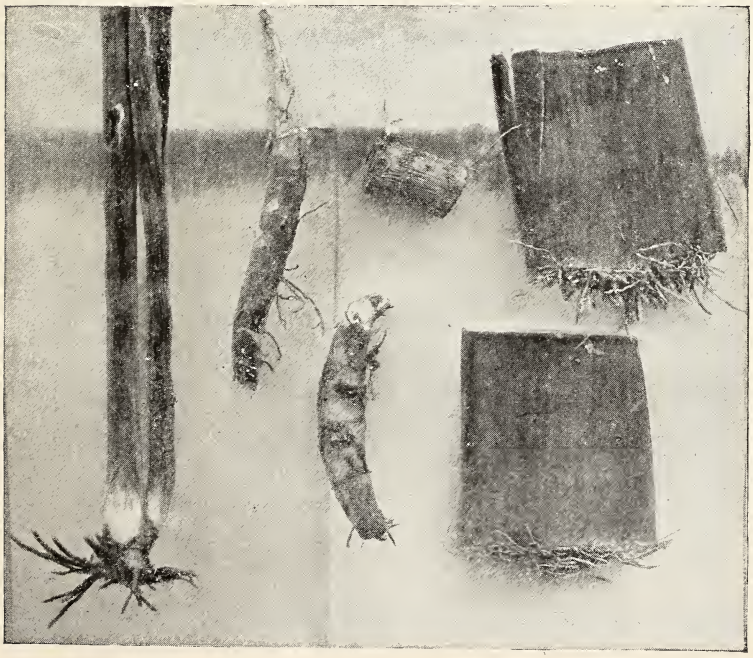


FIG. 2. GROUP OF PARTIALLY GROWN PLANTS.

FIG. 1. SANSEVIERIA PLANTS IN BLOSSOM.

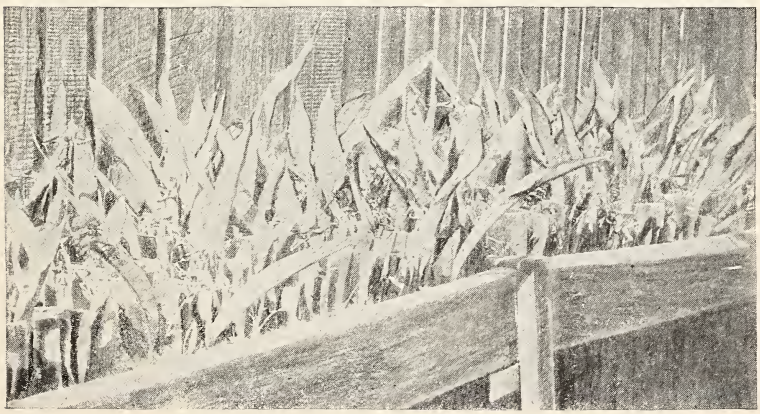


FIG. 2. ADVANCED PLANTS IN PROPAGATING BED.

if not cut, stand without injury for a number of years, the plant at the end of that time affording just as good fiber as in the first or second year of its growth. I am satisfied that a plantation would last over ten years without any necessity for renewing it or for interfering with it in any manner. *Sansevieria* will, after it is well established, afford a crop of 5 tons of clean fiber per acre, worth, upon estimate, about $100 per ton. I selected a few square feet, where the growth was thickest, as an experiment, to show how much a crop was capable of producing, cut and cleaned the leaves, and found it gave at the rate of 13½ tons of clean fiber per acre. I do not, however, believe that the average crop will go over 5 tons per acre, which I consider a fair estimate.

The fiber of the *sansevieria* is capable of being manufactured into anything from the heaviest cordage to the finest fabric for ladies' dress goods. I conversed with an English gentleman, who told me that he had seen a few yards of cloth manufactured from the fiber, as an experiment, in England, and that it rivaled the famous pineapple silk in beauty and fineness of texture. When we consider the great ease with which the plant is propagated, the rapidity of its growth, and its enormous yield of fiber, together with the various uses to which it may be applied, we can not fail to be impressed with its importance. Flax manufacturers are reported as saying that if they can get the fiber at $100 per ton they can run flax out of the markets of the world. Another great recommendation of the plant is, that it has absolutely no enemies among the insect tribe, and is not injured by rains or storms, nor by drought; when once fully established, a calculation can be safely made upon an average crop. The expense of cultivating the crop when established will, after the second year, be almost nothing, as the crop will take care of itself. About the greatest expense will be the cutting and hauling the crop to the machine for cleaning it.

I have been experimenting with the various fiber plants suitable to the climate of south Florida for more than twenty years, and know of no other fiber plant which I can conscientiously recommend for cultivation, with the view of making money. I do believe, however, that any person with any knowledge of farming, who has the necessary capital to back him, has a perfectly safe investment—certainly much safer than most investments made every day by the business world and considered as perfectly fair risks.

J. V. Harris, M. D.

Regarding the yield of fiber per acre, I can not accept Dr. Harris's statements as conclusive, as his estimates are based on the product of "a few feet square." In all experimental work such estimates are misleading, as has been demonstrated over and over again. There is no doubt, however, growing as rankly as this plant is known to grow, that the yield of fiber per acre will be very large. It is to be hoped that after Dr. Harris has harvested his first crop of leaves from the plantation recently set out, and the fiber has been reduced, that he will be able to give the actual yield of fiber per acre, with much other interesting data.

This closes the account of my work in southern Florida. Before leaving this section, however, through the courtesy of Mrs. Tuttle, of Fort Dallas, Miami, who furnished transportation and guide, I was enabled to enter the Everglades of Florida, and secure photographs of this wonderful inland sea. Although no fiber plants exist, to my knowledge, in this undeveloped district, the brief visit was interesting and profitable.

NEW ZEALAND FLAX.

Phormium tenax.

This plant, belonging to the same family as the Sansevierias and Yuccas, is a native of New Zealand, but was early introduced into Australia, and is now found in many portions of the globe. It has been naturalized in France, Algiers, the Azores, St. Helena, the Scilly Isles, and other similar localities. Capt. Cook first brought the fiber to the notice of Europeans, he having found it in common use by the natives of New Zealand; he speaks of it as "a grass plant like flags, the nature of flax or hemp, but superior in quality to either." (Plate x.) It grows on the north and south coasts of New Zealand, and is cultivated in Australia, though to no great extent. It was brought to Ireland by Underwood in 1798, and has been grown successfully in the open ground in gardens in Waterford, Cork, Limerick, Dublin, and Wicklow counties. It also flourishes on the west coast of Scotland, though the winters have occasionally been too severe for it. The leaves of the plant in Ireland grow to 5, 6, 7, and 8 feet high, and it is propagated by offsets which are not removed until the parent root is 4 years old. It thrives in California and could be successfully introduced into many other localities in the United States where the climate is not too cold for it, and that are not too remote from the sea.

The several varieties grown in New Zealand are: *Harakeke*, the common variety of the lowlands; *Paritanewha*, the yellow variety of the high regions or hills, and *Tihore*, a superior quality. It is also called *Koradi* or *Korere* by the natives, while the fiber is known by the name *Muka:*

At the close of the Philadelphia Exhibition of 1876 a large and valuable collection of the raw and manufactured products of New Zealand flax was presented by the representatives of the colonial government to the U. S. Department of Agriculture. In this collection the many uses of the fiber were fully illustrated, both hand and machine cleaned fiber having been shown. Specimens of cordage naturally come first in an enumeration of the list. Among these were 3-inch cables and ropes of all sizes, horse halters, small cordage, lead lines, fish lines (for sea fishing), and twine of the finest finish. The series of mattings illustrated the many ways that the fiber could be used in the household, as door mats, parlor and bedroom mats (in colors), and hearth rugs, while the finer kinds of fiber were made into cloth not unlike linen duck, into satchels, table mats, shoes (a kind of sandal), sacks, etc. Floor matting, carriage and railway mats were exhibited in variety,

NEW ZEALAND FLAX.

plain and in colors. The nets, of which there were many samples, could hardly be told from linen, both in color and finish. Some of the museum samples seemed to the touch as soft as the finest flax; I have no doubt many other beautiful fabrics could be made finer than were shown.

Murray, in a pamphlet regarding the plant, speaks of bedticking being made from it, and states that he has seen "fine fabrics of various kinds, affording demonstrative evidence that its fiber is susceptible of being woven into tissues of the most delicate description."

At that time much of the fiber was manufactured at home because the English rope-makers would not pay a price proportionate to that given for Manila hemp, and it was found to pay better to export the cordage rather then the baled fiber. The trade, however, has changed greatly in the past decade.

While considerable New Zealand flax came to this country in the past, Manila and sisal finally superceded it, but toward the close of the last decade, the demand for binding-twine fiber brought it again to our market. The imports of this fiber into the United States, for the fiscal year ending June 30, 1889, were 51 tons, worth $6,971. Referring to the circulars of Crocker & Co., fiber brokers, New York City, for three years, we find that 64,730 bales were imported in 1890; 76,000 bales in 1891, and 42,391 bales in the year just passed. This shows a demand for the fiber in the United States, without which, of course, home culture would be useless.

The following extract from the Wellington Post, illustrates the condition of the industry in New Zealand three years ago, at the time the demand for binding-twine fiber had begun to attract attention:

The demand for twine for binding purposes is now enormous, and every year it is likely to increase. Already it has reached proportions which would absorb far more flax than New Zealand is likely to be able to procure for some years to come, and no other fiber is at all likely to enter so far into competition with it as to materially reduce the present price, which enables the twine to be manufactured and sold at a price well within the reach of the agriculturists who use it. It is said that other and profitable uses have also been found for the New Zealand fiber, and in all probability the list of purposes for which it can be used with advantage will be constantly added to. The Government have, we believe, instructed the agent-general to obtain information as to what these purposes now are, and as to the probability of the demand being maintained. His report will be most anxiously awaited and will not, it is to be hoped, be long delayed. If it is favorable, there will be an immense impetus given to the flax trade, and the cultivation of flax will become an established agricultural industry. The natural supply will certainly not continue to be depended on. The area of uncultivated land now growing flax is comparatively limited. For years past wholesale destruction has been going on. On one large estate in this district alone many thousands of pounds have within the last five or six years been spent in destroying a natural growth, which if it were now in existence would be worth a vast sum of money. So it has been elsewhere, until good flax land is now very limited in area, and far from being adequate to supply the demand likely soon to arise for it. There are, however, large areas of land where flax could be grown under present conditions far more profitably than any other

crop. There are also large areas of swamp, which could at a trifling expense be drained, not perhaps sufficiently for ordinary agricultural purposes, but quite enough to produce rich and heavy crops of flax. It can not be doubted that in many parts of the colonies attention will soon be devoted to the cultivation of the once despised plant, and we would suggest to all owners of flax land that they would be wise to make provisions for the collection of seed next season on a large scale. The flax does not, we believe, flower annually. At least it is only at intervals of about three years that extensive flowering seems to take place, and unless provision is made in time for the collection of seed, it is possible that when the demand arises there may be great difficulty in finding a supply. Cultivation greatly improves the *Phormium tenax*, and in old days the natives used to cultivate the plant in the neighborhood of their settlements and make all their finest mats and other articles from the fiber of this cultivated flax, which in length, strength, and quality was greatly superior to most of the natural-grown wild flax.

It may be interesting to mention that in the five years from 1867 to 1871, inclusive, as gleaned from the official handbook of New Zealand, flax fiber was exported to the value of £280,827, or nearly $1,500,000. The average for the five years is £56,165, the highest exportation being in 1870, when the sum of £132,578 was realized from the industry by export alone. In the province of Westland the flax grows luxuriantly on the banks of rivers and in swamps, and if properly cultivated, and by stripping only the outer leaves of the plant twice a year, it is claimed that each acre of land would yield more than 2 tons of marketable flax. In many portions of New Zealand the plant grows wild, and the right to cut the leaves from the waste lands may be procured from the Government at a very low cost.

In December, 1890, Alex. M. Tovey, of Ashland, Colo., wrote to the Department, as follows:

SIR: I beg to respectfully call your attention to a plant which I believe might be introduced into this country, and which, if successfully acclimatized, would be an immense addition to our stock of fiber-yielding plants. I allude to the New Zealand flax (*Phormium tenax*). I am a native of New Zealand, of English descent, and came to the States in 1886. The New Zealand flax thrives best in low, swampy ground, but succeeds in any good moist soil; it is a perennial, evergreen plant, with tuberous roots, resembling a dahlia. It produces abundance of seed and can also be propagated by division of the roots. Once established in a favorable situation, it spreads of its own accord. The climate of all the Southern States ought to be exactly suited to it, and it might be employed to utilize the great swamps of Florida without first draining them. Cutting a crop off it does not kill it, and it comes up again immediately. Information about the method of preparing the fiber for market could be obtained from the United States consuls in New Zealand.

Respectfully,

ALEX. M. TOVEY.

Hon. J. M. RUSK,
Secretary of Agriculture.

About this time the Department received (through the State Department) a quantity of seed sufficient for experimental purposes, which was distributed in Florida and other Southern States. The seed must have been injured, however, as it failed to germinate, even in the conservatories of the Department. Should the attempt be again made, plants will be distributed instead of seeds, as the supply can easily be secured from the Pacific coast, and it is claimed that seedlings do not inherit the characteristics of the plants from which the seed is derived. Besides, the early growth of plants from seeds is very slow.

The plant has been grown in California for several years, and thrives in many localities. I have endeavored to learn the history of its introduction, but am unable to make positive statements at this writing. Prof. Hilgard, the director at the State agricultural experiment station at Berkeley, has grown it at the station for some time, sending plants to substations and to farmers to be grown for its leaves that are used instead of rope for tying vines. He informs me that—

The area on which it can be successfully grown is very large, as it seems to require much less water than is currently supposed. A tall variety is common as an ornamental plant in the gardens about the bay; the one we have been growing and distributing for years is of lower habit, but its fiber seems to be stronger and finer. Once started, it will do without irrigation almost anywhere in our coast range where frosts are not too heavy. In the Great Valley it seems to be limited to over 8 or 10 inches of rainfall, unless irrigated, but with irrigation it will grow fairly anywhere within the valley, and up to 2,000 feet in the Sierra foothills.

Small lots of leaves received by the Department from California were cleaned by Mr. W. T. Forbes, and a strong, valuable fiber was obtained from them. An effort was also made to secure leaves in sufficient quantity to obtain enough fiber for a practical test, but as the leaves do not stand transportation, and would necessarily be several weeks on the way, the attempt was abandoned.

SOIL AND CULTURE.

It is said that while the plant will grow in almost any soil, the quality of the fiber is dependent largely upon the degree that the soil is favorable. For example, in New Zealand the *Harakeke* or swamp variety thrives everywhere, but is rank in growth and the fiber coarse. The finer kinds, on the contrary, are grown on the uplands, where the soil is dry or at least free from excess of moisture.

The following are the requisites for successful culture:

The plant luxuriates in rich, moist, well-drained ground, and reaches its greatest size on the banks of running streams where the roots are abundantly nourished by water that never stagnates around them. A rich, dry, but not deep, clay soil, with a yellow clay subsoil, favored with plenty of light and air, but sheltered from the wind, is very suitable. Heavy crops are also raised on high-lying volcanic soil, and well-drained swamps give large returns. Stagnant marshes are prejudicial, but when drained and sweetened, without being made too dry, the plant assumes a vigorous growth.

Where drainage is necessary, it should be effected by open trenches, dug sufficiently deep to keep the water about 12 inches below the surface. If the land becomes very dry in summer, the drains may be temporarily stopped, so as to irrigate the soil, for, though the plant will not tolerate stagnant water, nothing conduces more to its rapid growth than occasional inundation. Reclaimed swamp should be ploughed in winter or spring and left to dry till autumn, then be again plowed, and planted, say, in March or April, or when the autumn rains fall, the earlier the better, as the plants make root during the winter and are ready for vigorous growth by the spring.

Propagation is most readily affected by division of the root, and one large plant will give from twenty to fifty roots suitable for planting. In planting the roots may be set singly, or two and three may be placed together, particularly where close planting is not followed. As to distances apart, 6 feet in the rows and between plants is considered a better distance, as the plants shelter each other, the leaves grow in better form and produce finer fiber. An acre of ground set out on the first plan will contain about 1,000 plants; the closer plan will require about a third more plants to the acre.

The plant forms large tufts, and has sword-shaped leaves, growing in opposite rows and clasping each other at the base. One variety forms leaves 5 and 6 feet long, while another is not more than half the length. Mr. Salesbury, of the botanic garden, Chelsea, found that plants 3 years old will produce on an average thirty-six leaves, besides a number of offsets. Six leaves have produced 1 ounce of dry available fiber after having been scutched and cleaned, at which rate an acre of land cropped with these plants, growing 3 feet apart, would yield more than 600 pounds of dressed fiber. The leaves being cut in the autumn, others spring up anew the following summer.

The yield of New Zealand, flax according to Spon's Encyclopedia, is as follows:

Production.—On the best land an acre may contain 2,000 bunches of the plant, or 100,000 leaves. These leaves, after cutting off the gummy and useless butts and drying in the sun, weigh about five to the pound, so that an acre may give nearly 10 tons of sun-dried leaves. When the outer leaves only are taken the quantity will be reduced to 4 tons. Assuming a yield of 15 per cent of clean fiber upon these 4 tons, the return should be 12 cwt. an acre, to which may be added about 8 cwt. of tow. The weight of green leaf required to produce 1 ton of fiber is stated by different authorities as follows: 5½ tons, 5½ tons, 6 tons, 6½ tons, 6¾ tons, 7 tons, 7 to 8 tons. To obtain 2,000 bunches to the acre, however, the planting must be very close.

EXTRACTION OF THE FIBER.

It will not be necessary, in the limits of the present report, to go into the subject of cleaning the fiber further than to make a few general statements.

By the hand method, as practiced by the natives, the principal operation is scraping and then separating the fibers with the thumb nail, after which combs are employed for a more minute separation. The fibers are subsequently dried in the sun, and are perfectly white, some short and strong, others fine and silky. According to the reports published by the New Zealand commissioner at the Exhibition of 1876, the Maoris (or natives) only use a portion of the fiber upon one side of the leaf, the leaves being selected with great care. They scrape the leaf with a mussel shell or piece of hoop iron, on the thigh, after which it is soaked in water and then dried. Their finest samples are obtained from particular varieties of the plant, only the youngest and best leaves being used, and careful attention being paid to the manipulation. This

native-dressed fiber, however, constituted but a small portion of the fiber actually prepared on the island at the height of the industry, as large manufactories were erected, where the fiber was stripped by machinery. Two modes of dressing the fiber are practiced, known as the "cold" and the "warm" water dressing. The leaves of the flax are fed to a machine, called a stripper, at the rate of 100 to 120 feet per minute. The drums of stripping machines are driven at the rate of 1,000 to 2,000 revolutions per minute, their diameter being from 14 to 20 inches. After passing through the strippers, the partially-cleaned fiber is hand-washed in bundles of about twenty leaves; these bundles are suspended in water, and are allowed to soak for about two hours; the fiber is then spread out on the bleaching ground for a time, which varies according to the weather, and then hung on lines to dry. It is then either scutched or hackled, or both, packed in bales, and pressed for shipment. When the stripper is in good order, and the fiber has been fairly cleaned, the loss in scutching amounts to from 3 to 5 cwt. per ton, and in hackling from 2 to 3 cwt. In the warm-water dressing the same operations are gone through with, with the exception that the fiber is washed and placed to soak from six to twenty-four hours in tanks filled with warm, water which is either kept heated by means of fire or a steam pipe.

New Zealand flax fiber is almost white in color, flexible, soft, and of a silky luster. The bundles of fibers form filaments of unequal size which are easily separated by friction. It has considerable elasticity, but readily cuts with the nail. Microscopically examined, according to Vetillart, the fibers are remarkable for their slight adherence. The individual fibers seem very regular, having a uniform thickness, and the surface is smooth; they are stiff, straight, and very fine, and the central cavity is very apparent.

As to tenacity, Royle gives the breaking point of New Zealand flax, compared with flax and hemp, as 23.7 to 11.75 and 16.75, respectively. In the official handbook of New Zealand it is stated that "during a severe gale at Auckland it was found that flax rope, when subjected to the same strain as Manila hemp (*Musa textilis*), remained unbroken while the latter gave way."

REPORT ON NEW ZEALAND FLAX BY CONSUL CONNOLLY.

In the United States Consular Report for May, 1890, appears a report from John D. Connolly, the consul at Auckland, which accompanied the New Zealand flax seed distributed by the Department. It contains interesting statements regarding the flax industry of New Zealand at the present day, with suggestions regarding the cultivation of the plant in our own country, that are worthy of being reproduced. The report is as follows:

The purchase of New Zealand flax by the United States has largely exceeded that of any other country during 1889. I have therefore deemed it my duty, in view of

the immense commercial value to which this exclusively New Zealand product has attained during the brief space of one year, to acquaint the Department of its growing importance as an article of export to the United States and other countries.

I am convinced that if handled with intelligence and care the *Phormium tenax* plant can be successfully and advantageously cultivated in the United States. The climate and swamps of many of the Southern States are peculiarly adapted to the propagation of New Zealand flax. The climate of California is also suitable for the cultivation of the flaxplant. *Phormium tenax* is indigenous to New Zealand, Norfolk Island, Chatham Islands, and other smaller islands situate between 30° and 50° south latitude. The most robust and finest plants are found between 35° and 41°. It grows on any soil from the sea level to an altitude of 2,000 feet; but it is found in the greatest luxuriousness in swamps and on the banks of rivers and lakes. The leaf or blade often attains the length of 15 feet and from 2½ to 3 inches in width. Before the Maoris adopted European clothing considerable care was bestowed on the selection and cultivation of the plant by them. They dressed it by a process of steeping and scraping and hand scutching, which produced a fiber almost as fine and glossy as floss silk, of which they wove their mats and "kakahu" (clothing). But of late years, since the Maoris have learned they can procure their clothing from their European neighbors with much less effort than they could manufacture it with the primitive methods at their command, no steps have been taken for the conservation of the better varieties.

The seed accompanying this paper is of a superior quality, was procured for me by a Mr. Jeffs, who has lived in this colony for nearly forty years, and who is thoroughly familiar with the flax industry of New Zealand. It may be proper to state that Mr. C. K. Jeffs, of Onehunga, New Zealand, is willing to furnish seeds and practical information to any one desiring to engage in the cultivation of *Phromium tenax* in America. The seed above referred to was obtained from an old Maori cultivation, and is highly prized by those natives who still devote their attention to the weaving of mats and other useful ornaments manufactured from the fiber.

The flax used for export is usually cut from the swamps, marshes, and river banks. It is in its wild, uncultivated state, and it is cut down and run through the machines without any attempt at selection. This is much to be regretted, as with a little care, even with the crude machinery in use at present, a much finer article could be produced.

The persons usually employed to cut the green flax are paid by the ton. It is therefore to their interest to get as much weight as possible, and, in consequence, they cut as close to the ground as they can. The lower end of the leaf is thick and fleshy, containing a large amount of gum and vegetable matter, and weighs heavily as compared with upper portions of the leaf; besides, the fiber obtained from the butt end is very much inferior in texture to that procured from the body and top of the blade.

To imperfect machinery and carelessness in the selection of green plants may be ascribed the apparent coarseness and the inferiority so often complained of in the flax exported from certain portions of New Zealand. But with improved flax-dressing machinery and proper care exercised in the selection of the raw material a very superior article can be produced. The *Phormium tenax* fiber is susceptible of a much higher degree of preparation than has been bestowed upon it up to the present. This, however, is not altogether the fault of those who are engaged in its manufacture; it is for want of the necessary machinery. The hand-dressed article prepared by the natives is as fine as silk as compared with the modern machine-dressed flax of to-day. This only demonstrates the fact that the fiber may be reduced to a much finer quality, and all that is necessary to do this is an improved machine. If New Zealanders can not produce the requisite machinery I trust the inventive genius of America will come to the rescue. There is certainly a splendid opportunity and a fortune for any man who will invent a machine that will successfully and economically reduce New Zealand flax to a proper degree of fineness.

Many who profess to thoroughly understand the toughness and durability of the *Phormium tenax* believe that if it could be properly reduced it would enter largely and successfully into the manufacture of valuable textile fabrics.

The quantity of seed I have forwarded to the Department, I am reliably informed, is nearly sufficient for an acre of ground, and with ordinary care in its cultivation will be in a proper condition to send to the flax-mill at the expiration of three years from the date it is put in the ground. It takes about 1,200 healthy plants to the acre, and, to use Mr. Jeff's expressive language, "in three or four years it would be so close you would hardly be able to ride a horse through it."

For additional information on the subject reference to my report to the Department, dated December 31, 1889, may be of some value.

While this report is going through the press I learn that a considerable quantity of New Zealand flax fiber has been used in the construction of the "staff," or outer covering of the principal World's Fair buildings at Chicago. It is used to toughen and hold together the plaster and other materials which, when combined, form this building material.

BEAR-GRASS, OR YUCCA FIBER.

Yucca filamentosa, et div. sp.

The principal species of Yucca growing in the United States are known to botanists as *Yucca aloifolia*, *Y. angustifolia*, *Y. baccata*, *Y. filamentosa*, *Y. gloriosa*, etc. Among the many common names may be mentioned Adam's needle Spanish bayonet, Aloe-leaved Adam's needle, bear-grass, dwarf palmetto, etc. The name bear-grass, however, should be given distinctively to the *Y. filamentosa*, the fiber of which has been variously called bear-grass, silk grass, Eve's thread, etc. *Y. gloriosa*, also called *Petre* by the Mexican-Spaniards, according to Nuttall, "is used for cordage, ropes, etc., as well as for packing cloth, and is extremely durable." Elliott, in his Botany of South Carolina, speaks of it as one of the strongest fibers of the vegetable kingdom. Bear-grass is used all over the South in a rude way as a "tie-plant," the twisted leaves being employed for hanging hams, and in other similar uses. There are no records to show that these fibers have ever been employed other than experimentally in this country, if we except the limited use made of the fiber by Indians and Mexicans of Arizona or Sonora, in the rude manufacture of cordage. There is one sample of rope in the Museum from New Mexico. It is fully half an inch in diameter, very rudely made, the fiber coarse and harsh, but of great strength. This sample, as well as fine specimens of the fiber from which it was prepared, was derived from *Y. baccata.*

The species of Yucca are found in all portions of the United States, and flourish on the poorest soils. Probably no other leaf fiber has so often been the subject of correspondence with the Department, and but for the short length of the fiber it would doubtless have come into commercial use long ago. While being natives of the warmer portions of the United States, the species abounds in Europe, Africa, India, and Australia. One species finds its way into our gardens even in more northern sections of the country, and is conspicuous in the blooming season for its large, white, lily-like flowers, as well as for its long, sword-shaped leaves, each terminating in a sharp point.

In Bernardin's list I find *Yucca filamentosa* is also called henequen (*Agave rigida*, etc.), from which it may be inferred that the Yucca has been regarded to a certain extent a commercial fiber, probably exported with the sisal fiber under the one name henequen, just as *Cannabis*

sativa is sometimes exported from India with *Crotalaria juncea* under the one name of "Sunn."

The French authority, Vetillart, in speaking of Yucca, makes this statement: It seems certain that in the cargoes of *Pita* which arrive at the markets of Europe there is found a proportion, more or less considerable, of Yucca fiber. It is difficult to distinguish the one from the other, and it is adaptable to the same uses. In this case it is exported with fiber of *Agave americana.*

FIG. 12.—Yucca aloifolia at Jupiter, Fla.

Yucca fiber possesses a moderate tenacity, but is somewhat brittle, and can not be made to lose its harshness. If it could be manufactured cheaply, however, it would make a good binding-twine fiber, and experiments in this direction are now in progress by the Department. The filaments of Yucca are described as white in color, brilliant, and stiff, composed of irregular bundles, the most of which are large. By rubbing briskly between the fingers the bundles break up into finer fibers,

but always preserving a great deal of stiffness. The walls are usually thick, and the central cavity very apparent. The ends grow slender regularly, and are rounded at the extremity.

From the Australian collections (Exhibition of 1876) the Department secured examples of *Y. aloifolia*, the Aloe-leaved Adam's Needle, prepared by Dr. Guilfoyle, who stated that though a native of South America, it succeeds admirably in Victoria, and is of moderately quick growth. (Fig. 12.) He also calls it the Dagger plant. Dr. Guilfoyle sent a specimen of the *Y. filamentosa* also, called the "Thready Adam's Needle," which thrives in Australia, where its leaves are found rich in fiber and of good quality.

Early in the present fiber investigations of the Department a large number of letters on the subject of Yucca were received from Southern and Western States, in reply to a general circular sent out by the Department to its statistical correspondents. One of these is reproduced as showing how the plant is regarded by agriculturists. It is from Mr. E. N. Robeson, Tar Heel, N. C., and is as follows:

> Bear grass grows on our poorest sand hills and is considered quite a pest when the land on which it is found is cultivated for any of our crops. It is hard to destroy. Is propagated either by seed or the roots. The roots when cut will sprout and put up new plants, so an attempt to destroy it often increases the growth and causes it to spread. It is evidently benefited by the effert to destroy it in cultivating other crops. It is used by farmers for strings to hang up bacon, and sometimes for other purposes. It is prepared for this use by scalding in hot water. It is very strong and durable and has been used to make cords, and would be used more if some process could be invented to convert it into rope without the aid of machinery, and cheap enough to be in reach of the ordinary farmer.

If it could be grown over an area sufficiently large to supply the amount needed to cover or wrap up our cotton I think it could be used to make a better wrapping than jute. In our efforts to find a substitute for jute I really believe bear grass should be given a trial.

On the authority of cordage manufacturers, who inform me that fiber under 2½ feet in length could not be advantageously used, I have made the statement that the short length of Yucca fiber has prevented it from becoming a commercial product. Mr. J. C. Todd, of New York City, whose name has long been connected with fiber manufacture and the construction of fiber machinery, informs me that a shorter fiber than 2½ feet can be worked, though possibly not upon all forms of cordage machinery. He is much interested in bear-grass, and is coöperating with the Department in the present experiment. The Department has secured a large quantity of leaves from Georgia. The first lot has already been cleaned by Mr. Todd, on the machine described on page 26, and when a sufficient supply of fiber has been produced the material will be manufactured into binding-twine and possibly into other coarse manufactures. As the experiments will run into another year, however, the results must be given to the public in a later

publication. The question of the cost of producing the fiber, as well as of gathering the leaves, is also a subject of present investigation.

Regarding the extent of supply of leaves, it would seem to be almost inexhaustible, as large wild tracts of the plants are found in many of the Southern and Western States, and special cultivation would not be necessary, as the leaves are reproduced rapidly after cutting. The Georgia leaves cleaned by Mr. Todd in December, 1892, were received from Mr. John T. Haunson, Longview, Ga., who writes that they have grown since July of that year.

The result of a number of tests with this fiber, twisted by hand to the size of binding-twine, showed a breakage strain varying from 45 to 55 pounds, which is about half the strength of Kentucky hemp. This is not given out as an authoritative test, as such a trial should be made with machine-manufactured twine to be comparative. However, it will doubtless be found inferior in strength to any of the commercial cordage fibers now in use, and quite inferior to manila and common hemp.

The *Yucca filamentosa* was not found by me in southern Florida, though *A. aloifolia* abounds wherever the false sisal is found. Sometimes the tracts of this species extend for miles along the coast in broken patches or clumps, the masses of bud leaves often rearing aloft their spiked crowns a dozen feet from the ground. The leaves of this species are too difficult to secure, and too short when secured to ever prove valuable for fiber production. It produces a fair quality of fiber, however. About 40 pounds of leaves cut on Sands Key and passed through the machine gave a product of about 1 pound of dry fiber, not over 12 to 15 inches long, or the equivalent of 56 pounds to the ton of leaves. This would not pay commercially, as the yield is low for an inferior fiber. Pineapple fiber with the same yield would be three or four times as valuable, while the leaves could be gathered for one-fourth the cost.