HAWAII AGRICULTURAL EXPERIMENT STATION, HONOLULU.

J. G. SMITH, SPECIAL AGENT IN CHARGE.

BULLETIN No. 4.

The Cultivation of Sisal
IN HAWAII,

BY

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UNDER THE SUPERVISION OF

OFFICE OF EXPERIMENT STATIONS

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HAWAII AGRICULTURAL EXPERIMENT STAT ION, HONOLULU.

[Under the supervision of A. C. TRUE, Director of the Office of Experiment Stations, United States Department of Agriculture.]

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LETTER OF TRANSMITTAL.

HONOLULU, HAWAII, *March* 5, 1903.

DEAR SIR: I have the honor to transmit herewith for publication, as Bulletin No. 4 of this station, a paper entitled "The Cultivation of Sisal in Hawaii," prepared under my direction by Frank E. Conter, Assistant. Very respectfully,

JARED G. SMITH,
Special Agent in Charge of the Hawaii Agricultural Experiment Station.

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INTRODUCTION.

The natural conditions which seem to be requisite for the profitable development of the sisal plant are such that the areas in which it may be cultivated commercially are comparatively limited. The outlook for the future of this industry in Hawaii is therefore very good.

The growing demand for sisal fiber is the result of the more general use of corn binders in the United States, and the steadily increasing use of grain binders throughout the world, resulting in greater demand for (sisal hemp) binder twine. In 1902 many twine mills were taxed to their utmost to supply the demand.

In 1900 the United States imported 75,241 tons of sisal hemp from Mexico, and 1,680 tons from other countries, a total of 76,921 tons, valued at $11,782,263. Raw sisal fiber was quoted in the New York market in April, 1902, at 10 1-4 cents per pound, and in August, 1902, at 10 cents per pound. Hawaiian grown sisal fiber sold in San Francisco, in February, 1903, for 8 cents per pound, f. o. b. Honolulu.

HISTORY.

Many species of *Agave,* to which sisal belongs, are natives of Mexico; some furnish fiber; some yield soap; some pulque, and from others mescal is distilled. The common name of all is "maguey." So seldom are the flowers of the agaves seen in the temperate zone, that they have long been called "century plants."

Sisal hemp, or henequen, is the name given to the cleaned and dried fiber of the cultivated varieties of *Agave rigida.* This product doubtless owes its name (sisal) to its having been first exported through the port of Sisal, in Yucatan. The sisal industry was probably started in Yucatan by the Toltecs, who emigrated to Campeachy from Central Mexico about A. D. 1060. *Agave rigida,* the maguey, sosquil or jenequin, called "chelem" by the aboriginals, has been extensively cultivated in Yucatan on account of its fiber for probably several centuries.

In 1832, Dr. Henry Perrine, U. S. Consul at Campeachy, applied the name *Agave sisalana* to two varieties called yashqui (greenish) and sacqui (whitish).[1]

Agave rigida elongata is the botanical name now given to the sacqui, and *Agave rigida sisalana* to the yashqui.

Dr. Engelmann's varietal name, *longifolia,*[2] is synonymous with the older varietal name, *elongata.*

BOTANICAL DESCRIPTION.

The trunk of the chelem, the wild plant of Yucatan (*A. rigida*), is 1 to 2 feet high, leaves 1 1-2 to 2 feet long and as many inches wide, contracted above the broader base and widest about the middle; lateral teeth 3-4 to 1 inch apart, mostly straight, from a broad base 1 to 2 lines long, rather unequal, with smaller ones interspersed; dark brown terminal spine 1 inch long, 1 3-4 lines in diameter, straight or often somewhat twisted; terete, scooped out at the base, but not channelled, dark red-brown, a dark corneous margin extending down the leaf edge for several inches and bearing the uppermost teeth. Scape 12 to 15 feet high; flowers pale, yellowish-green.

This may be termed the wild plant from which the following cultivated forms have arisen:

Agave rigida elongata, extensively cultivated in Yucatan, has a trunk, and is principally distinguished by its much longer spiny

[1] Rep. No. 564, 25th Congress, 2d Session, Ho. of Reps., Feb. 17, 1838.
[2] St. Louis Acad. Sci., Vol. III, 1875.

leaves, 4 to 5 1-2 feet long, 3 1-2 to 4 inches wide; flowers very similar to those of the wild plant, but filaments greenish.

Agave rigida sisalana has a short trunk; leaves pale green, but not glaucous, 4 to 6 feet long and 4 to 5 1-2 inches wide, generally smooth-edged, but here and there bearing a few unequal, sometimes very stout and sharp, teeth; terminal spine stout, often twisted, purplish-black; scape 20 to 25 feet high, panicle 8 feet long and half as wide; from 32 to 37 branches in the panicle, the

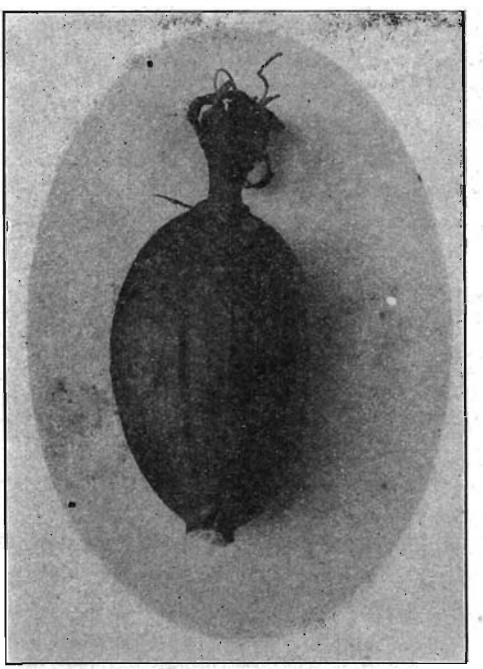

Fig. 1. Seed Capsule, Natural Size.

largest near the middle 2 feet long, upper and lower ones shorter; thicker ovary; stamens inserted a little higher up in the tube. The plants seldom bear fruit, but produce an abundance of adventitious shoots or bulbs, by which they propagate themselves. Sometimes there occur seed capsules, the same size and shape as appear on the wild plant (fig. 1).

This variety is said to furnish a lower percentage of fiber, but of much better quality, than *Agave rigida elongata.*[1]

[1] U. S. Sen. Doc. 300, 1838.

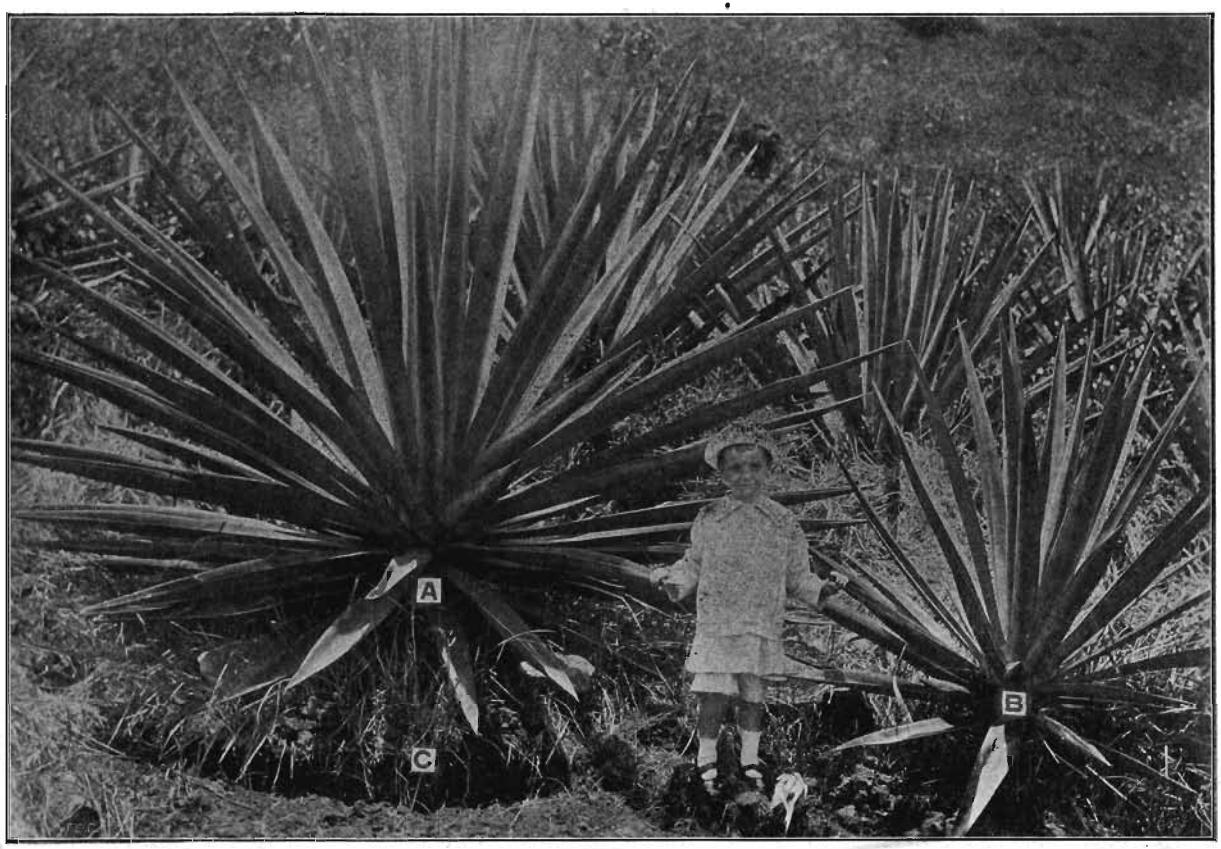

PLATE I. Sisal Plants: A, fully developed; B, stunted plant; C, extent of Root system.

GEOGRAPHICAL DISTRIBUTION OF SISAL.

Plants of the "yashqui" variety of sisal were introduced into Florida from the vicinity of Merida, Yucatan, by Dr Henry Perrine in 1836.[1] The plants thrive well in Florida below the frost line, and have spread over large tracts.[1] The same variety was introduced into the Bahamas from Florida, and has been extensively cultivated there since 1892. Trinidad imported 12,000 plants from Florida in 1891. On the Island of Mauritius 25 plants of the same variety were given to various fiber growers in 1893. In the Turks, or Caicos Islands, there are several prosperous plantations. In British Honduras, *A. rigida* and the variety *elongata* were found growing near Corosal by Dr. D. Morris in 1882. According to the same author, the plants were introduced to Grenada, St. Vincent, and St. Lucia, of the Windward Islands, in 1890 and 1891. There are plantations on the Islands of Antigua and St. Kitts. A plantation of *Agave sisalana* and *Furcraea gigantea* started by the Government exists at Anguilla, in the Leeward Islands. Dr. Morris also states that plants were introduced in large quantities into Cape Colony and Natal, South Africa, the tropical parts of Australia, Fiji Islands, various districts in India, and one or two localities in West Africa.

In 1893, the Hawaiian Commissioner of Agriculture and Forestry ordered 20,000 sisal plants from Reasoner Bros., of Oneca, Florida, which were carefully set out on a number of experimental plots. A trial of sisal was made about that time on the worst soils of the Ewa Sugar Plantation. The indications of favorable results led to the formation of the Hawaiian Fiber Co., Ltd. In consequence of the success of this enterprise, and the promising outlook, a large number of plantations have been started in various districts of the Islands. Notable among these are the Knudsen plantation on Kauai, started in 1902 with 300,000 plants. Other smaller plantings have been made on Molokai, in Kona and Olaa on Hawaii, and on the Island of Maui.

HABITS OF GROWTH.

The roots of the sisal plant feed near the surface, and do not descend to any great depth, in hard clay rarely over 12 inches, and in loose, rocky soil seldom over 18 inches. When given sufficient room the roots will generally spread out over an area equal to the area covered by the mature leaves (Pl. I).

[1] Report Secretary of Agriculture, Washington, D. C., 1891 and 1892

When the plants have become firmly established in the field, the main stalk throws out underground runners or rhizomes. The point of such a runner reaches the surface beginning with the second year, and forms a bulb. This bulb is known as the sucker or shoot (Fig. 2, C). This sucker takes root and obtains nourish-

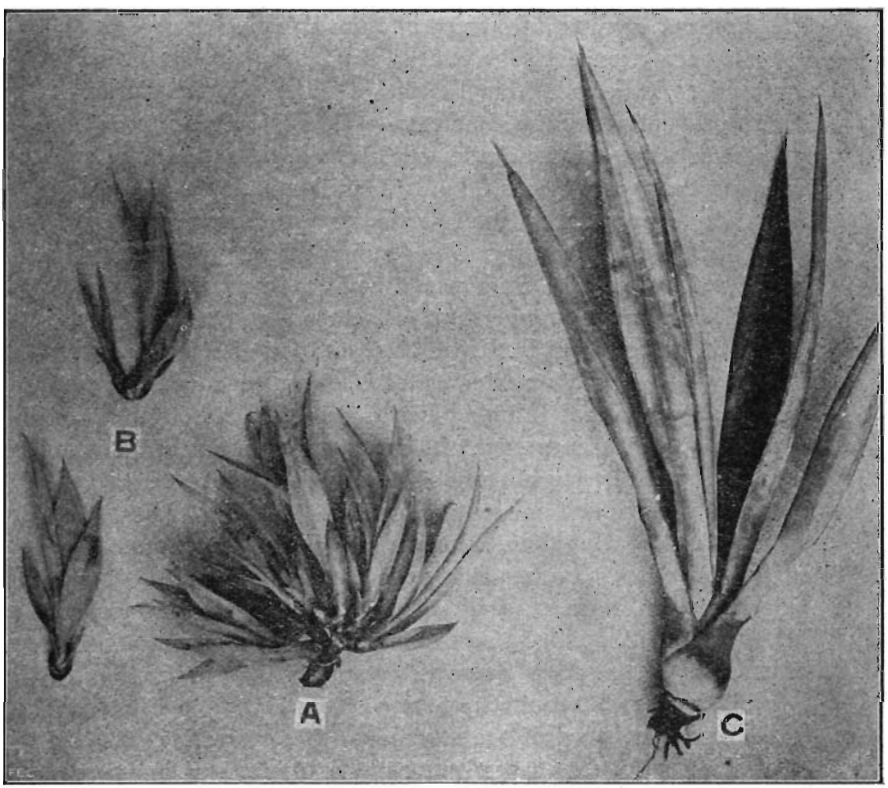

Fig. 2. Sisal Bulbs and Suckers.

ment through the runner from the old plant, and also through its own roots (Pl. II). New suckers continue to appear during the life of the plant. After the third year the lower leaves, 2 to 2 1-2 feet long, assume a horizontal position and show yellowish spots. These are called "mature" leaves. As the plant grows older more leaves mature, which, however, are longer and wider, attaining at the age of 5 to 7 years a length of from 4 to 6 feet. After a vigorous growth of about 6 years, which may be extended to 7, or even 9 years, after planting, a central stalk or "pole" grows up rapidly. This pole is 4 to 6 inches in diameter at the base, tapers upward, and attains a height of 30 feet. It bears flowers, which

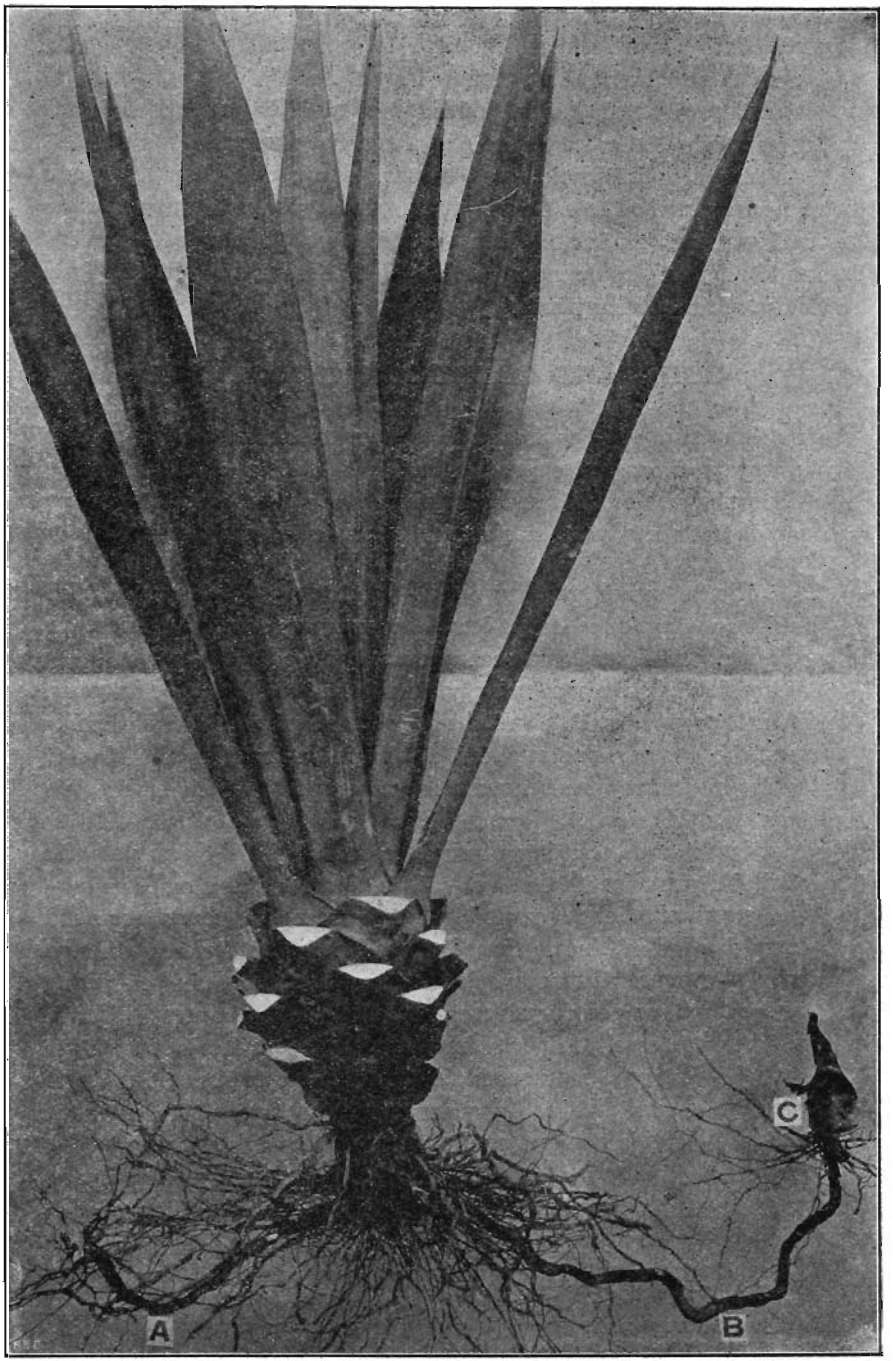

PLATE II. Root system: A and B, Rhizomes; C, a sucker.

fall off and are replaced by 2,000 to 3,000 bulbs. These bulbs grow to be about 6 inches long (Fig. 2, A, B). They finally fall to the ground and thus reproduce the plant. When this has been accomplished the leaves of the plant have become brown and leathery, and the whole mass dies and forms considerable debris. Suckers attached to the plant at this time will throw out a central stalk one inch thick, and from 3 to 6 feet high. Some bear flowers and bulbs; others bear only bulbs, which are usually smaller than those of the mother plant.

SOILS AND CONDITION OF GROWTH.

The sisal plant will grow in tropical or sub-tropical countries in any well drained soil anywhere from sea level to frost line. When planted on rich soil and given some care, the plants grow rapidly, attain a large size and throw up poles when 7 or 8 years old.

Plants which grow rapidly—i. e., those planted on rich moist soils, produce larger leaves, containing a larger percentage of water and a smaller percentage of fiber than plants which grow more slowly on comparatively dry and sterile soils. However, even though in such cases the percentage of fiber in the leaf is less, the greater size attained by the leaves enables the planter to secure more fiber per acre on comparatively rich moist soils than on arid ones.

Continuous planting of sisal on the same field exhausts the available plant food. On such soil the plant makes slower growth and requires a longer period to reach maturity. Coral rock soil in cultivation in Yucatan in 1832 produced plants giving the first crop two years after transplanting, and maturing in ten years, giving an average of 23 leaves per annum,[1] or about 750 pounds of fiber per acre. Reports from the same locality in 1902 state that the first crop matures in five years after transplanting; also that the annual yield is only from 12 to 15 leaves, and that the plants yield this amount annually for from 15 to 20 years. The leaves in the latter case being 4 1-2 feet long and 4 to 5 inches wide, would indicate a probable annual yield of only 400 pounds of fiber per acre. This emphasizes the fact that it does not pay to plant sisal on the same land for an indefinite period. Neither is it commercially profitable to choose for a plantation land which is too dry or too sterile.

[1] Rep. No. 564, 25th Congress, 2d Session, Ho. of Reps., Feb. 17, 1838.

The plant feeds most heavily on lime, magnesia, potash, and phosphoric acid. This will be at once apparent upon an examination of the following table, which gives respectively the composition of the ash of the whole leaf and of the fiber:

The green leaves contain:[1]	%	The fiber contains.[2]	%
Moisture	89.58		11.75
Dry matter	10.42		88.25
Minerals	1.135		2.24
Nitrogen	0.098		0.084
Ash of green leaves:		Ash of fiber:	
Silica	0.56		0.442
Chlorine	.28		.888
Sulphuric acid	.88		.784
Phosphoric acid	3.29		2.605
Lime	33.40		36.247
Magnesia	15.37		1.449
Manganese	.....		.151
Potash	18.80		15.776
Soda	1.42		1.297
Iron	.69		.....
Carbonic acid, etc	25.31		37.595

The leaves of sisal gather water from the dew or rain. This water flows down the furrow of the leaf toward the stalk, and is taken up by rootlets at the base of and in the axils of the lower leaves, and is also absorbed directly by the growing tissues at the bases of the leaves. The plant, therefore, requires a moist atmosphere, or heavy dews. Light rain is very beneficial. The roots are most sensitive to moisture. A field subject to overflow, or soil liable to remain saturated with water for any considerable length of time, is unfit for a sisal plantation. In such localities the plant makes little growth; the roots die during the period of saturation of the soil, and new ones are thrown out again when the conditions are favorable. Heavy clay soil, in baking and cracking open, breaks and otherwise injures the spreading roots of the plant and greatly checks its growth.

On a broken and porous limestone or coral soil, under the influence of a moist atmosphere and a high temperature, subject only to moderate changes, the sisal plant grows well, produces the largest quantity and a large percentage of high-grade fiber.

[1] P. Boname, Station Agronomique, Colony of Mauritius, Rap. Annuel 1901, p. 58.

[2] Dr. E. C. Shorey, Food Commissioner, Board of Health of Hawaii.

Alkaline chlorides, like chloride of sodium (common salt), tend to increase the cellulose in plants at the expense of starch and sugar.[1] Alkaline salts are usually present in a greater proportion in the soils of dry regions than in soils of humid regions. In the latter case the mineral salts are washed out in the drainage waters. Hence, theoretically, a fiber plant such as the sisal should be cultivated in dry rather than in humid regions in order to secure an increase in the amount of fiber.

Perrine[2] states that the soils around Merida, the leading sisal producing district of Yucatan, are composed of arid, cavernous limestone, and that in the whole region there is not a single running stream. Dodge,[3] writing of the same region, describes it as being barren of soil, the sisal plants often being propped in place by small stones or stuck into crevices in the coral rock. The adaptability of both Yucatan and the Bahamas to the cultivation of sisal is apparently due as much to the climatic conditions as to the soil; in other words, proximity to the sea and high temperatures, with low rainfall, are quite as essential as suitable soils.

The leeward or Kona districts of the Hawaiian Islands are naturally adapted to the cultivation of this important fiber plant.

THE PLANTATION.

The selection of the land having been made, the next step is to mark out the site for the fiber extractor, baling press, drying and storage sheds, manager's residence, and the nursery. This site should be centrally located, as near to a railroad or road as possible, and must have a good supply of water. As it is necessary that the bulbs and suckers should be set out at the earliest possible date, it is essential that a nursery be prepared at once. This done, the construction of a stable, buildings for the laborers, and the manager's residence may next be undertaken.

The next step is clearing the land of all brush and weeds. The laying out and mapping of the plantation fields may now begin. The main road extending from one end of the plantation to the other, and passing the mill site, should be wide enough to allow the use of wagons and a portable track for cars. Roads 16 feet wide, running at right angles to the main road, should leave space between for 20 rows of plants. On a plantation where only mule or wagon transportation is contemplated, the intervals should be for 10 rows and the road of suitable width.

1 Storer's Agriculture, Vol. II, p. 742 (1897).

2 Rep. No. 564, 25th Congress, 2d Session, H. of Rep. (Feb. 17, 1838).

3 Charles R. Dodge, Scientific Am. Sup. No. 1837, Aug. 2, 1902.

Stakes marking the lines for the plants are driven 8 feet apart, and the plants nearest to the roads should be 4 feet from the road line. Holes 10 inches in diameter and 15 inches deep should be made at distances of 8 feet along the line to receive the plants from the nursery. In porous rock soil holes 9 by 9 inches are sufficient.

THE NURSERY.

The nursery should be protected from strong winds, and have good, well-drained soil. All brush and weeds must be removed and the soil properly cultivated. A supply of water should

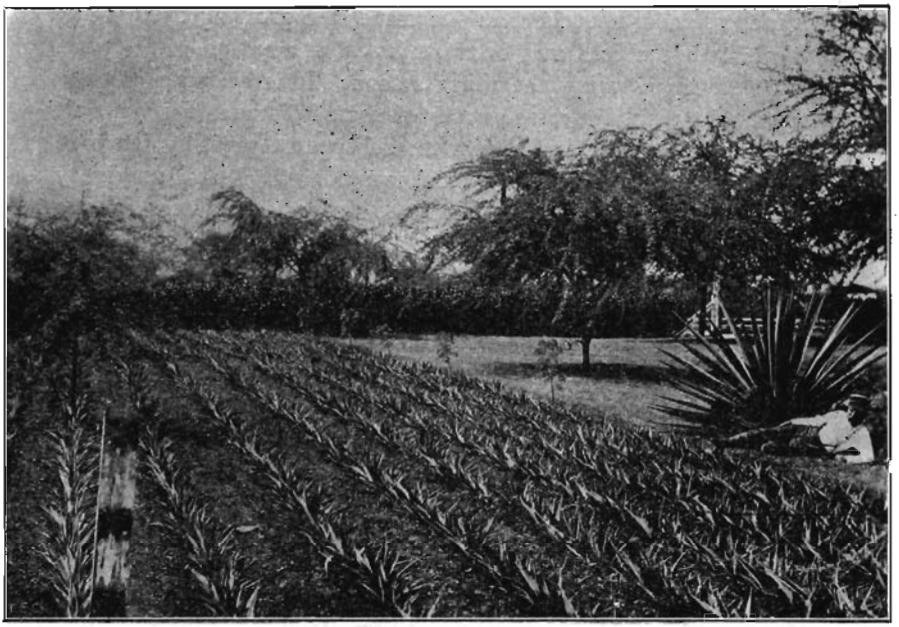

Fig. 3. The Sisal Nursery.

be provided. The young bulbs may be planted 9 inches apart in rows 18 inches apart, and must be cultivated and watered with hose or watering can wherever necessary, but never irrigated,

One-year-old plants will, with proper treatment, be 18 inches high, and may be transplanted to the field. Bulbs planted 12 by 18 or 24 inches, and left in the nursery for a longer period, will be stronger and furnish mature leaves earlier, but the increased bulk of the plants will add considerable to the cost of transplanting. Bulbs (pole plants) are generally procured from the nearest plantation for the first planting. Suckers (shoots) may be set 12 inches apart in nursery rows 24 inches apart, and given the same

treatment as bulbs. These can be used to make new plantings, or replace other plants, in from 6 to 9 months.

It is best to start all plants in the nursery, as this will insure a more vigorous growth than can be obtained from suckers growing slowly beside the parent plant.

All dwarfed plants should be discarded, and only vigorous plants set out in the field. (Fig. 3).

PLANTING.

The plants in the nursery having attained a height of 18 to 24 inches, and the suckers of the same size growing around the old plants in the field, may be transplanted at any time of the year, but preferably during the rainy season. It is an advantage to put out the plants in rows exactly the same distance apart. This facilitates the work, and allows for subsequent planting between the rows. The distance between the plants in each row may vary according to the character of the land. In very rocky land advantage must be taken of the small "pot holes." The minimum number of plants to the acre should not be less than 600 for the best soil, and the maximum not over 900 for poor soil.

The field having been prepared, the young plants are taken up from the nursery. A large portion of the roots and a few lower leaves are then quickly removed, and the plants are transported to their destination and set in the holes made for them. The roots must be covered as well as possible, and sometimes a few small stones are necessary under the lower leaves to keep the plant in an upright position. No soil should be allowed to fall between the leaves, as this would cause them to wilt or decay, and check the growth of the plant. The plant will now take care of itself, and under favorable conditions will begin to throw out new leaves in three weeks.

CULTIVATION.

The planting having been performed with ordinary care, the loss will not be worth mentioning. The weeds and brush must be kept down while the plants are small, great care being taken not to injure the leaves. A bruise or injury to them stains the fiber and lowers its quality. As the plants grow older the leaves cover the ground, and cultivation becomes difficult. A thick matted growth of grass between the rows is very detrimental to the best development of a sisal plantation, as the grass envelops the lower leaves and the base of the trunk, and causes the formation of new

roots in the axils of the lower leaves, so that a large portion of the original roots, together with the first or lower leaves, die.

Shoots thrown out by the plant may be removed to the nursery when 8 to 10 inches long, or two may be left on each plant until 18 to 20 inches long for transplanting to another field, or used to replace poling plants. In the latter case the rhizome must

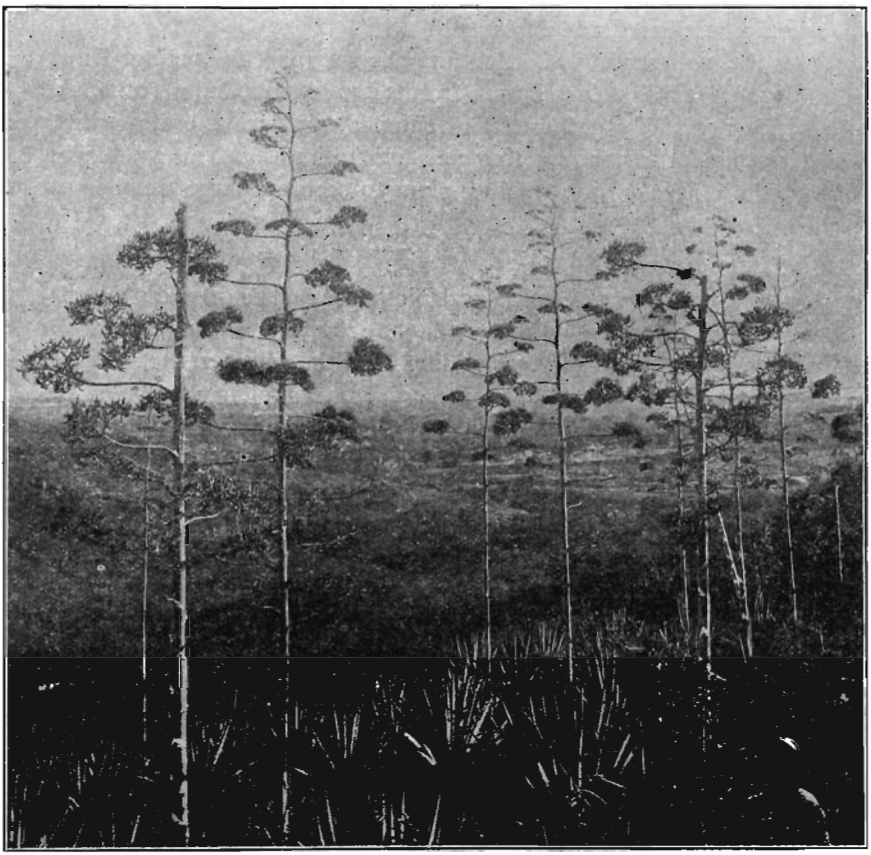

Fig. 4. Poling Sisal Plants, Bearing Flowers Followed by Bulbs .

be cut so as to separate the sucker from the old plant. All suckers not needed should be cut away, as they obtain a large portion of their sustenance from the old plant, especially in the early part of their growth.

The flowering scape (pole), upon reaching a height of 4 feet, must be cut off just above the base of the upper leaves. If allowed to grow taller the pole becomes woody and is difficult to cut. The cutting prolongs the fiber-producing power of the plant

another year, and saves considerable labor as well. All the suckers must be separated from the plant at this time, as otherwise they would soon throw out flowering scapes.

When all the leaves have been cut, the stalk is cut away and the old plant is replaced by a sucker or a plant from the nursery. When a field becomes covered by a dense growth of brush, none of the maturing plants should be replaced. The whole field should be cleared and replanted.

A small portion of a field may be set apart for poling plants (Fig. 4). Each pole will bear from 2,000 to 3,000 bulbs (bulbils), which are easily gathered and shipped, and are therefore very desirable for use in starting new plantations. About 75 leaves should be left on every poling plant to secure a large number of bulbs.

HARVESTING.

Three years after the sisal plants have been set out in the field, the lower leaves assume a horizontal position and show other signs of maturity. Buildings for the fiber extracting and cleaning machinery, baling press, and power plant must now be erected, and the machinery set up. Storage buildings and drying sheds must be put up in a convenient location. A steady supply of water must be secured and the necessary pipe connections made for the engine and for the cleaning machine.

The portable tracks should be put in, starting from the mill, over the main road and down the cross roads, changing the track from one cross road to another, as the work of transportation progresses.

Cars and motive power must be secured. Light and easy running cars with a capacity for 2,000 leaves (2,500 to 3,000 pounds) can be operated with a 10-horse-power engine at the lowest cost on all roads with grades not exceeding 5 per cent.[1]

Portable rails can be laid quickly over rough ground, thus saving time and the great expense necessary in making suitable wagon roads. Mules and wagons for the transportation of leaves and plants should be used only by small planters, who deliver to a near-by plantation. This method is slow and expensive, and would not be economical from a practical point of view for large plantations. Mules can be used to pull cars on portable tracks whenever necessary.

When a sufficient number of mature leaves develop on most plants on the field, the time has arrived for cutting, provided the

[1] Annal. de L'Agric. d. Colonies, Paris, Vol. II, 1860, pp. 12-38.

PLATE III. Harvesting Sisal.

tracks, motive power, machinery and water supply are in order. To obtain the largest quantity, as well as the highest percentage of fiber, the cutting should be done during the dry season.

The leaves are cut close to the stalk with a large knife shaped like a pruning knife. On a basis of ten hours for a day's labor, a man should be able to cut 2,500 leaves as a fair day's work. The leaves should be tied in bundles of about 50 pounds with strips torn from a leaf (Pl. III).

The bundles may be carried to the road, piled up in convenient places, loaded on the cars, delivered and stacked up at the mill, put on the feeding table of the extractor when needed, and opened. The leaves are fed to the machine singly. It is recommended that the fiber be extracted within 24 hours after cutting, as otherwise the cut end of the fiber will be stained.

The following paragraphs illustrate the methods of harvesting sisal in Yucatan, where this crop is grown on a commercial scale:

The lower and older leaves are cut close to the head, tied in bundles, piled upon little flat cars and run to the factory over diminutive narrow gauge railroads, which extend to every part of the farm. At the factory the bundles are sent up to the machine platforms by endless carriers and dropped upon the feed tables. The leaves are there fed, one by one, by a Maya Indian attendant, into the grip chains of the machine. These endless chains convey the leaves to the scraper wheels, where the fiber is extracted and cleaned automatically in an instant, the same chains carrying the cleaned fiber to other attendants, usually boys, who secure it and lay it evenly in piles. A dump car under the machine platform catches all the waste, and as these cars are filled they are run out over the same railroad to the dump pile. The wet fiber then goes to the yard to be dried in the sun, spread over low frames upon which galvanized iron wires have been stretched. When thoroughly dry the fiber has only to be stored and baled, and it is ready for market.[1]

DRYING AND BALING THE FIBER.

After passing through the machine, the fiber is hung out to dry in the sun, and afterwards spread on the raised wooden floor of an open shed for a few days, when it is ready for the press. (Pl. IV). The fiber loses its lustre and is rendered unattractive when left in the sun for a long period, or when exposed to rain or heavy dew. Protection is therefore necessary.

The fiber must be kept clean and straight; care should be taken not to get it mixed up like hay. When perfectly dry, the fiber is carried to the press, which must be 5 feet long, so the fiber can be laid evenly without doubling over. The bales require

[1] Charles Richard Dodge, Scientific American Supplement No. 1837, Aug. 2, 1902.

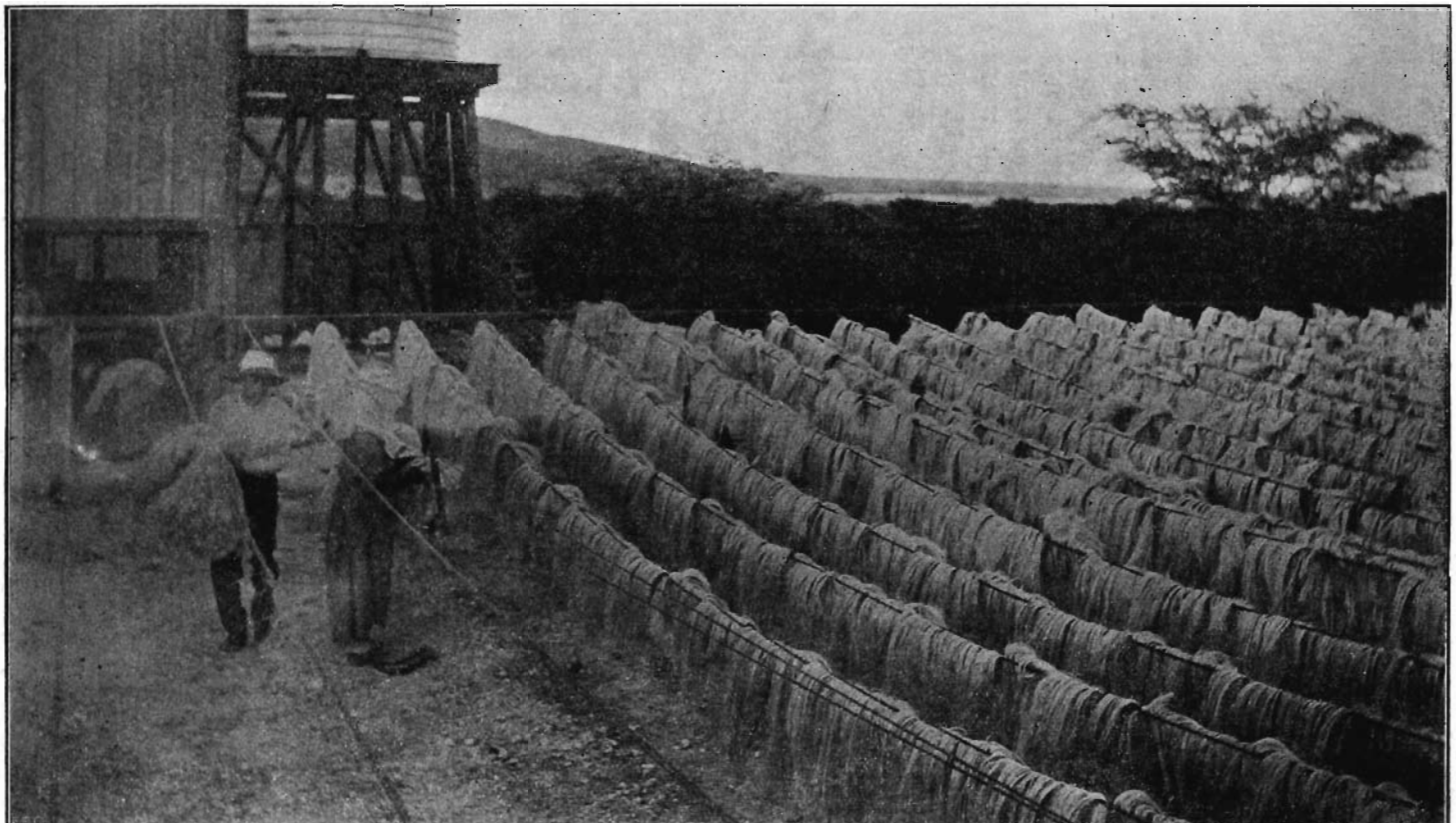

PLATE IV. Drying sisal fibre, at Sisal, Oahu.

no covering, and may be tied with twisted fiber. The net weight of the bales would thus include the weight of the binding fiber. All bales should be 5 feet long, but may weigh from 250 to 500 pounds.

FIBER EXTRACTING MACHINERY.

In Yucatan a primitive machine known as a "raspador" is used on all small plantations. A correspondent of the Syracuse Herald in Yucatan described the raspador as follows:

> It is simply a wheel like a 4-foot pulley, 6-inch face, with pieces of brass an inch square and 6 inches long running across the face about a foot apart. This wheel runs in a heavy wooden case. When working well it makes about 110 revolutions a minute. The leaf is put in through a small hole in the case, and being held by a strong clamp, is allowed to whip downward as the wheel moves around. A heavy block, like the brake of a car-wheel, is, by lever, brought to bear on the leaf, pressing against the revolving wheel. In a second the pulp is crushed and thrown into a pit under the wheel and the fiber is drawn back, one-half of the leaf being cleaned quicker than one can follow the motions. The leaf is reversed and the other end cleaned in the same manner.[1]

On larger estates, powerful modern fiber extracting machines are used, while several raspadors are kept on hand for use during a break-down.

In Yucatan over 1,300 machines of different types were in use in 1900. On the Island of Mauritius 2 1-2 horse-power machines called "gratte" are used. The type of machine used in Hawaii (Pl. V) is practically an improvement of the "raspador."

The leaves are cleaned by two scutching wheels working on alternate sides (Pl. V B). They are fed in at one end, and the cleaned fiber is delivered at the other. The operator places himself on the right of and facing the feed table, and lays the leaves flat together, pointing from him. The leaves are taken up by feeding belts and pass into the machine sideways. About one-half of the leaf is presented to the first scutching wheel, and by an interchange of jointed belts the leaf is moved to the left, presenting the uncleaned portion of the leaf to the second scutching wheel. The fiber is taken up at the end of the jointed belts clean and straight (Pl. V, C).

Experiments have been made in the extraction of the fiber from leaves of malino (*Fourcraea gigantea*) and bow-string hemp (*Sanseviera*) with this sisal cleaning machine. The fiber was

[1] U. S. Dept. of Agr., Rept. of Secretary, 1891, p. 430.

taken up clean and straight, and the quantity was the same as when cleaned by hand. It must be noted, however, that the short fiber at the butt of the sisal leaves is thrown out with the pulp. It is impracticable to save this short fiber, no matter what method of extracting is employed, but some method may be found to separate it from the waste.

In some of the best machines the mechanism may be complicated to such an extent as to require a power out of proportion to their capacity.

Dr. F. Martinez Calleja's method of extracting the fiber by steam and saving the juice for the manufacture of sugar is entirely practicable, but is too expensive for the Hawaiian Islands.[1]

For use in Hawaii, a fiber-cleaning machine must be selected that will give the largest possible percentage of clean straight fiber. The operating expenses, together with the cost of repairs and allowance for wear and tear and interest on cost price, should compare favorably with those of machines in use in other countries.

YIELD OF FIBER.

A sisal plant (*Agave rigida sisalana*) at time of poling has about 235 leaves, of which 185 are mature leaves, or nearly so, and 50 leaves which will mature within one year, provided the pole is cut off just at the base of the uppermost leaves.

The first cutting of leaves takes place 3 to 3 1-2 years after planting, and averages 25 mature leaves per plant. The leaves of the first cutting are smaller, and give a lower percentage of marketable fiber than those of subsequent cuttings. The time required to mature the other 210 leaves, together with their size, weight and percentage of fiber, are regulated by the conditions under which the plant grows.

Subsequent cuttings may be made at intervals of 6 months, but should be made when conditions are most favorable. A wet season, the scarcity of labor, or the low price of fiber, are sufficient causes for postponing the harvest for a year or more. The plants may be injured by cutting too many leaves. The soft fiber of immature leaves is wasted by the machine.

A considerable number of mature leaves from plants grown at the Hawaii ExperimentStation, and also from plants grown at Sisal, Oahu, have been examined, the fiber extracted by hand,

[1] Explotacion de los Textiles, Mexico, 1895.

and all pulp removed from the fiber. These leaves were weighed separately, and the dry fiber from each was carefully weighed. The percentages of fiber as given below are much less than the working averages obtained on the sisal plantations by the use of fiber-extracting machines. The reason for this difference is that when the fiber was extracted in the laboratory, each fiber in the leaf was carefully cleaned of all adhering pulp, and was then washed and dried. On the contrary, where the fiber is extracted by machinery, enough pulp and soluble impurities remain attached to the fiber to account for the increased percentage obtained. The percentages given are hence the actual fiber content of the leaf—not the per cent. which is marketable. The investigations and experiments made to ascertain the yield per acre give the following figures as the lowest obtainable under conditions referred to, and without the influence of salt in the soil or air, which would doubtless increase the percentage of fiber. It is believed that this method of calculation is the safest to ascertain the yield of a new plantation:

In the case of plantings 7 by 7 feet apart (giving 889 plants to the acre), on the poorest soil, without cultivation, the first cutting of 12 1-2 pounds of green leaves should give 4 3-4 ounces of fiber, or 2.37 per cent. The remaining 210 leaves would probably mature within 6 1-2 years from the date of the first cutting, and would give 150 pounds of green weight, yielding 4 1-2 pounds of fiber, or 3 per cent., making a total of 4 pounds 12 3-4 ounces of fiber per plant, or at the rate of 4,264 1-2 pounds per acre.

On poor average soils, plantings should be made 7 by 8 feet, giving 799 plants to the acre. The first cutting will give 20 pounds of green leaves, yielding 8 3-4 ounces of fiber, or 2 3-4 per cent. The balance of 210 leaves will probably mature within 5 1-2 years from date of first cutting, and give 200 pounds, green weight, yielding 6 pounds 8 ounces of fiber, or 3.25 per cent., making a total of 7 pounds and 3-4 ounce of fiber per plant, or 5,630 1-2 pounds per acre.

In porous coral rock having only a trace of soil, the plants must be set 8 feet apart each way, making 680 plants to the acre, and should be given a little care. The first cutting may be made 3 years after planting, and will give 25 leaves, weighing 31 1-4 pounds, yielding 15 ounces of fiber, or 3 per cent.; 150 additional leaves will mature within 4 1-2 years, green weight 225 pounds, weight of fiber 7 pounds 14 ounces, or 3 1-2 per cent. The re-

maining 60 leaves, maturing after cutting the pole, will vary in green weight and percentage of fiber, but will produce about 1 pound 9 ounces of fiber. This makes a total of 10 pounds 6 ounces of fiber per plant, or 7,055 pounds per acre.

Porous coral rock with a mixture of soil is considered the best for the cultivation of sisal. The large size of the leaves makes increased distances between plants necessary. To prevent the leaves of one plant from injuring the leaves of the next, the plants should be set out 8 by 9 feet, or 8 1-2 by 8 1-2 feet apart, which would allow 605 and 602 plants, respectively, to the acre. The first cutting, made 3 years after planting, together with the cuttings made during the 5 years following, will yield 8,500 pounds of marketable fiber. Attention, however, is directed to the fact that at that time all the old, original plants will have been replaced by new ones, and some of these may be large enough to yield their first crop. The weight of green leaves per acre will be greatly increased if the plants in the field receive a reasonable amount of care. The amount and percentage of marketable fiber will be much higher if the leaves are cut two or three months after the close of the rainy season. The yield per acre will be increased accordingly.

Estimates of yield, made by various authorities, are given below, all showing a larger return per acre, as well as a higher percentage of fiber:

Dr. D. Morris says:

In Yucatan the yield of fiber, as a general rule, is 50 pounds from every 1,000 leaves. From the fifth to the seventh year, the average yield of good plants is 75 pounds per 1,000 leaves. With 650 plants to the acre, each yielding 33 leaves containing at the rate of 60 pounds of fiber to the thousand leaves, we would have a total yearly yield of 1,200 pounds, or a little over half a ton per acre. This is the usual return in Yucatan. In the Bahamas, with closer planting and more improved machinery, it is likely to be higher. It is not likely in any case to fall below half a ton. It may be as high as three-quarters of a ton per acre.

Dr. Francisco Martinez Calleja says:

[1] From the henequen they obtain 50 pounds of fiber from every 1,000 leaves, which weigh on an average of 1,250 pounds.

[1] This would indicate a yield of 4 per cent. of fiber from the Mexican leaves.

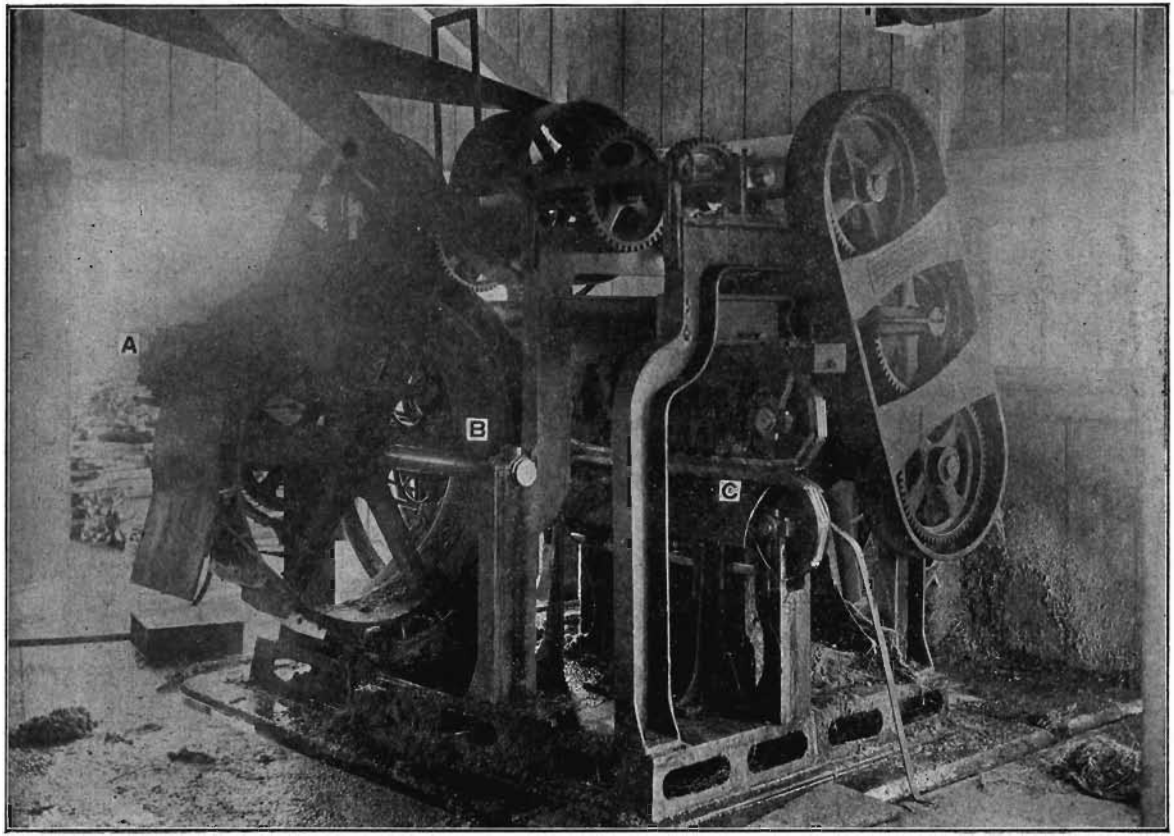

PLATE V. Fibre extracting and cleaning machine in use at Sisal, Oahu.

Charles Richards Dodge says:

1 According to Mr. Preston's report (on the Bahamian culture), 40 leaves may be cut annually from a mature plant. At the average of 1 1-2 pounds to the leaf, on the basis of 650 plants to the acre, this yield gives a total of 39,000 pounds of leaves, or 19 1-2 tons. At one of the farms visited by Mr. Preston in Yucatan, 48,000 leaves, or 72,000 pounds (36 tons), of crude material was cleaned daily. A yield of 5 per cent. of fiber, which is his estimate, gives a little over 1 3-4 tons of fiber per acre from 36 tons of leaves. Mr. T. Abbee Smith informs me that 1,000 leaves of henequen weigh in the rainy season 160 to 200 arrobas (arroba—25 pounds); in the dry season, 100 to 160 arrobas per 1,000 leaves. One thousand leaves average a yield of 55 pounds of fiber.

The average weight of a leaf of the Mexican form of plant is 1 pound 10 ounces, according to reliable authorities. A calculation placed 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 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. 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 4 pounds more than the yield of Indian Key fiber. This difference is more than accounted for in the excessive waste made at the Florida Experimental factory.2

The same authority, Mr. Dodge, says:

3 From the age of 5 years and upward—from the date of transplanting to the time when the plant blossoms and dies—12 to 15 leaves may be taken off annually for the extraction of fiber. These leaves are about 4 1-2 feet long, 4 to 5 inches wide and a quarter of an inch in thickness, and weigh from less than one pound to over two pounds each. In Yucatan the conditions of soil and climate are such that a plant may live to be twenty, twenty-five, or even thirty years old before blossoming; while some, it would appear, never blossom, as very old fields were seen by the writer where the plants were simply drying up and dying of old age.

In the question of longevity of the plant is involved a dollars and cents proposition. If the leaves of a plant, as they develop, can be annually cut until it reaches an age of twenty years in cultivation before blossoming, as in Yucatan, it means that an annual crop of leaves may be taken for fiber during a period of fifteen years. A fifteen-year-old plant in Yucatan has not only developed a definite "trunk," but successive annual cuttings of leaves has added to the length of the trunk, so that the leaves, instead

1 Report of the Secretary of Agriculture, Washington, D. C., 1891, p. 428.

2 U. S. Dept. of Agr., Report of the Secretary, Washington, D. C., 1892, p. 363.

3 Scientific American Sup't., No. 1837, Aug. 2, 1902.

of spreading out near the surface of the ground, are produced at the height of a man's head.

A jenequen field commences to yield in the fourth or fifth year after being stocked, and continues to do so for fifty to sixty years, and even longer. Each plant during that time furnishes annually an average of 25 full-grown leaves, yielding one pound of marketable fiber at $1.50 per 25 pounds at port of Sisal.[1]

ENEMIES OF THE SISAL PLANT.

Cattle and goats are fond of the juicy leaves of sisal plants, and must therefore be kept out of the fields. Mice sometimes try their teeth on the roots of tender stems, but the damage caused is not important.

A mealy bug (*Dactylopius* sp.) is occasionally found in large numbers on individual plants, and causes some damage. This pest may be easily kept in check by spraying the plants with kerosene emulsion.

This crop has been considered remarkably free from serious fungous diseases. However, a disease has recently appeared in the Bahamas which is described in the following letter from Lyster H. Dewey, Botanist in charge of fiber plants, U. S. Department of Agriculture, dated Washington, D. C., Jan. 16, 1903:

When I was in the Bahamas last May, I noticed that there were in a few localities indications of a diseased condition of the sisal plants. I brought back with me some specimens, and referred them to the plant pathologist of the Bureau of Plant Industry, who reported the presence of a fungus on the leaves, but that it was not in a condition for determination. Recently I have received from one of the principal growers in the Bahamas a letter stating that while the diseased condition seems to be confined to small areas, it is slowly spreading, and is causing some alarm lest it may prove destructive.

The symptoms are described as follows:

Yellowish spots or patches are first observed on the leaves. These spots spread. The leaf gets dry and curls, usually half-way down from the point, the edge of the leaf becoming pinkish in color. In a week or two, sometimes longer, the leaf dries and becomes black and hard. Usually the upper half of the leaf is affected, the lower half remaining green much longer. Sometimes the funnel, as it is called in the Bahamas, consisting of the unopened leaves, is attacked at the tip. The disease usually affects only 5 or 6 inches of the upper part of the funnel, but sometimes extends clear to the base.

This condition has not been observed in the Bahamas until within the past year. It may have existed there before, but to so small an extent as to be regarded as of no importance.

[1] Report Secretary of Agriculture, 1869.

I would suggest that the sisal growers of the islands be warned in regard to the possible introduction of such a disease, and that they be urged to go through their plantations, and, if any sisal plants are found exhibiting symptoms of the character described, they should be grubbed out and destroyed.

PROSPECT OF THE SISAL INDUSTRY IN HAWAII.

The sisal plant thrives under most adverse conditions. It is therefore a suitable crop for the waterless, and hence comparatively barren, soils on the leeward coasts of all of the islands of this group. Wherever water is obtainable for irrigation, sugar-cane, tobacco, cacao, vanilla or other crops requiring intensive cultivation, will prove more profitable, but lacking water, sisal may be properly substituted.

As a result of the introduction and wide distribution of sisal by the Commissioner of Agriculture and Forestry in 1893, the fact that this fiber plant is adapted to Hawaiian conditions has been indubitably established. It is no longer an experiment, but is an established industry.

Good management of carefully selected land, together with rail transportation and up-to-date machinery, will, with the rapid growth the plants make in these islands, insure the success of the sisal industry in Hawaii.

THE HAWAII AGRICULTURAL EXPERIMENT STATION, HONOLULU, HAWAII.

The Bulletins and Reports of the Station will be mailed free to any citizen of Hawaii upon request. A cordial invitation is extended to all persons to visit the Station grounds at any time. All correspondence relating to the work of the Station should be addressed to

JARED G. SMITH,
Special Agent in Charge.