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THE SISAL HEMP PLANT.

CORDAGE FIBRES:

Their Cultivation, Extraction and Preparation for Market

BY

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PREFACE.

IN compiling this volume, the author is merely putting together in book form a series of articles which have appeared from time to time in the "Jute, Hemp, Flax, Rope and Twine Trades' Journal." He hopes that the book will prove a valuable work of reference to those interested in the cultivation of colonial and tropical fibres as well as a reliable text-book for technical students. He would also recommend its perusal to rope and twine makers and others who use such fibres, as many such have a very vague idea as to the origin of their raw material.

H. R. CARTER.

BELFAST, 1909.

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CORDAGE FIBRES.

CHAPTER I.

INDIAN JUTE.

JUTE is grown almost exclusively in the province of Bengal. The commercial fibre is chiefly derived from two species of plant, *i.e.*, the *Corchorus capsularis* and the *C. clitorus*. The fibres exist in the plant as a skin under the cuticle or bark of the stem. The finest jute is grown on the high ground, and the middle qualities on the river banks, deltas, &c., known as "Salilands." A hot, damp climate, without too much rain, is best suited to the proper development of the plant.

The textile qualities of jute were known to the natives long before the advent of the white man, who discovered that from it they wove a coarse cloth and formed it into cords and ropes. Samples were sent to manufacturers at home, who at first found the material rather hard to spin. It was in the year 1832 that the Dundee flax spinners first tried jute, and ever since that date the trade has gone on increasing. Since 1857 a number of large jute mills have been erected in the neighbourhood of Calcutta, and at the present day the Indian jute-spinning industry rivals, if it does not exceed, the Dundee trade in importance.

The average annual jute crop amounts to about 1,500,000 tons. About half of it is manufactured in India; in fact, Indian competition has nearly driven Dundee out of the market for heavy goods, although Dundee still holds the field for special fabrics.

The jute-growing region of Bengal is of vast extent, chiefly situated in the north and east, and annually inundated in many parts by the overflow of the Ganges, Brahmaputra, and Migna Rivers, producing abundant crops with little labour, which is besides very cheap and plentiful, the population being amongst the densest in the world. The water communications are so pervading and accessible that the crop is easily and cheaply conveyed to market. The facilities for shipment at Calcutta are unsurpassed.

Land intended for jute is generally broken up in the fall. With unwearied industry, the natives plough the land over and over again—in some instances as many as twenty times—until the soil has been thoroughly pulverized, deeply exposed to the sun and air, and richly manured. The seed is sown broadcast, 20 to 30 lb. to the acre. The time of sowing varies with the district and the climate. In the north-eastern provinces of Bengal, where nearly all the jute of India is raised, the seed is sown in February, March and April. Near Calcutta the seed is often sown as late as July. Sometimes two crops are raised in the season, but this is very exhausting to the soil. After the jute has come up, it is carefully thinned and then left to ripen. It matures in from twelve to fifteen weeks, and sometimes grows to a height of 20 ft. The average height is from 10 to 12 ft., and the diameter of the butts from $\frac{1}{2}$ to $1\frac{1}{2}$ in. One variety, which is extensively cultivated, has a smooth, white bark and wide-spreading branches. In the northern provinces of Bengal the average yield is from 2,000 to 3,000 lb. per acre. Near Calcutta it is only from 500 to 1,000 lb. per acre. In the north of the Bengal Presidency the quantity of seed raised per acre is from 1,000 to 1,100 lb; in the south it is from 1,400 to 1,500 lb. per acre.

Jute is cut while the plant is in flower, as the fibre is then at its best. The seed ripens one month after flowering. After cutting, the stems are usually kept for a few days until the leaves fall off.

In order that the fibre may be easily separated from the stem, the stalks are bound in bundles and steeped in water for about ten days, the fermentation thus set up softening the tissue in which the fibres are imbedded until they come away quite easily from the woody portion of the stem. The stalks are examined periodically to test the progress of the retting operation, and when it is found that the fibres peel off easily the operation is complete, and the bundles are withdrawn. Fibre retted in clear running water is strong, white, and glossy, but the process is longer than if stagnant water is used. The fibre is separated from the stalk by hand at the same time as it is being lifted from the dam. The natives, standing waist deep in the water, strip off the bark, wash the fibre, wring it out, and hang it up to dry on lines. The fibres in the raw state are of a light brown colour, and are fairly fine and pliant, if somewhat harsh. Before packing, the root end, which is generally hard and woody, is usually cut off. About 14 cwt. of fibre may be obtained per acre on the average, the cost of cultivation being about 28s. The usual length of the fibre is from 6 to 7 ft., but is occasionally met with up to 14 ft. in length.

In the Calcutta market a series of commercial staples are recognized and based on the districts whence they are drawn, their values being a fairly constant relation to each other. These classes in order of quality are :—

(1) Uttariya, or northern jute, coming from Rangpur, Goalpara, Bogra, and the districts north of Sirajganj. These jutes are unequalled for length, colour, and fineness.

(2) Deswal, or Sirajganj jute, which is valued on account of its softness, bright colour, fineness and strength, being superior in the latter characteristic to Uttariya jute.

(3) Desi jute, coming from Hooghly, Bardwan, Jessori, and the twenty-four Parganas.

(4) Deora jute, which is produced in Faridpur and Bukar-ganj, and yields a coarse dark-coloured fibre, used principally for rope-making.

(5) Naraingunja jute from Decca, a strong, soft, and long fibre of inferior colour.

(6) Bhatail jute from Decca, which is a good rope-making fibre, being coarse and strong.

(7) Bakrabadi jute from Decca, soft and fine in colour.

(8) Karimganji jute from the Mymensing district, a long, strong staple of good colour.

(9) Mirganji jute, the produce of Rangpur, which is harsh and woody from over-ripeness.

(10) Jangipuri jute from Patna, a weak, and foxy-coloured fibre of very inferior quality.

In the European markets these distinctions do not carry much weight, traders' marks and classes being the accepted standards of quality and condition.

Jute marks are very numerous, consisting of letters, circles, hearts, or triangles. The letters frequently indicate the name of the exporter, the well-known C.D.M. mark, for instance, being connected with the name of its originator, the late Mr. C. D. Mangos. The four kinds chiefly imported into this country are Serajgunge, Naraingunge, Daisee, and Dowrah.

Serajgunge jute has a soft fibre, of a whitish or dull grey colour, with a bluish tinge, and without the red root or tips found on some jute. The roots of this sort of jute are sometimes of a somewhat dark shade. The best qualities are used for high-class yarns, both warp and weft, the lower qualities being used for medium and common warps and wefts. This jute is more easily bleached than other varieties.

Naraingunge fibre is strong and pliant, but of inferior quality to Serajgunge, having a tendency to redness at the tips and to hard roots, even in the best qualities. The colour ranges from a bright cream colour to a dark red. Best quality fibre of this description is used in the production of superior warps and wefts, and the remainder spun into medium quality warps and wefts and into common wefts.

Daisee jute is soft and fine, and without hard root ends.

It is, however, usually of a bad colour, varying from light pink to a dull slate, and is only of medium strength. It is always used as a mixture in Hessian and common weft yarns, and sometimes also in small quantities in warp yarns, in order to reduce their cost.

The lowest class jute is Dowrah, which is dark or dull grey in colour, with a slight tinge of green. The fibre is harsh, dirty and brittle, and can only be used in a mixture for sacking yarns, or mixed sparingly for heavy common wefts. A peculiarity about Dowrah jute is that when put into yarn, the harder the twist of the latter the weaker it becomes. Consequently it is not at all suitable for warp yarn.

The jute fibre trade of Calcutta is almost exclusively in the hands of Europeans. The fibre is sorted and then pressed into bales, of 400 lb. each, for export. Each sort has its own special mark, and in selling a lot, the shipper usually guarantees a certain quantity of each sort, such as 5 per cent. of first numbers, 50 per cent. of second numbers, and 45 per cent. of third numbers. Special qualities are sold separately.

The greatest defects found in the fibre, as imported into Scotland, are heart and surface damage, and the presence of roots and runners. Heart damage is caused by heating, in the centre of the bale, owing to the fibre having been pressed in a damp condition.

Surface damage is done in transit by exterior dampness, usually due to the ship's hold not being properly ventilated.

Runners are fibre produced from stems of the plant which have fallen down and grown along the ground, and are consequently of very inferior quality.

A coarse root end is a common defect, and if not removed, reduces the spinning quality of the fibre very materially.

A good deal of jute is now prepared in Calcutta by the snipping process, instead of by cutting off the roots. The snipping or knifing machine consists of a toothed cylinder,

running at a speed of about 200 revolutions per minute. In the rear of the cylinder, and horizontal with its centre, are a pair of fluted rollers, driven independently of the toothed cylinder by a separate belt. By a suitable arrangement of three pulleys—one of them being a loose one—and a long handle for shifting the belt from one to the other, the feed rollers may be stopped or driven at will in either direction. In this way the operative is enabled to spread a “strick” of fibre upon the endless feed sheet, introduce the bad end between the feed rollers as far as required, retain it there until the toothed cylinder has acted upon it sufficiently long, and then withdraw it again without danger.

The hard and flat ends are cut away and thrown down below the cylinder, and may be sold for spinning into coarse sacking yarns.

In the provinces where jute is raised the distaff is in every hovel. The Mohammedans, deterred by some religious scruple, restrict themselves to the manufacture of cotton; but among the native Hindu population the spinning and weaving of jute is still an important domestic industry. Gunny cloth is woven in several qualities, according to the purpose for which it is intended. That intended for bags to carry poppy or rape seed and sugar must be comparatively closely woven. A more open cloth serves for rice and seeds of a like size, while a still coarser cloth serves for covering packages. Rice, cotton, sugar, coffee, pepper, and other articles of East India commerce, are almost wholly carried in jute gunny bags, which are made and exported from Bengal.

At Dundee, the ordinary fabrics made from jute are Hessians, sackings, carpets, tarpaulins, and backings for linoleum or floorcloth. The latter fabric is usually woven on wide looms. Dyed carpets, curtains, and table covers are also made, and are cheap and attractive in appearance, but not very durable. Millions of small, brightly dyed prayer carpets for Moslems have been sent from Dundee to the

East. Jute is also used to some extent to make theatrical wigs, &c.

According to information received at the Board of Trade, through the India Office, the record of the Indian Jute industry is one of uninterrupted progress. The number of looms and spindles in operation has increased to a very much larger extent than either the number of mills at work or the amount of the nominal capital employed. The production of the mills has, however, increased to a still larger extent.

The value of the jute manufactures exported by sea in 1906-7 was over twelve times as great as the average value of the exports in the periods 1879-80 to 1883-4.

The exports of raw jute have also increased, but to a much smaller extent. The price of raw jute has nearly trebled itself since 1879, and in the last three years the rise in price has been very marked. There is, however, no corresponding rise in the price of gunny cloth.

The raw jute required to supply the world per week is about as follows: Scotland, fully 18,400 bales; England, 1,860 bales; Ireland, 730 bales; France, 4,000 bales; Germany, 2,170 bales; other countries, 2,500 bales. The annual consumption of Europe is about 1,800,000 bales.

India uses about 107,000 tons per year, America and Australia 107,000 tons per year. Total consumption per annum, 535,400 tons, which may be valued at £6,000,000.

In 1901-2 India exported 737,755 tons of raw jute, valued at £7,864,848. Of this, £3,529,727 worth went to Britain, £1,527,425 worth went to Germany, £999,453 worth went to France, £938,512 worth went to United States America.

There were thirty-five jute mills near Calcutta in 1902, giving employment to 113,946 persons. There were 16,056 looms and 329,300 spindles at work in these mills.

In Calcutta a weaver's wages are about equal to what they are in Scotland, but Scotch hands of other sorts earn from one-half to two-thirds more than the same class of hands

do in Calcutta. In India, however, unskilled labourers get very little. It is said that to produce a finished piece of jute cloth in India seven persons are required to do as much work as three at home. However, the class of work turned out is not the same.

Some of the Indian jute factories are immense. There is an establishment at Barnagpoor, near Calcutta, which employs more than 4,500 workmen, and manufactures annually more than 30,000,000 lb. of jute.

CHAPTER II.

SOFT HEMP.

THERE is but one species of the true hemp plant (*Cannabis sativa*)—Fr. *Chanvre*, Ger. *Hanf*, Italian *Canappa*—although fibre produced from the plant in India, for instance, differs considerably from the European-grown fibre, owing to the difference in the climate. The plant is cultivated extensively in Russia, China, Japan, Italy, Austria, and France. It grows to a height of from 5 to 15 ft., the stems being hollow and fluted. The fibre is found in the outer skin which envelops the woody core or boon.

Hemp growing in England has almost died out. In former days, hemp was fairly extensively grown in the alluvial districts of Lincolnshire, and at Holderness, also in Ireland and in the county of Suffolk. Forty years ago 500 to 600 tons of dressed English-grown hemp were exported, chiefly to France.

The hemp plant is peculiar in that the staminate or pollen-bearing flowers and the pistillate or seed-producing flowers are on separate plants. The latter, or female plant, is larger than the male plant, does not ripen so early, and should consequently be harvested last.

As the best and finest hemp fibre upon the market is grown in Italy, we will describe the method of cultivation as there practised. In that country, and particularly in the districts of Bologna and Ferrara, where the growth of the plant has been carried to a high degree of perfection, a rich, strong loam, well manured, is considered to yield the best fibre. The rotation

of crops followed is (1) hemp ; (2) maize, barley, or oats ; (3) wheat ; (4) hemp, and so on. The soil is first deeply ploughed and then pulverized with mallets or rolled until the surface is quite fine. Seed is sown in March, being sown more thickly on rich soil than on poor land, for the reason that if the plants were not close together upon the rich ground they would grow large and coarse, whereas the most valuable fibre is obtained from the more slender stems. The seed is machine-sown and harrowed in. In order that the male plants may be first pulled, small paths must be left open along the field, lengthwise, at about 7 ft. pitch. The plant comes abroad in ten or twelve days, and should be carefully weeded when the stalks are a few inches long. The plant is subject to two diseases, viz., pallor and rickets, the former due to lack of iron in the soil, and the latter showing itself in the drying up of the stalk and leaves. The male plant is known to be ripe by the fading of the flowers and the falling of the pollen, and from some of the stems growing yellow. The female plants are less numerous than the male, and are known to be ripe by the stems becoming pale.

When the male plants are ripe they are pulled up by the roots in handfuls, the female plants being left for the seeds to ripen, when they are uprooted in a similar manner. The roots are then cut off, and the leaves, seeds and branches stripped off in the ripple, a sort of very coarse hackle through which the top end of the stems are drawn in handfuls. The stems are then made into bundles for steeping. The hemp is retted in dams or in substantial stone basins or tanks called *macera-tojo*, the operation occupying from four to eleven days, according to the temperature and the quality of the straw, the slenderest stems requiring the longest steeping.

When the stems have been sufficiently retted, or when the fibre separates easily from the woody portion of the stem, the bundles are lifted out and allowed to drain. The straw is then grassed and dried, and then beaten with wooden mallets

to separate the fibre and break up the boon, or passed through a brake with a like object before thoroughly cleaning the fibre by repeated blows of a scutching blade. The cleaned fibre is then sometimes rolled or beaten, sometimes by a beetling engine, with the object of softening the fibre, splitting up the reeds, and rendering it finer and of better spinning quality.

The Italian hemp farmer often adopts what is known as the *metayer* system in dealing with his workpeople. He arranges with a family or gang of workers to accomplish certain parts of the cultivation, in payment for which they receive a fraction of the produce and certain perquisites. The farmer ploughs the land and sows the seed, and the peasants break the clods, drive off birds, do the weeding, pull the crop, do the retting and grassing, and finally clean the fibre.

When hemp was grown in England it was the custom to drill about 6 pecks of seed per acre in the middle of April, the drills being about 18 in. apart. The male plants were then pulled in August and the female plants in September.

Large quantities of Russian hemp are cultivated in Poland, and in the centre and south of European Russia, and exported from St. Petersburg, where special attention is given to its storage and shipment. A good quality of Russian hemp is likewise exported from Riga, the fibre being brought down the Dwina.

Three-fourths of the hemp produced in America is grown in the State of Kentucky, in the counties of Fayette, Woodford, Jessamine, Garrard, Clark, Bourbon, Boyle, Scott, and Shelby. The nine counties are in the famous blue grass region, of which Lexington, the principal hemp market, is the centre. Of secondary importance are the hemp markets of Nicholasville, Versailles, Lancaster, Danville, Winchester, Paris, Georgetown, Shelbyville, and Frankfort. Small, scattered areas of hemp are cultivated in other parts of the State of Kentucky, and attempts made to establish a hemp-growing industry.

In Nebraska there are two centres of hemp cultivation, viz., Fremont and Havelock. In California, hemp is cultivated at Gridley, in Butte County. Trials of hemp cultivation have also been made on Ryer's Island, near Rio Vista, in the Sacramento Valley, in San Benito County, and also near Houston, Texas, where, with improved methods of handling the crop, it seems probable that it may become a profitable industry in that region. Hemp has been grown in the vicinity of Champaign and Rantoul, in Eastern Illinois, and along the Missouri River, between St. Joseph and Kansas City, but its cultivation in these localities has been almost discontinued, except at Rantoul, where about 400 acres are still cultivated each year.

In Kentucky, as stated, hemp is cultivated most successfully in the blue grass region, where the soil is chiefly a yellow clay loam, or a rich, sandy loam, rather firm in texture, and usually underlaid with a subsoil of yellow clay. The land is gently rolling, affording excellent drainage. Exceptionally fine crops are produced on the bottom lands along the Kentucky River and its tributaries, although it is regarded as risky to cultivate it where it is subject to overflow. A good stand of well-developed hemp plants is rarely obtained in undrained hollows in the uplands, although the soil in these hollows seems more fertile than that on the surrounding hillsides.

In Nebraska, hemp is cultivated on rich, black, friable loam, comparatively loose and light in texture, and lying high, with good drainage. Repeated efforts to cultivate hemp on the "gumbo" and other low-lying soils there have demonstrated that, while these soils may produce some large hemp plants, it is practically impossible to secure on them a good, even stand of hemp stalks of the proper size for fibre. In Texas, good crops of hemp have been produced on rich, dark, prairie soil, but on upland soils, subject to drought, the crop has proved a failure. In California, hemp is grown on alluvial soils in the bottom lands along the rivers.

An ideal hemp soil must be rich in available fertilizing elements, especially nitrogen and potash, to ensure a rapid growth; deep and sufficiently loose in texture, to permit the development of the roots, and also to allow good drainage; sufficiently friable, to make a good, mellow seed-bed, so as to insure uniform germination of the seed, yet with clay enough to give it a good body and firm texture. A good supply of decayed vegetable and animal matter is necessary, not only to furnish plant food, but to retain moisture. Very few crops require as much water as hemp, yet it cannot stand surface water about the roots. In soils of a loamy character, where the general water level is within 10 ft. of the surface, there is little danger of injury from drought after the first thirty days, during which the roots will establish themselves.

Although in Kentucky hemp sometimes follows hemp on the same land for ten or twelve years, if the stalks are retted on the same land, and fertilizers applied to make up for the fertility taken off by the crops, no serious injury results. It is, however, doubtless the better practice to cultivate a series of crops in rotation. A common five-year rotation is clover, hemp, corn, wheat, clover. Hemp follows clover whenever this is practicable. The stubble and roots of the clover, rich in stored up nitrogen, furnish the desired fertilizing elements well distributed, and also the decaying matter necessary for the development of a rapid growing crop like hemp in soils long under cultivation.

In California and Nebraska no crop rotation is practised for hemp, and on the deep, rich prairie soils of Nebraska, where there seems to be an almost inexhaustible supply of decaying vegetable matter, it is claimed that the best results are obtained where hemp follows hemp through a long series of years. Hemp prevents the growth of weeds and other vegetation which would be found on such soils in most other crops, or after other crops are laid by, and its cultivation also seems to make the soil more uniform in character.

In California and Nebraska the hemp is retted on the land where it is grown, and in this manner a portion of the fertilizing elements in the crop is returned to the soil. No other fertilizer is used in those States, and none seems necessary as yet on the deep, rich soil. In Kentucky the soil has been kept in a high state of fertility by herds of cattle and sheep. Barnyard manure is applied to corn and wheat—the crops preceding hemp in the rotation—but no fertilizer is applied to the hemp crop itself. Fresh stable manure applied as a top dressing produces an uneven growth of hemp plants, and when ploughed under just before sowing time, it has a tendency to dry out the soil. Fertilizers, to produce a satisfactory result with hemp, must be thoroughly and uniformly mixed with the soil, and should have a tendency to retain moisture. Barnyard manure and clover sod, therefore, being humus formers, may be expected to give better results in the long run than commercial fertilizers, which tend to deplete the humus or decaying vegetable and animal matter. In the Southern States, where clover does not succeed, and where stock-raising has not yet received due attention, cowpans and cottonseed meal will make good fertilizers for hemp. Alkaline chlorides like common salt (chloride of sodium) tend to increase the cellulose in plants at the expense of starch and sugar. The application of salt may therefore be expected to increase the quantity and also the quality of the fibre, and in experimental culture it has been proved to be true. Salt must be used with caution, however, since it is likely to prove very injurious on light soils or soils lacking in fertility. Muriate of potash has an effect similar to that of common salt.

The best results are usually secured by deep ploughing in the autumn, followed by thorough harrowing in the spring. Thorough deep ploughing is necessary to fit the soil to retain moisture and to give opportunity for the development of the roots. Harrowing before the seed is sown is generally necessary to make the seed-bed fine and uniform. Harrowing is

advisable even in loose, friable soils, which are pretty well pulverized by the plough, since the rough furrows left by the plough will result in uneven covering of the seed, and lack of uniformity in germination and coming abraid.

The best results are obtained by sowing the seed in the spring. In Kentucky, hemp seed is sown from the middle of March to the end of April; in Nebraska, from April to June; and in California, in February and March. The best hemp crops are obtained by drilling and cross-drilling with a force-feed drill. This distributes the seed evenly, and covers it at uniform depth. An even stand of plants, uniform in size, is one of the principal objects to keep in mind in nearly every operation in hemp and flax culture. It is well nigh impossible to make good fibre from a mixture of stalks of various sizes. Unevenness in size of stalks will result from a lack of homogeneity of soil, or from a lack of uniformity in the surface, in the distribution of the seed, or in the depth at which the seed is covered. A bushel of seed per acre is the quantity usually sown for hemp in America. If the seed is fresh, of small size, and of good germinating power, this quantity is usually sufficient. On rich soils, however, it is advisable to sow a larger, and on poor soils a less, quantity. Good hemp seed should germinate 85 to 95 per cent. within ten days. Before sowing, it is advisable to make a test to determine the germinating power of the seed, and to use the data thus obtained in determining the amount of seed to sow per acre.

If the land has been properly prepared before sowing, and if the soil is suitable, weeds will seldom grow sufficiently to injure the crop. In some instances it may be advisable to pull out long weeds when these overlap the hemp before it is 24 in. high, but it is best not to tramp through the crop more than necessary, for bending and breaking the young plants will cause uneven growth. In Kentucky and Illinois the hemp crop is sometimes completely ruined by broom rape, an annual plant, parasitic on hemp roots. Broom rape is an incon-

spicuous plant, growing not more than 6 to 12 in. high at the base of the hemp stalks, and is usually not noticed until the hemp plants suddenly begin to turn yellow and die a few weeks before harvest time. In some instances a partial crop is saved by cutting the hemp as soon as the first effects of broom rape are observed, but the fibre thus obtained is usually rather weak. The seeds of this weed retain their ability to germinate for a long time, and lying dormant in the soil, their eradication is rendered extremely difficult. They can develop only on the roots of a few crops like hemp, tobacco and tomatoes, and the best remedy is to leave these crops out of the rotation on infested land for a period of at least twelve or fifteen years. Apart from broom rape, which being parasitic, does not require light, there are few weeds which can live in the dense shade produced by the hemp as grown for fibre. The hemp grows so fast and attains such a height that it overtops all ordinary weeds and chokes them out. It is generally regarded as an excellent crop for clearing land of annual or biennial weeds, and it has been suggested as a good crop for killing the growth of wild vegetation on reclaimed river bottom lands.

In America hemp is cut when the staminate plants are in flower. The time of harvest varies from eighty to one hundred and forty days from the date of sowing, the period of growth depending upon the mean temperature and the supply of moisture, and on the variety of seed sown. When sown at the proper season, hemp in Kentucky is usually cut late in August or September, and in California and Texas in July.

In some instances good fibre has been secured in Nebraska from hemp cut before flowering, but ordinarily the fibre is best when the crop is harvested just before the staminate plants are in full flower. If cut too early the fibre will be fine, but lacking in strength, deficient in yield, and will waste at every operation in its preparation. If allowed to become too ripe the fibre will be coarse, harsh and brittle.

In California and Nebraska hemp is cut with reaping machines, and their use is becoming fairly general in Kentucky also. Much of the hemp in Kentucky, however, is still cut by hand with a reaping hook or a hemp cutter, which is something between a reaping hook and a bush scythe, but unlike either. An experienced hand with a reaping hook will cut about $\frac{1}{2}$ acre per day. With a sweep rake reaping machine, under favourable conditions, from 5 to 7 acres may be cut in a day, and with a mowing machine 7 to 10 acres. Hemp does not lodge like grain or heavy clover, but on windy days it is impossible to cut with either reaper or mower in the direction in which the wind is blowing, for instead of falling back on the cutting bar the stalks drop down between the guards, where they are repeatedly cut off. The heavy, green, woody stalks, $\frac{1}{8}$ to $\frac{1}{2}$ in. in diameter, and 8 to 14 ft. long, are much more difficult to handle than grass or grain, and they cause a much greater strain on the machine. A successful hemp harvesting machine of the self-rake type should be made specially strong, and have a cutting bar not more than 42 in. long arranged to cut within 2 in. of the ground, extra heavy section with rapid motion, and driving wheel with broader rim and larger lugs than are usually made for self-rake machines. Opinions differ as to whether two or three rakes give the best results. A team of four good farm horses is generally regarded as necessary for cutting hemp with a self-rake reaper, and in Kentucky an extra hand is employed to drive. In California and Nebraska one man attends to both horses and machine.

After the hemp is cut it is allowed to lie on the ground from four to eight days to dry. The unbound bundles are usually turned, so as to dry both sides. To turn them a stick or fork handle is run under the tops, and they are thrown endwise over the butts. When dry the hemp is usually bound in small bundles with cheap twine, and the stalks are set up in shocks or stacked. If it is soon to be spread for retting on the same land it is placed in shocks without binding. When cut with

a mowing machine the tangled stalks are raked into windrows like hay. In properly built stacks the hemp will remain uninjured for several years; furthermore, the quality of the fibre is improved, and the processes of breaking and cleaning it are made easier by a kind of sweating or fermentation that the stalks undergo in the stack.

Nearly all the hemp now produced in the United States is dew-retted. It is spread in long rows on the ground during the autumn and early winter, and exposed to the weather until the bark, including the fibre, readily slips from the inner woody portion. In Nebraska and California the hemp is spread on the stubble fields where it has been cut. In Kentucky it is often spread on closely cropped blue grass pasture land, and is sometimes carted several miles from where it is grown to the retting ground. The time required to dew-ret hemp depends upon the weather, and varies from two to ten weeks. Warm, rainy weather causes the hemp to ret rapidly. When the hemp has been retted sufficiently for the fibre to be readily separated, the stalks are raked together and set up in loose shocks to dry, and then carted to the place where they are to be broken.

Breaking is the process by which the fibre is separated from the stalk and roughly cleaned. Nearly all the hemp is still broken by hand breaks made of wood, such as have been used for centuries. With one of these an experienced hand can, under favourable circumstances, clean about 250 lb. of fibre per day. The work is done by alternately crushing or breaking the stalks between the long jaws of the break, and beating them over the break to clear the harl from the fibre. It is a slow process, requiring both strength and skill.

A machine consisting of a series of coarsely fluted rollers, followed by a rapidly revolving spiked cylinder, has been in use for some years in California and Nebraska. It breaks the hemp and delivers the fibre in the form of tow. This machine does well enough to extract the fibre from the tangled hemp stalks cut with a mowing machine.

Decorticators have been tried with some success upon unretted hemp straw. The stalks are first crushed between fluted rollers. The harl is then loosened by a rapidly vibrating mechanism, and the fibre is then partly cleaned by a kind of carrier, which gives a rapid scraping motion. The average production of such a machine is about 2,500 lb. of roughly cleaned hemp daily. The fibre thus produced is degummed and prepared for spinning by a chemical process.

The rough hemp fibre is tied in bales weighing about 150 lb. each, and most of it is sold in the local markets to dealers who hand hackle it. If only hackled over a coarse hackle, it is known on the market as "Kentucky single-dressed hemp." If of good quality and dressed over a finer hackle it becomes "Kentucky double-dressed hemp," which is the finest grade of American hemp.

Under fair average conditions an acre of hemp yields about 1,000 lb. of rough fibre, or about 6,000 lb. of dry retted stalks. At 2½d. per lb. for the fibre it is a very good paying crop.

The principal French hemp-growing centres are Picardie, Anjou and Bourgogne. Hemp from Picardie is of a white or greyish colour, and of good and fine quality. Anjou hemp is strong and regular in fibre and light in colour. Bourgogne hemp is coarse and brown, and only suitable for rope yarns.

The most important of the Indian hems are Bombay, Jubbulpore, and Allahabad hems, which must be carefully distinguished from a spurious hemp called Sunn hemp, which is grown all over India.

Under the microscope, hemp fibres resemble those of flax. The average length of the ultimate fibre of European hemp is nearly 1 in. Nearly all the hemp imported into the United Kingdom is landed at Liverpool, London, Hull, and Leith, and is employed in the manufacture of cables, ropes, cordage, twine, sacking, tarpaulins, canvas, and sailcloth.

CHAPTER III.

MANILLA HEMP.

MANILLA hemp or feather fibre is derived from several species of *Musa*, chiefly from *Musa texilis*. The cultivation of the plant is an important industry in the Philippine Islands, and especially in the provinces of Albay and Camarines, on the island of Luzon. The islands of Leyte, Marinduque, Cebu, Mindoro, and Samar also produce large crops. The fibre is obtained from the long leaves which envelop the stem. The plant grows to a height of from 12 to 20 ft. Almost any land will do for Manilla hemp. It grows well in the mountainous districts, and particularly in the volcanic regions in the eastern part of the islands. It also thrives on rich, flat land, and does not suffer from floods so long as the water drains off quickly and does not leave the ground swampy.

It is a perennial crop, and month after month young shoots spring up from the original root.

In starting a plantation, the timber and undergrowth are cut down and allowed to lie until dried by the sun, when they are burned, and the young suckers planted. Nothing more is done in the way of cultivation, except to cut down weeds and extraneous growths to permit of access to the plants, and to replace those which may die from accident or old age. The plants reach maturity in about three years, and should then be cut down, as at that age they yield the best fibre. If they are cut earlier the fibre is short and comparatively weak, and if allowed to grow too old before cutting it becomes harsh and

brittle. The stems, weighing from 20 to 80 lb., are, when cut, separated up by the natives into their individual leaf stalks, the inner leaves producing the most valuable fibre.

These leaves contain over 90 per cent. of water, consequently the yield of fibre from the green leaves is comparatively small, being, in fact, only about $1\frac{1}{2}$ per cent. of the green weight. For this reason it requires the produce of about 5 acres to produce 1 ton of fibre at each cutting.

To extract the fibre from the leaves, the native first makes a slight incision just beneath the fibre at the end, and, giving a sharp pull, brings away a strip or ribbon of the outside skin containing the fibre. When a sufficient number of ribbons are thus obtained they are carried to the knife machine, which is used for cleaning the fibre. This apparatus is of a most primitive character, consisting of a rough wooden bench with a long knife-blade hinged to it at one end and connected at the other to a treadle, by means of which the operator can raise the knife for a moment in order to insert one end of a fibrous ribbon, which, being twisted round a small piece of wood in order to afford a good hold, is dragged through between blade and block, and all the pulp, weak fibre, and pithy matter scraped off. The leaves must be drawn several times between the blade and the bench before the fibre is sufficiently clean. The unscraped end, which is held by the operator, is then scraped by a boy, the fibre being then cleansed by washing, dried in the sun, and packed for shipment. One man can clean about 50 lb. of fibre per day. Nearly 1,000,000 bales are exported annually. The trade is in the hands of Spanish and Chinese merchants, who buy from the planters and re-sell to the shippers. There are three principal classes of Manilla hemp, *viz.*, "current," "fair current," and "brown." *Lupis* and quilot, now rarely seen on the London market, is the white, brilliant, and fine fibre produced from the inside leaves of the saga. It is very valuable, being worth, say, £60 per ton, while current,

fair current, and brown sell at, say, £48, £42, and £39 respectively.

It was in 1825 that Manilla first appeared in European markets. In 1830, when the monopoly of the Spanish Government was abolished and the Philippine Islands opened to foreign commerce, a great extension in the trade took place. At this time the trade was practically in the hands of two American houses, Messrs. Russel and Sarges, and Messrs. Pelle, Hubell and Company, who held out various inducements to the natives with a view of developing the industry. In 1850 Messrs. Kerr and Company started business in Manila. The principal exporters are now stated to be Messrs. Smith, Bell and Company, Messrs. Stevenson and Company, Messrs. Kerr and Company, and Messrs. Aldecon Company. Manila and Cebu are the ports of export. The natives still make coarse cloth and ladies' hats from the fibre.

CHAPTER IV.

SISAL HEMP.

SISAL hemp or agave fibre is indigenous to Yucatan, and is also cultivated in the Bahamas, Florida and North-East India. In Mexico the plant is known as "henequen." Yucatan fibre is derived from the spined form of the plant *Agave rigida elongata*, while the species grown in the Bahamas is the smooth-leaved variety of *Agave rigida Sisalana*. Sisal hemp will grow on arid land that seems incapable of any other vegetable life, but the best fibre is grown on gravelly soil of medium quality. It is independent of irrigation, and is actually injured by too much moisture. As far as North-East India is concerned, sisal will accommodate itself to any elevation from sea-level up to 2,000 ft. Fibre grown at high altitudes yields less, but is finer.

The leaves of the plant which contain the fibre average 5 to 6 ft. in length, and are cut down every year after the plant is about four years old. In harvesting the leaves for fibre only the lower leaves are taken, there being a perfect system in the manner and time of cutting, only twelve to fifteen leaves being taken from one plant annually, and these are not all cut at one time. The leaf is taken off close to the stem of the plant by means of a sort of hatchet; the stalk becomes longer each year, until in time the lower leaves are produced at a height of a man's head from the ground. The young leaves unfold themselves from the *cogolla* or central

FIG. 1.—Model Sisal Decorticating Plant at work in Mexico.

leaf spike, which is simply a cluster of unopened leaves in various stages of formation. A leaf weighs from 1 to 2 lb., and measures 5 to 6 ft. in length. It is lance-shaped, $4\frac{1}{2}$ in. wide near the centre, and $\frac{1}{2}$ in. thick. The fibre is the structural system of the leaf, and is surrounded by pulpy matter, the whole being covered by a tough green skin. The quantity of fibre in the leaf varies from $3\frac{1}{2}$ to 5 per cent. Sisal hemp fibre is whiter and flatter than that of Manilla hemp, and is lacking in pliability. There is now a handsome profit to be made in its cultivation.

FIG. 2.—Irene No. 21 Machine.

Yucatan produces the best sisal hemp. This hemp is, in fact, the only product of the State; every other agricultural product is neglected, so that the State imports from other parts of Mexico, or from the United States, all the corn, flour, vegetables, &c., &c., for its subsistence.

The shoots are planted in rows, about 4 ft. apart, and each row is about 12 ft. from the other. Land is measured there by squares of 24 Spanish varas, and in this square about ninety-six shoots are planted. No fertilizer is ever used.

The land on which the plant grows best is a calcareous rocky soil, on which almost nothing else will grow.

It takes about five to six years for the plants to grow to the proper maturity to begin cutting leaves. When the plant is growing, all its leaves point upwards. As the plants mature, the leaves begin to open; as they open, they begin to fall toward a horizontal position. As soon as the leaf becomes horizontal, it is perfectly mature, and must be promptly cut, in order to secure from it the most fibre in the best condition. From four to six leaves become horizontal at the same time on

FIG. 3.—Irene No. 21 Machine.

each plant. The small leaves, which first drop from the plants, are never cut; they are allowed to remain on the trunk of the plant and rot there. The leaves that are first cut from the mature plant are always from 4 to 5 ft. long.

When plants mature, say in five to six years, and the first four to six leaves become horizontal and are cut, it takes from two to four months before the next row of four to six leaves drop to the point of cutting. Each plant always has from twenty-five to twenty-seven leaves. When four to six are cut, the same number have opened in the centre of the plant,

which, therefore, always retains from twenty-five to twenty-seven leaves. If properly cared for a plant continues to yield leaves for about fourteen years in rocky soil, and eight years in fertile soil, but if the leaves which become horizontal are not properly cut, then the plant throws up a stalk, instead of leaves, and this is the death of the plant. When the plant reaches the limit of its age this stalk grows from the centre, and the plant dies. If the cutting of the mature leaves be neglected the plant throws the stalk up, and when this stalk appears there is great danger that all the plants in its vicinity will also send the stalk up and die. Some planters say that a plant, if properly cared for, will yield from 1,000 to 1,500 leaves before dying. Our frontispiece shows the general appearance of the plant when growing.

A peculiarity of the culture of the sisal hemp plant in Yucatan is that the blossoming (which destroys the life of the plant) is sometimes retarded twenty years or more after the first harvest of leaves. In other countries where the plant is grown it blossoms and dies about seven years after planting. The reason is that the climate of Yucatan is so hot and dry, and the soil so arid, being often a mere bed of semi-decomposed coral rock. In Yucatan as many as twenty crops of leaves are taken off when the plant is from five to twenty-five years of age.

The separation of the fibre from the pulpy matter which surrounds it is accomplished by scraping, either by hand or machine. In India steeping in water is also resorted to, there being a divergence of opinion as to whether plain water or a mild solution of brine, such as is obtained from springs in the neighbourhood, gives the best results.

Of machinery for cleaning the fibre, the best results have been obtained with the Prieto machine, constructed in several sizes, which will clean from 30,000 to 150,000 leaves per day, and which require from 15 to 45 h.p. to drive them. The leaves are run into the machine and held between chains while

they are scraped by scraping wheels provided with knives, against which a shoe presses the leaf being cleaned. The fibre tapers from the butt to the tip of the leaf, a single fibre being capable of bearing a strain of 9 lb.

FIG. 4.

The quantity of fibre varies from 50 to 75 lb. per 1,000 leaves; $62\frac{1}{2}$ lb. being a fair average. Where the planters take good care of the machines and the leaves are specially good, they get from 75 to $87\frac{1}{2}$ lb., but this is very exceptional.

The weight of the leaves varies, but three test runs on the Irene machine gave the following results : 1,000 leaves, weighing 900 lb., produced 50 lb. of clean fibre, loss in bagasse 12 oz. ; 1,000 leaves, weighing 1,050 lb., produced $62\frac{1}{2}$ lb. of clean fibre, loss in bagasse $12\frac{1}{2}$ oz. ; 1,000 leaves, weighing 1,350 lb., produced $87\frac{1}{2}$ lb. of clean fibre, loss in bagasse 14 oz.

Fig. 1 shows a model plant operating in Mexico, where 125,000 to 150,000 leaves are cleaned per day of ten hours by the Prieto Irene No. 21 Machine, of which two views are given in figs. 2 and 3. The leaves can be carried, in the most convenient manner, to the machine and be deposited in bundles of fifty leaves on the table. The elevator arms will take up the bundles to the top and drop them upon a rather steep incline, where the strings which hold the bundle are removed and the leaves drop on the less inclined table, where they are spread and pushed along until the feed chains which pass the leaves into the machine are reached. The machine passes the leaves automatically from one disc to the other, and the clean fibre is delivered at the rear end. A piece of wood, similar to the rail of a stairway, is placed near the rear disc, and a boy attends to transfer the fibre from the disc to the rail. As this rail is sharply inclined, the fibre slides down to the lower floor, where it is received by the men who take it to the drying racks.

Fig. 4 shows an hydraulic press used for baling the fibre for exportation.

CHAPTER V.

EAST INDIAN HEMP.

THE most important of the Indian hems are Bombay, Jubbulpore, Allahabad, and Sunn hemp. Sunn hemp (*Clotolaria juncea*) is one of the commonest of Indian fibre plants, and is cultivated from sea-level up to very high elevations. It thrives well from the Himalayas in the north to the coast of Ceylon. It is a shrubby perennial which grows from 8 to 12 ft. high. The stem is marked with peculiar longitudinal furrows, and is much branched as it grows in a wild state. In a cultivated state, the seed is thickly sown, so that the plant grows up with a straight, branchless stem.

The cultivation of Sunn hemp proper is not difficult, for the plant thrives in almost any poor soil. Sandy soils and loams are generally considered to be the most favourable to its successful growth, whilst in clay soils it is a decided failure. A better crop of fibre is obtained if the plant is not grown in a rich soil and if manures be not applied, for the richness of the soil makes the plant more vigorous and healthy, and therefore retards the formation of tough fibre. The Sunn hemp plant is either cultivated on land specially devoted to raising it, or often on the margin of fields, where spare pieces of land are covered with it. The land is well tilled and levelled, and the seeds are sown thick. An average quantity of 60 lb. of seed per acre is sown. The plants, when growing, should not be more than 2 to 3 in. apart. The crop is harvested in four

or five months after sowing. The best fibre is obtained by cutting down the plants just as they flower ; but in India the plant is not cut until the seeds are produced, the cultivators preferring to have a strong, coarse fibre which is easily manipulated rather than a superior soft kind, which, although fetching a higher price, would require greater care in preparation, and which is liable to be spoiled by the slightest neglect.

The stems, after being cut, are steeped in water for two or three days, when the bark is softened and is partially detached from the woody core. When taken out of the water, the common practice is to bend the stems and break the wood without injuring the fibrous bark, and the whole is next beaten up in water until the woody particles are removed and the fibre is held in the hand of the workman. In some places, instead of breaking the wood and then removing the parts by beating in water, the bark is pulled off just after the stems have been sufficiently soaked. After washing and getting rid of the woody particles, the fibres are hung up on bamboo poles to dry ; when dry they are combed, in order to separate the filaments from each other. The Sunn hemp is then ready for market, and is considered to be superior in strength to some Russian hems. The average produce of Sunn hemp fibre per acre is about 6 cwt.

Bombay hemp is obtained from a plant of the *Hibiscus cannabinus* family, and is commonly known in the Deccan as the *ambari*. It is an annual which is found growing wild in many parts of India, from the sea-level up to altitudes of 3,000 ft. It has a prickly stem, growing from 6 to 8 ft. in height, and has deeply cut leaves. The regular method of cultivation is very similar to that practised in the growth of the Sunn hemp plant. Moist, friable land is selected, and after preparing the soil by tilling and levelling, the seed is thickly sown broadcast. Sowing is generally done immediately after the rains, and the plants grow up in three months time and are then harvested. The stems are either cut quite close to the ground

or pulled up by the roots and made into bundles. The bundles of stalks are steeped in water for from six to ten days, and are then taken out. Each stem is held singly in the hand of the workman, and the bark is easily stripped off and washed to remove all the particles of woody matter. In appearance the fibre is white and silky, and from 5 to 10 ft. in length.

Bombay hemp is generally used in the manufacture of rope, cordage, sackcloth, &c., and is sometimes used to adulterate jute, which is a superior fibre but akin in appearance.

CHAPTER VI.

ALOE AND AGAVE FIBRE.

THE name aloe fibre includes the fibres obtained from a large number of plants of the same and allied species. Some of the best-known aloe fibre-producing plants are :—

Agave Americana (blue aloe).

A. angustifolia (small-leaved aloe).

A. rigida (Sisal hemp).

A. morrisi „

A. vivipara „

Furcroya gigantea (Mauritius hemp).

F. Cubensis (silk grass).

The *A. Americana* has a long sword-like leaf, with parallel veins, and 8 to 10 ft. long. The leaf terminates in a strong spike.

When the young suckers, which are both given off from the stem of the mother-plant and produced in the long flower-stalk, are planted in the ground, they put forth a quick growth, and become full-sized plants within three or four years of their planting.

The aloe does not flower as soon as it matures. It takes from eight to twenty years before it produces the long pole-like flower-stalk, 12 to 18 ft. in length, which bears an immense number of branches, all of which produce flowers, and at last young suckers. The fibre is found in the leaves, and is long and strong. Aloe fibre has long been used in Mexico in the manufacture of ropes and cordage, whilst in the West Indies, ropes, fishing nets, and hammocks are made from it.

In India aloe fibre is produced from the plant *A. vivipara*. The leaves are cut from the stem and split lengthwise into strips about $\frac{1}{2}$ in. wide. The strips are generally dried in the sun for about four days, steeped in running water for a period of from seven to ten days, and then beaten with a wooden mallet or against a stone.

Yucatan has a valuable fibre trade in agave fibre, its chief article of commerce being Sisal fibre, produced from the plant *A. rigida*, which grows abundantly in the country, taking its name from the port of Sisal, from whence it was originally exported. A chapter has already been devoted to Sisal, which stands highest among the aloes as regards quality and value.

The formation of an aloe plantation is not attended with much difficulty. Any dry, poor land will suit it, but rocky, gravelly soil is considered the best for producing the finest fibre.

In moist and rich lands the plant grows so vigorously that the fibre becomes poor in quality and smaller in quantity in proportion to the weight of the leaves. It is also noteworthy that a shade of any kind is always prejudicial to the plant in all stages of its growth. It is always advisable to select vigorous specimens for the purpose of planting, and the young plants which grow around the stem are preferable for the purpose to those which are produced in the flower-stalk. The rainy season should be taken advantage of for planting purposes, not that a plantation would fail by planting in dry weather, but the plants would commence their growth well and begin to yield earlier. The number of plants which should be put down per acre differs greatly according to the practice of planters. While the Mauritius planters consider 1,200 plants per acre a fair number, in Yucatan they put down only 600. In three to four years the plants begin to yield. The leaves are then cut close to the stem, and are made into bundles and sent to the mill for the extraction of the fibre.

There are various methods in use for the extraction of the fibre from aloe leaves. In Yucatan it is frequently extracted by Death's fibre machines, with a wheel 50 in. in diameter and 8 in. face, which carries eight knives or scrapers, and is driven by a 10-h.p. engine, nearly 8,000 leaves being prepared in a day.

In Mauritius the natives extract the fibre by striking gentle blows on the leaf with a piece of wood to bruise the pulp and render it less adherent to the fibre, which they then scrape by hand. In large plantations machines of various sorts are used, one of the favourites being the Marabel machine. In Mauritius the production of fibre per acre ranges from 1 to 2 tons. Aloe (*A. Americana*) yields 6 to 7 per cent., but in many places not over 3 per cent. of fibre from the green leaves.

Aloe leaves contain a large percentage of pulpy matter, amounting to from 96 to 98 per cent. of the weight of the leaves. Wrought iron is attacked by aloe juice, which is strongly acid. Cast iron, however, is but little affected by it, and bronze not at all. The leaves must always be treated when in a green state, for when the leaf gets yellow it becomes nearly dry, the fibre loses its strength, and the once pulpy substance adheres firmly to the fibre, making it unfit to be worked, as the fibre in this state can hardly be separated. When the fibres come out of the extracting machine they are gummy and still moist. They should consequently be steeped in hot water from twelve to fifteen hours before being dried and packed.

CHAPTER VII.

NEW ZEALAND HEMP.

THE New Zealand hemp plant (*Phormium tenax*) is abundant in New Zealand, and is also found on Norfolk Island. Captain Cook discovered the plant in the course of one of his voyages, and it is recorded in his diary that "the country (New Zealand) produced a plant like flax, of the nature of hemp or flax, but superior in quality to either of these; the natives make clothing, lines, nets, &c., from it."

In appearance the plant resembles the ordinary flag or sedge, but varies greatly in the length of leaf, in the degree to which the leaf is curved and split at the top, in the general colour of the leaf, in the tint of a coloured line that borders the margin and midrib of the leaf, and in the colour of the flowers and the size of the capsule. As a rule the flower is reddish and the capsule three-cornered and straight.

The stem is not well defined; the leaves are long and sword-like, varying in length from 5 to 7 ft. They are hard in texture, contain but little moisture, and are perennial.

There are nearly 100 varieties of the plant growing in New Zealand. These may be roughly divided into three sorts, *viz.*, the hill, the swamp, and the téhore varieties. The last-named grows on ordinary plains, and bears shorter leaves than does the swamp variety, but produces a better quality of fibre. The swamp, and commonest, kind, of course, grows in marshy places. It grows in both fresh and brackish waters, as well as by the sides of running streams. This species yields a large quantity of fibre of coarse quality. The first,

or hill variety, has leaves of comparatively small size, which seldom exceed 5 ft. in length, and which produce the best quality of fibre. Originally the plant grew quite wild, but since the fibre became an article of commerce it has been regularly cultivated in some places.

As a general rule the plant grows best on swampy ground, where it is found in abundance, as well as on the sea coast, but some kinds, notably that known as the yellow hill plant, affect localities that are not swampy or damp.

In forming a plantation, if the land be swampy trenches should be dug at convenient distances to prevent excess of water. The suckers are obtained from the buds or side-shoots of growing plants. When such are unobtainable, seedlings may be obtained by planting seeds in a special seed bed. The suckers are planted in lines about 6 ft. apart, the plants being about the same distance apart in the row, an acre thus holding about 1,000 plants.

The leaves of the New Zealand hemp plant are not fit for cutting until the plant is five or six years old. The best and finest fibre has a silky lustre, and is procured from the fresh green leaves. The fibre resembles Manilla somewhat, but is of inferior quality and strength. The average length of the fibre is about 10 ft.

When the long flat leaves are cut down they are submitted to the action of a stripper, similar to the flax scutcher's handles, which detach much of the bark. The partially cleaned fibre is then put into a trough through which water circulates, and is washed and scraped with a flat piece of wood. The fibre is then "grassed" and partially bleached by the action of the sun and air, after which it undergoes a further scutching process, which softens, cleans and renders it a saleable article.

The yield of cleaned fibre is about 12 per cent. of the weight of the green leaves.

This fibre first attracted the attention of the colonists during

the American Civil War, when there was a general scarcity of textile fibres. Until the year 1860 any fibre which had been placed on the market was extracted in a primitive fashion by the natives. A few years ago the New Zealand Government offered a bonus of £1,750 for a machine or process for extracting the fibre by clearing away the bark and gums and producing the best quality and quantity of clean fibre. A further bonus of £250 was offered for a machine or process for treating the tow or waste, so that it might be used for textile purposes. Various machines were offered, but have proved failures in regard to coming up to the requirements of the New Zealand Government. Notwithstanding this, New Zealand fibre as at present extracted has been of late years more and more utilized, and its exports from the Colony have increased annually, last year amounting to no less than £900,000 worth.

Land-owners charge a royalty of 12s. per ton for the right to gather leaves for extraction purposes, and the cost of packing and baling comes to about another 2s. The plant yields in New Zealand from 12 to 18 tons of leaves per acre of uncultivated land per annum. On cultivated land a yield of about 50 tons may be expected.

As exported New Zealand hemp is a coarse fibre only suitable for ropes, binder twine, &c. It is classed as "good fair Wellington," "fair Wellington," &c. Quite recently the New Zealand Government have issued bye-laws with reference to the grading the fibre and controlling the industry. These rules are briefly as follows:—

(1) All New Zealand hemp for export shall be packed in bales of the following dimensions, or thereabouts:—

Length after leaving press	...	...	...	...	...	4 ft.
Width after leaving press	...	...	...	...	...	2 ft.

(2) No bale shall contain any hank exceeding 5 lb. in weight.

(3) Each bale shall be securely bound with five ropes made of the fibre. No rope made of tow to be used.

(4) The following will be the standards on which the grades will be determined :—

1st grade (superior)	91 to 100 points, both inclusive.		
2nd „ (fine)	81 to 90	„	„
3rd „ (good fair)	71 to 80	„	„
4th „ (fair)...	61 to 70	„	„
5th „ (common)	51 to 60	„	„

(5) Any bale of the fibre awarded less than 51 points will be condemned.

(6) A tin tag is to be placed in the middle of the bale, connected by wire with a leathern one at the other end, upon which in large letters will be the brand or mark and the number of the bale, and a space will be left on the leathern tag for the grader to affix the grade tally.

No fibre will be graded while in a wet or damp condition.

In grading the fibre the following will be the maximum points for allotment :—

For stripping	...	...	...	...	20 points.
For washing	...	...	...	...	20 „
For scutching	...	...	...	..	20 „
For colour	...	...	...	...	20 „
For strength	...	...	...	...	20 „

No hemp will be allowed to be exported from the Colony unless examined by the grader and the tally of quality affixed to each bale.

The alterations in the grading came into force on September 2, 1907.

It is expected that the enforcement of these rules will lead to a decided improvement in the quality of the fibre exported.

When chemically treated the New Zealand hemp fibre may be spun much finer than it usually is, and woven into canvas, &c. A process of this sort has been patented by a German chemist. He recommends the selection of the leaves of the younger plants. Removing the brown edges, he boils the leaves in a solution of the alkaline salts, borax, soda, or sodium bicarbonate. The moist and warm leaves are then to be beaten with wooden hammers until the woody tissue has

been loosened and opened up. The fibre is then to be completely cleaned by washing in warm soap and water and subsequently hackled.

The present value of the fibre as now imported is about £30 per ton for "fair Wellington," which quality is usually regarded as a base.

Mills are now springing up all over the country, but the Auckland district still leads, although just around Foxton in the south there are about thirty-six mills at work. During the last ten years the exports of fibre have risen from 2,000 tons to 280,000 tons.

A crop can be taken every three years from each plant about 8 tons of green leaves producing 1 ton of fibre.

CHAPTER VIII.

RAMIE, RHEA, AND CHINA GRASS.

RAMIE, rhea, and China grass are the strongest of all the textile fibres, and possess many other valuable qualities, such as lustre (almost equal to that of silk), non-liability to rot in water, and superior dyeing properties. Nevertheless, owing to difficulties which have been encountered in its preparation, its manufacture has not yet attained the importance of that of cotton, hemp, or flax.

There are two sorts of plants which produce ramie, or fibre, of similar appearance : one called the *Boehmeria tenacissima*, has leaves of which the backs are green; the other, the *B. neri*, has leaves with white backs and is the ramie plant proper, the former plant being often called rhea. Ramie fibre is generally of a brighter colour than rhea, and is finer but rather weaker. The fibre called China grass is produced from either of these plants.

Rhea is grown in Sumatra, Borneo, Java, Malacca, India, and Mexico; ramie principally in China and Formosa. The attempts which have been made to cultivate the plant in European countries have ended in failure, as the winter is too cold.

A suitable soil is one which is moist but not sodden; a friable loam with a porous subsoil. A hot and rainy climate is the most suitable, for dry heat kills the plant. It is perennial, and gives from two to five crops of fibre per annum for many years in succession. When the plant is produced from seed it is only possible to get one crop of fibre the first year,

but if root-cuttings be planted two crops are usually gathered. An acre will produce about 16 tons of green stems per annum, if four crops be taken, and from these stems about 130 st. of fibre may be extracted. If the plant be produced from seed, the latter should be germinated in open boxes placed under cover. The most approved way is to first fill all the boxes with earth and then spread over the surface a thin layer of fine loam in which the seeds are mixed. No watering should be done for fully a week, when the seed-leaves begin to appear. The plants may then be watered with a fine watering-can. When the young plants are about 2 or 3 in. high they should be carefully transplanted into specially prepared beds, care being taken that the roots are kept surrounded with a ball of earth. They should be set at a distance of about 3 ft. from each other, as in this way too much branching is prevented, branching producing short fibre. When the stalks are long enough they are cut down. The stalk is built up of woody matter, of the fibre, of gum, and of an exterior skin or epidermis, the removal of which is most difficult and forms the object of the decorticating process.

Decortication should be practised on the stems when in a green state, because when they become dry the outside skin becomes hard and brown and most difficult to remove. Up to the present time no machine has been found to give such good results, as regards yield and clean fibre, as the manual process practised by the women and children in China, who produce from the ramie or rhea plant the fibre known as China grass. Hand decortication is a long and costly process, because a woman can produce only a few pounds of fibre per day. This she does by placing a few green stems on a flat board and scraping them with a piece of wood in order to remove the woody matter with as much of the gum as possible. China grass produced in this way costs about £50 or £60 per ton. A good decorticating machine should do the work as well as

it can be done by hand, without breaking or "slaving" the fibre. If the fibre is broken in the process, the yield obtainable from the combing machine is much diminished. Many decorticating machines have been patented, but most of them have been found defective.

When the commercial fibre arrives at the mill it still contains from 20 to 30 per cent. of gum, which must be removed before it can be spun into fine yarns. The degumming may be conveniently affected by employing the process and the apparatus invented by Boyle. This process consists in passing the material through tanks of chemical solutions. The first trough contains a weak soda lye, and the second a feeble solution of hydrochloric acid, which acts upon the soda remaining in the fibre and sets up fermentation. The third tank is similar to the first. The fourth contains a solution of permanganate of potash, and the fifth a mixed solution of hyposulphite of soda and hydrochloric acid. The sixth tank contains hyposulphite of soda, and the seventh a solution of hydrochloric acid. On leaving the latter bath, the fibre is washed in pure water, and then steeped in a weak solution of soap and water in order to give it back a little of the oleaginous matter extracted by the action of the soda. The material should be passed through these successive baths between endless open-work travelling aprons, in thin layers, in order that the fibre may preserve its parallelism and not become too much matted. Between each bath it passes between wringing rollers to remove superfluous moisture.

True China grass, from which much of the gum has already been removed by hand scraping, does not require such severe chemical treatment as that just described. It is sufficient to boil it in soda lye, to steep it in chloride of lime solution and then in an acid bath, repeating the two latter processes, with a washing in pure water between each, until the gum has completely disappeared and a pure white filasse is produced. The fibre should be placed in the boiling kiln between trays of wire

network, one above the other, to prevent the matting of the fibre. The trays of the fibre are placed in the pot with the lye at 3° Tw., and allowed to boil for about seven hours. The fibre is then taken out, rinsed in pure water to remove all traces of soda, and then steeped for ten or twelve hours in chloride of lime solution at $\frac{1}{2}^{\circ}$ Tw., contained in a stone trough. When taken out of this steep it is again rinsed in pure water and placed in a solution of sulphuric acid or oil of vitriol of 1° Tw., where it is left for some hours, and then again thoroughly washed. If all traces of gum have not completely disappeared the two latter processes are repeated as frequently as required.

After the fibre has been submitted to all this chemical treatment it will be found to be rather harsh and dry. In order that it may lend itself easily to the spinning operations, it will be found advantageous to give it back its suppleness by treating it with oily matter, or "prepare," to replace that which has been removed by the action of the soda and the acid. A good result will be obtained by steeping the fibre, before finally drying it, in an oily solution prepared as follows: To every 15 qt. of boiling water add 7 oz. of glycerine, 7 oz. of Castile or white oil soap, 4 oz. of white wax, and 2 oz. of tallow; 5 oz. of olive, castor, or rape-seed oil, with 5 gr. of caustic potash, may be used instead of soap if desired.

CHAPTER IX.

COIR.

COIR is the fibre extracted from the husk of the cocoa-nut. In the Philippines the fibre of the cocoa-nut is taken in its natural condition, and split and combed until it is suitable for twisting into yarn.

The fibre is held in high esteem for certain purposes, such as for tow-ropes, on account of its strength, lightness, and elasticity. Increased elasticity, a factor of great importance in tow-ropes, is given to those made from coir fibre by forming and laying the strands with the twist in the same direction as that of the single yarn, a practice quite at variance with the usual usages of rope-making.

Coir comes to us chiefly in the form of single or doubled yarn produced by the natives by twisting between the palm of the hand and the thigh. The fibre is difficult to spin mechanically, the best results being obtained with a hand-fed one-spindle spinner.

Hand-spun coir yarn is largely imported from India and Ceylon. The price of Cochin yarn usually varies from £10 to £17 per ton. Common and fair Ceylon weaving yarn sells at from £17 to £22 per ton, and Ceylon mattress at £8 per ton. Coir resists the action of salt water. It soon rots, however, in fresh water.

CHAPTER X.

FLAX.

THE plant which yields flax fibre is unique in its history. Cultivated for the last 5,000 years or so, it has not been replaced by any modern fibre. It was grown in Egypt and Southern Europe in ancient times, and at the present day is one of the most important vegetable products grown in Russia, Austria, Belgium, Holland, Italy, and other European countries, as well as in Egypt, Turkey, India, China, and Japan.

The figures depicted on the walls of ancient Egyptian tombs have among them representations of the flax plant. The mummies which have been discovered in the same country are wrapped in linen, many of them being considered to be dated not later than 2300 B.C. Ancient Greek authors make frequent mention of flax as a textile material. The remains of flax fabrics have also been discovered in the pile dwellings bordering the Swiss lakes.

In its cultivated state the flax plant is an annual, growing from 20 to 40 in. in height, with alternate sessile leaves, narrow and lance-shaped. It bears a cluster of blue or white flowers on its top, which in the course of time produce capsules, having five cells containing ten flat, oily seeds, either red or white.

A deep sandy loam is the soil which best suits the flax plant. After a fine and level seed-bed has been prepared by ploughing and harrowing, a reliable brand of seed should be sown rather thickly broadcast over the field and covered in by the passage of a harrow.

The fibre produced is of better quality when the seed is thickly sown, since the stems then grow up straight, and do not branch until quite high up. Branching spoils the quality of the flax for spinning purposes, and is to be avoided. Two and a half bushels per acre is a suitable quantity of seed to give good results. When a "braird" appears, and is a few inches long, the field should be carefully weeded, as the value of the fibre will be much reduced if it be afterwards found that weeds are mixed with it. Towards the middle or end of August the plant should be ready for pulling. The best fibre is obtained if the flax is pulled before it has quite reached maturity, or at the moment when the stems begin to get yellow

FIG. 5.

at the base, and the seed bolls become firm. When hands are obtainable the stems should be pulled up by the roots, as the fibre which they contain is then more suitable for spinning than if the stems be cut down, as they sometimes are in America, where labour is scarce and dear. In pulling it is of the utmost importance that the long and short stems be kept separate as much as possible, and also that the root ends be kept perfectly even, as the yield of fibre will be thereby improved, both in the subsequent scutching and hackling processes. As the cultivation, harvesting and retting of flax straw is a regular industry in Belgium, and particularly along the banks of the River Lys, on both sides of Courtrai, we will give a description of the methods there employed as representing the best practice.

The Flemish pullers pull the flax straw up in handfuls about one-half larger than they can grasp in one hand. When pulled they spread it a little as they lay it on the ground in rows. The bunches should be laid with tops and roots alternating, which prevents the seed bolls from sticking to each other in lifting. The straw is stooked as soon after pulling as possible, and never allowed to remain overnight unstooked, except in settled weather. The stooking goes on at the same time as pulling, as if rain comes on while on the ground its colour is injured. A good stoker can put up the produce of an English acre per day with two boys or girls to hand him the bunches. The flax straw is handed with the tops to the stoker. The handfuls are set up resting against each other, the root-ends well spread out, and the tops

FIG. 6.

joined like the letter **A** as shown in fig. 5. The stooks are made 8 or 10 ft. long, and are very narrow at the top, and the straw thinly put up, so that it may dry. In six or eight days the straw is ready for tying into sheaves, like corn sheaves, (see fig. 6). It is then ricked (see fig. 7), and allowed to stand in the field until the seed is dry enough for stacking. In building a stack (fig. 8) two poles are laid parallel on the ground, as shown in the figure, about 12 in. apart, with strong upright poles at each end. The straw is then built in, the length of the sheaf in thickness or breadth. The bottom poles are laid north and south, so that the sun gets at both sides of the rick during the day.

In building, the sheaves are laid tops and roots alternately, built 7 or 8 ft. high, and finished on the top by laying a single row of sheaves lengthwise across the others, and then another

row as before, but with the tops all the same way, which gives a slope to throw off the rain. The stack is then finished by putting a little straw on the top and tying it down with a rope. In this way, if properly built, it stands secure for months or years without injury.

Under the Courtrai system the seed is taken off during the winter and the straw restacked or kept under cover until the spring, when it is sometimes watered, grassed, &c. It is generally considered better, however, that the flax straw be kept for at least a year, and it is often kept for two years before steeping.

To remove the seed the sheaves are loosened and the straw spread flat upon the ground, the top ends being struck with

FIG. 7.

the implement shown in fig. 9, which knocks off the bolls. The straw is then bound up again as before and restacked or stored.

In steeping, the bundles of flax straw are packed either horizontally or vertically in large wooden crates lined with straw. The upright position is usually adopted, as it is said to be more favourable to the production of light-coloured fibre, as no sediment or deposit can rest upon it at any stage of fermentation. The crates or ballons are about 3 or 4 ft. deep, and usually contain about 150 bundles or beets from 8 to 12 in. in diameter. Straw and boards are afterwards placed on top, and the crate thus charged is anchored in the

stream and weighted with stones, so that it is submerged a few inches below the surface. In a few days fermentation begins, and as it proceeds additional weight must be added from time to time in order to prevent the rising of the crates through the evolution of gas. As a rule, after steeping a short time the flax is removed from the crates and set up in a hollow sheaf (fig. 10) to dry. It is then repacked in the crates, and again steeped until the retting is complete. According to the temperature, quality of flax, &c., the duration of steeping is from seven to twelve days, say about seven days in August, ten

FIG. 8.

in May, and twelve in October. The end of the process is accurately determined by occasionally examining the appearance of the stems and applying certain tests. The bundles of straw should feel soft, and the stems should be covered with a greenish slime easily removed by passing them between the finger and thumb. When bent over the forefinger the central woody portion should spring up readily from its fibrous sheath. If a portion of the fibre is separated from the stem and suddenly stretched, it should draw asunder with a soft, and not a sharp, sound. When the retting is complete the flax straw

is carefully removed from the crates and again set up in sheaves to dry, as shown in fig. 10.

The retted and dried straw is then stored in barns and sheds until winter, when the "scutching," or cleaning the fibre from the woody part of the stem, takes place.

In Ireland and elsewhere flax straw is retted in dams 9 to 10 ft. wide and 40 to 50 ft. long, and not more than 4 ft. deep. A dam of this size should be of sufficient capacity to ret the product of one acre. As the dams must be water-tight, the best soil to make them in is clay. Their position should also be such as to command, if possible, a supply of water at the right time. Of course, if a proper level can be obtained near a large

FIG. 9.

supply of water, the dams can be filled at any time, but when surface water is to be depended upon attention must be given to secure a sufficient supply beforehand. Bog water is liable to cause discoloration, and spring water is generally too hard. Where rain-water can be gathered it is best, being free from mineral impurities. Water containing lime is quite unfit for flax-steeping, and should on no account be used. Even good soft water must be gathered with discretion, for if allowed to stand too long in the dams before being used it may become stagnant. This must be avoided, for no matter how offensive flax water may be after retting, water already stagnant should not be used for flax. Having the dams now thoroughly pre-

pared, and either supplied with water or in such a position that water can be turned on at pleasure, the flax is arranged in the following manner: A row of beets or sheaves is placed against the end of the pond, almost perpendicularly, but, of course, leaning against the bank. Then the next row is placed leaning against the first one, and so on until the dam is filled. The beets should be all placed with the root ends down, though in some cases every second row has been reversed without any appreciable effect; flax will ret in any position. The reason, however, given for keeping the head of the plant up is, no doubt, a good one, namely, that the finer end of the stem requires more retting than the coarse, and, being next the air

FIG. 10.

and heat, this process is accelerated. If the dam is not too wide—say 8 to 10 ft.—a plank or two across the top will facilitate the work, and save the workers from standing in the water, and if it is 4 ft. deep the beets set in on end will not reach the level of the bank, and a layer may be placed flat on top of the others. Next a covering of straw or rushes is spread over the whole, and securely covered with sods well fitted together. If these are not convenient, old boards with stones on the top are made to serve the purpose, or, if broad flat stones are at hand in sufficient numbers, boards are dispensed with, the object in view being to keep the flax below the surface from 8 to 10 in. During fermentation, at an early stage, a certain amount of inflation takes place, and additional weight is put

on to keep any portion of the flax from rising above the water. After this stage is passed the load is gradually diminished, since the flax settles down in the water of itself as the retting draws to an end. In order that these natural movements during fermentation be not impeded, it is necessary that the beets be not too tightly tied or too closely packed in the pond.

The continued tendency of the flax to sink down, requiring the removal of extra weight, is in itself taken as a sign that retting is approaching completion, and that careful attention is needed. No absolute rule can be given as to the number of days required in the water, but ten to eleven is a usual time. Two circumstances contribute to this uncertainty: one is the quality of the water used in the fermentation, which, of course, varies so much that it cannot be accurately gauged beforehand; the other is the temperature of the season and the strength of the sun, and just as these causes may be acting will the results be hastened or retarded. Water readily acted upon by the chemical constituents of the flax straw, and which at the same time happens to be affected by a strong sun, will exhibit a change within twelve hours, whilst in water of greater hardness or under a lower temperature, or where both are in conjunction, no change will be observable for twenty-four hours, or even longer. Consequently, the number of days required for retting can only be guessed at, having regard to these conditions. At the time of year when retting usually takes place in Ireland, the rivers are liable to be flooded. Every precaution has, therefore, to be taken to lead these floods or heavy rains away from the dams, as an influx of fresh running water would retard the whole process, to the detriment of the fibre. Flax water cannot be used a second time for steeping, for, as already pointed out, stagnant water is quite unsuitable. If a dam is to be used a second time in the same season it should be well cleaned, as any sourness remaining after the first fermentation will undoubtedly be injurious.

After the straw has been thoroughly retted it must be

immediately removed from the water, as delay is most injurious. Although the subsidence of the flax in the dam may be taken as a general sign that fermentation is over, the precise moment for lifting it from the water is more difficult to determine. Among several tests employed by farmers we may cite the following: (1) Double up the straw, and if sufficiently retted the core or heart will break and not bend, as in the green state. (2) Take a few stalks in both hands, hold one hand steady and move the other a little backwards and forwards, and the woody part will separate from the fibre if retting is sufficiently advanced. (3) Attempt to draw some inches of the shove from the fibre without breaking it; if retted this can readily be done. (4) Catch the straw in both hands and twist smartly, and the fibre will become detached from the core. (5) Pull the straw over the forefinger, under the thumbnail, and observe whether the glutinous or slimy substance of the green flax may be freely squeezed out. When these various trials indicate that the flax is not quite ready for lifting, the farmer examines it three or four times a day until the right moment arrives, and then acts promptly. When satisfied that all is ready, the beets are lifted separately from the dam, being given a gentle plunge or shake in the water to remove any dregs which may have settled upon them, and left to drain upon the bank of the dam. Although disagreeable, the safest way of lifting it is by standing in the water.

After the beets are drained for a short time they are removed to a convenient place for the next operation, called spreading or grassing. Clean, short pasture land, or meadow recently cut, is the most suitable. The beets are carefully laid down in rows along or across the field, the bands removed, and each beet spread out thinly and regularly, the root ends being kept as even as possible. Turning on the grass is sometimes resorted to, and has some advantages, the chief being that the flax is more evenly acted upon by the sun and air. The danger is, however, that at the time of year this takes place

high winds may prevail, and the flax, when turned, lose the hold it had on the short grass and be tossed about and injured. When turning is resorted to it is conducted as follows: A light rod, firmly held, is steadily pushed under the heads of the flax, and the entire layer folded quickly over, by which means the underside is brought uppermost. The operation is carefully carried out down each row till all the flax is headed in an opposite direction to the first spread, but in this partially dry state it will not adhere to the ground as firmly as when brought from the dams, and for this reason it is better to turn before rain, so as to assist the stems as much as possible to adhere to the grass and resist the effect of high winds. Three or four days are often sufficient for this stage, but as much as ten days is sometimes required, for the softening influence of the weather should be complete before the straw is again put into bundles. The straw, being dried and bundled, is either stacked on the farm or at the scutch mill until the scutching commences. It is unnecessary to recommend that the straw should never be lifted in rainy weather, as it would then be liable to heat. The greatest care should be taken in lifting to have the root ends even, because in whatever manner it is tied up at this stage, so it is put into the hands of the scutcher. If put up in a slovenly and irregular manner, it leads to much unnecessary waste at the mill. There are few seasons when there is not sufficient sunshine and dry weather to have the flax lifted off the spread, tied up, and stooked in good order. Under no circumstances should the old practice of drying on a kiln be resorted to, as it is very injurious to the flax and lowers its market value very much. If the weather should unfortunately be so inclement as to make sufficient drying in the field impossible, the straw may be removed to some barn or loft, and carefully watched until all danger of heating is past. If properly dried it will safely keep, and storing it for some time has a good effect upon the quality of the fibre.

Another method of retting is practised in some parts of Russia, France, and Belgium. It is termed dew-retting, and consists in spreading the freshly pulled straw lightly over a field and allowing it to remain there until the action of the sun, rain, and dew has accomplished the partial dissolution of the gummy matter which binds the fibre to the wood.

Of the various systems of retting, that effected in a slow current of running water undoubtedly gives the best results as regards colour and quality of the fibre produced. There are very few rivers like the Lys, with a slow enough current, while the poisonous effect of the flax water on the fish in the river causes flax steeping to be prohibited in a number of other rivers. Of recent years, however, Continental experts have studied the question of producing the same effects by other means, and a rettery is now working near Bruges which is producing even better flax, both as regards colour and quality, than that produced on the Lys, over which steep it has the further advantage that it can be carried on all the year round, whereas the factors on the Lys have to discontinue operations during the winter months.

The new retting system referred to is known as the Legrand system, and is one which might be advantageously adopted in all flax and hemp-growing countries, and carried on by a company or by a co-operative society of farmers. Briefly described, the process is as follows :—

The sheaves of flax or hemp straw are placed upright in openwork crates, similar to those used on the Lys. These crates are loaded upon small trucks and wheeled under an overhead travelling crane, which raises them and lowers them into the first of a series of three tanks. The crate remains there for about twenty-four hours and is then raised and submerged in the second, or retting tank proper. While in this tank it is raised and lowered repeatedly, to which operation a large part of the success of the process may be attributed, for air and oxygen are thereby introduced into the water and fer-

mentation thus increased. The retting operation is then completed on the third day, in the third or rinsing tank. The operations are continuous, the tanks being all kept full and their contents passed on in sequence. Only a very small quantity of water is required and is admitted to the third tank, and from thence led to the second and first tanks by means of syphons, entering through the perforated bottoms of the tanks and rising up through the stems. The current of water thus resembles that in the River Lys, but while the quality of the water of the river varies from time to time, the flow of water through the tanks is perfectly uniform, both as regards quantity, quality, and temperature. The direction of the current of water through the tanks being parallel with the stalks of the flax instead of perpendicular to it, as in the river, is another factor in favour of the new process, assuring more active and regular fermentation.

When the crates of fully-retted straw are lifted from the last tank they are deposited upon a truck and allowed to drain before being removed to the drying-ground or shed. The mechanical manipulation of the wet straw is in itself a great advantage, for the handling of the wet straw in the usual way, before the slimy matter has had time to dry, does not improve the quality of the fibre.

Owing to the methodical and regular manner in which the retting operation is conducted, flax and hemp retted under the Legrand system is more regular in strength and colour than those produced in any other way, and it is universally admitted by experts to be worth even more than fibre from the same straw retted in the Lys. It has besides, as we have said, the advantage that it can be carried out in any flax-growing centre, and the operation performed all the year round without stopping.

The period required is reduced to three days instead of fifteen or eighteen days, and a considerable reduction is effected in labour, for two men can ret two tons per day. The production of "water-slain" fibre is avoided. Water-slain fibres are

those wholly deprived of their gum and thus of all strength. They are produced at the end of the usual retting process, when that portion of the gummy matter which should remain in the fibres is reduced to a mucilaginous state and is removed by too strong a flow of water or by the friction of the workman's hands. Under the Legrand process the straw receives no bruise, friction, or impact of strong water-current. Through each little channel formed by the spaces between the stalks, there is no motion beyond the very feeble and slow circulation of the water.

The small but constant run-off of water from the retting tanks, which contains a large percentage of phosphoric acid and potash and is a valuable manure, may be absorbed by the land, and is thoroughly filtered before reaching a river. Undoubtedly this system of retting is rational and gives the fibre its full value, and is therefore worth applying to all flax and hemp straw except where the increased value of the fibre does not repay the expense involved. At first sight this would seem to be the case for all low-class flax and hemp, since, for these, retting establishments in practice do not exist or consist merely of a hole or pond with a few boards and stones, while the labour is that of agricultural hands at small wages or of the farmer and his family, in which case the expense is not taken into account. But note, as against this, that the degree of inferiority of the work increases out of proportion to the lowering of the cost; that is to say, that the loss sustained through this bad workmanship, both in yield and quality, is nearly always greater than the saving effected in cost. No one need wonder at this when it is borne in mind that the large proportion of stalks are too much or too little retted in the straw handled by farmers, and, of course, the over-retted stalks will go to tow in scutching, and the insufficiently retted ones will give a dirty fibre of very low value.

If tanks were universally used, things would be different. Everywhere large farmers could easily construct a small in-

stallation of tanks for their own use, and in flax-growing countries small farmers could do the same by co-operation, while rural authorities could also get local retting places constructed. Besides, the installations of some farmers, too large for their own production, could by them be placed at the disposition of others for a small rent, so that the proprietor would reap the advantage of being able to ret his own crop quickly without having to leave his retting establishment inoperative during the remainder of the season.

These different combinations would, of course, allow the farmer to continue retting his own crop and would also induce him gradually to relegate it to specialists. It will easily be seen that, according to circumstances, the retting could be charged for while the farmer continued to scutch at home, or the scutching also might be done by the retters either at home or in steam mills, or else the farmer might sell his retted flax to the scutchers or dispose of the straw "on foot" to the retters, and so on.

In Ireland and Russia the flax straw is pulled and retted by the farmers and peasants themselves. The consequence is that through lack of skill, care and scientific knowledge, dirty, poor, irregular, over- and under-retted, water-slain and badly handled fibre is produced which fetches less than one-half the price which the same flax would if otherwise treated.

In Ireland, flax succeeds best if sown after potatoes, wheat, or oats. A very good rotation of crops is oats, turnips, wheat, clover and grass, potatoes and flax, for flax should not be sown in the same field more frequently than once in every seven years. Care taken in the preparation of the soil is amply repaid. Weeds allowed to grow up with the flax greatly interfere with its subsequent handling and scutching, and lower its value. After potatoes or wheat, one ploughing in the early spring on light or medium land is sufficient, but in heavy soil two ploughings are necessary—one fairly deep in the autumn and the other before sowing time. Harrowing is

very essential. Rolling precedes sowing, so that clods may be broken up and a fine seed-bed prepared.

Good seed is essential to success. In Ireland Dutch seed has been found the most suitable for heavy land, and Riga seed for medium. Good seed is heavy, plump and glossy, and weighs about 56 lb. per bushel.

About 2 bushels of seed are usually sown broadcast per statute acre. The seed is then rolled in and with a favourable temperature comes up in from seven to nine days. As the plant approaches maturity, the stalks turn yellow, the seed bolls change from green to a pale brown, the leaves begin to fall off the lower part of the stem. The state of the seed capsule is the best guide as to the proper time for pulling. The seed capsule when cut across with a sharp knife should show the contents to be of a green shade and firm. When this stage of maturity has arrived there should be no delay in pulling, as the seed will, with the heat of the sun, quickly draw away from the stem the most nutritive substances, leaving the fibre dry and husky.

In Ireland retting is effected in dams, but is frequently spoiled by unsuitable water, or by the admission of fresh water while fermentation is in progress. The average cost of producing an acre of flax in Ireland may be made up as follows:—

				£	s.	d.
Rent and taxes	...	...	...	1	14	6
Seed	...	...	...	1	5	0
Preparing the land		...	...	1	3	0
Sowing	...	...	...	0	7	6
Weeding	...	...	...	0	5	0
Pulling	...	...	...	0	10	6
Retting	...	...	...	0	5	6
Grassing	...	...	...	0	12	0
Scutching	...	...	...	1	13	0
				<hr/>		
				£7	16	0

Flax scutch mills represent a rural industry of considerable extent in the North of Ireland, and during the autumn and winter months are centres of great activity. Each mill contains a set of rollers for breaking or crushing the straw, and a number of stocks and beaters for cleaning the fibre. The mills are of various sizes, and are classed according to the number of stands and stocks they contain, each stock being used by one man, and consisting of an upright board or iron plate, over the upper end or in a slot in the side of which the flax is held by the worker who stands on one side, whilst the beaters strike the ends of the flax in rapid succession on the other. The beaters or handles are five or six in number, fixed in a horizontal shaft, which revolves at a high speed. The flax, divided into handfuls or stricks, is handed to the scutchers, who first put the one end and then the other over the stock, and thus clean it for its entire length with perfect ease, if properly retted and rolled or broken. The stricks or streaks pass through the hands of several scutchers, called buffers and finishers, after which they are tied up in bundles and made ready for market.

Flax straw loses on the average about 25 per cent. of its weight in the retting process. The yield per cent. of scutched flax fibre from retted flax straw is about $18\frac{1}{2}$ per cent., or 14 per cent. on the straw before retting. An acre of fairly good flax is estimated to weigh on foot, or when freshly pulled, about 5 tons. In drying, it loses rather more than one-half its weight, say about 55 per cent. Rippling further reduces its weight by about 20 per cent. Steeping reduces the weight by another 25 per cent., and if the yield of fibre be taken at 18 per cent. the loss in scutching would be 82 per cent.

The following figures, which show the above more clearly, trace the flax from the field to the market.

One statute acre of green flax weighs, say 100 cwt. = 5 tons.

Drying takes away 55 per cent. ... 55 „

Leaving ... 45 „

Seeding or rippling takes away 20 per cent. 9 „

Leaving ... 36 „

Retting or steeping takes away 25 per cent. 9 „

Leaving ... 27 „

Breaking and scutching take away 82 per

cent. ... 22 „

Leaving ... 5 cwt.

Or 40 stone per acre.

Taking the average cost of production as £7 16s. per acre, the average yield of fibre per acre, $37\frac{1}{2}$ stones, the average value of the flax per stone as 6s., the profits per acre would be £11 5s. *minus* £7 16s., or £3 9s.

The gross acreage of land under flax in Ireland has varied from 67,444 acres in 1893 to 229,178 acres in 1869, while prices have averaged from 5s. 6d. per stone in 1895 to 9s. 9d. per stone in 1869.

Flax from almost every flax-growing district of Ireland has its special characteristics. Fibre from the Cookstown district is of the best produced, being a strong, warpy flax. Magherafelt, Randalstown, Lisnaskea, Armagh and Newry all produce good flax. Monaghan, Cootehill, and Ballybay are, as a rule, of medium strength. Strabane and Letterkenny are generally wefty and badly handled. County Down flax is very often of a light colour, and a large-fibred thread flax. Strabane, Letterkenny and Ballymoney flax is generally made up in large bundles containing about 3 stone, and sold at so many shillings per hundredweight. In the other Irish flax markets flax is sold per stone of 14 lb.

Irish hand-scutched flax is getting rarer and rarer. Hand-scutching used to be a favourite winter occupation for the farmer's family, but old times are changed, and the flax is now almost invariably sent to the scutch mill. To facilitate the

hand-scutching process, the peasants dried the straw in the smoke of the chimney, which gave the flax a smoky smell, and an appearance not unlike Riga flax.

It is only in the vicinity of Yale, in Eastern Michigan, at Northfield and Heron Lake, Minnesota, and at Salem and Scio, Oregon, that flax is cultivated in America for fibre. In all these localities the seed is also saved, and it is doubtful if the industry would yield sufficient profits from the production of fibre alone to warrant its continuance under present conditions. In the State of Oregon, U.S.A., the valley of the Willamette river, along the river bank and railway, for a distance of 150 miles, is particularly well suited for the cultivation of flax for fibre. As regards climate, the temperature is very regular all the year round; it is rare to have a fall of snow or hail, storm of rain, or tempest to lay the flax. The mean rainfall is 46 in. Rain seldom falls from June 15 to September 1. Flax has been cultivated for a long time for seed, and the Oil Trust has a large crushing mill at Portland. Mr. Bosse, Belgian flax expert, has shown that the flax straw will give a good spinning fibre. Sowing is generally done at the beginning of April, but sometimes in March. Winter flax may be sown in November. The stems are often 4 ft. in length. Flax sown in March is ripe in one hundred days, sown in April in ninety to ninety-five days; sown in May in eighty to eighty-five days. At the time of pulling or cutting the weather is dry. Pulling costs 29s. per acre. Cutting with reaping machine, 2s. per acre. Cutting and binding with self-binder, 4s. per acre. Rippling the pulled straw, 2s. per acre. Rippling the cut straw with a threshing machine, 3s. per acre. Cartage, 2s. per mile. Dew-retting and stacking 21s. per acre. Mill scutching, 2d. per lb. Sown for fibre each hectare yields 5 tons of dried straw with the seed on. Sown for seed and cut the yield is $3\frac{1}{2}$ tons per hectare. The pulled straw may be bought from the farmer at £3 per ton, and the cut straw in square sheaves at £2 per ton. Seed may

be bought and sold at 12s. per cwt. Land for flax-growing may be rented from the farmers, who will do all the work, at £2 to £2 10s. per acre. The writer had the above information from a native who a few years ago was trying to get up a company to erect scutch mills and prepare fibre for the home and European markets.

Flax is also grown for seed at Pudget Bay Sound, State of Washington, around Idaho, California, in Argentina, North Dakota, and Ohio. In most of these regions the straw is burned or used for stable bedding, or sometimes for forage where there is a scarcity of hay. A small portion of the flax straw produced in North Dakota is used for paper stock, and in a few localities in the Dakotas, Minnesota, and Ohio, it is made into upholstering tow. Of recent years flax-binder twine has been made to some extent from mechanically cleaned and unretted flax straw. Patents have been taken out in Canada to scutch unretted flax straw, and the results obtained are not discouraging, the fibre produced being of sufficient quality to spin twine yarns.

CHAPTER XI.

SOME OF THE LESSER-KNOWN CORDAGE
FIBRES.

SIDA is a vegetable fibre found in India. It resembles jute in structure and chemical characteristics, but is more uniform, cleaner, and softer to the touch. An important factor in its component parts is the relatively high percentage of cellulose—83 per cent., as compared with 75 per cent. in the case of jute.

According to Matthews, the commercial fibre known as Chinese jute is not a variety of jute at all, but is derived from *Abutilon avicennæ*, or Indian mallow. The bast fibre is white and glossy, and has considerable strength. The plant produces about 20 per cent. of fibre.

Gambo Hemp, or Ambari, is an East Indian fibre derived from the bast of *Hibiscus cannabinus*. The fibre, when carefully prepared, is from 5 to 6 ft. in length, and is of a lighter colour than hemp, and harsher. It is not quite so strong as Sunn hemp, and, like this latter fibre, is principally used for cordage, although it is also employed in India for the manufacture of a coarse canvas.

Hemp Palm (*Chamærops excelsa*) is a palm of China and Japan, the leaves of which contain fibre, which is much employed in those countries for making cordage.

Esparto is a plant which grows wild in Spain and Africa, and is applied by the natives to the manufacture of coarse cordage, matting, &c. The plant, called by botanists *Stipa*, or *Macrochloa tenacissima*, is a species of grass, growing in tufts

like rushes, to an average height of about 3 ft. It has long, flat blades, which are pulled up by the roots, dried in the sun, and packed in bundles. In Algeria there is a closely allied fibre called alfa (*Macrochloa arenaria*), and in Tripoli and Tunis a third fibre called dis (*Festuca pabula*).

Cordage made from esparto is largely exported from Spain to France, Italy, Holland, Portugal, the United States, and England. The port of Lake Aguilas, near Carthagena, ships about 20,000 tons of different kinds of fabrics made from it, and those ports on the coast from Alicante to Almeria about 5,000 tons more. No less than 50,000 persons are said to be employed in twisting this fibre in the two last-named districts. The Spanish marine and mining industries employ a great quantity of cordage made with esparto, which costs about £11 per ton on the average.

The zapupe fibre plant is very similar in appearance to the henequen plant of Yucatan. The leaves, however, are longer, and not so fleshy. The centre of its cultivation is the town of Tuxpam, in Mexico. In preparing a plantation the land is cleared, and scions or suckers planted about 7 ft. from each other in either direction. Until the third year of their growth, when their shade checks injurious undergrowth, they must be weeded. The plant yields its first cutting of leaves in the fourth year. From the first to the third year after beginning to yield it will produce from 100 to 110 leaves annually, gradually decreasing to between seventy-five and eighty leaves; and retaining that production consecutively for fifteen years. Cutting the leaves is a very simple operation, the labourer being supplied with a long-bladed knife, having a sharp hook-like curve at the end, which is introduced between the stump and the leaf, and the latter cut off close to the stump with a dexterous upward jerk. The leaves may be harvested throughout the year, from twenty to twenty-five leaves being cut every ninety days. If the leaves are not cut regularly the life of the plant will be materially

shortened, for at the end of five years it will throw up from the centre a long stem about 8 ft. high, and will then shortly cease to produce leaves, and die. If the leaves are constantly cut this will not occur until the fifteenth year, and frequently not until the eighteenth year.

Branches develop from the top of the stem, and in time become diminutive zapupe plants, which eventually become detached, and are scattered over the ground, where they take root and become strong, vigorous plants. The stem produces from 2,000 to 2,500 of these tiny scions, in addition to which others spring from the roots of the stump.

After the required number of leaves are gathered and assembled in lots of fifty, the long needle-like points are cut off and the leaves made up in bundles, tied, and carried to the cleaning shed. A modern cleaning machine can deal with about 100,000 leaves per day of ten hours.

The plant seems to thrive best on slightly elevated ground of a sandy and rocky nature. The least shade is harmful, and marshy ground fatal to its growth. The suckers, or scions, can be set out at any time of the year, but from October and March is the most favourable season. The plant is remarkably exempt from disease or attacks of insects. Drought does not affect it, nor do the heavy tropical rainfalls prove injurious, provided it has good drainage.

The Indians have for centuries manufactured ropes, bags, lariats, bridles, cordage, and slines from the fibre of the plant. Cordage made from it is white, resists the action of water, and is flexible.

Palma pita grows wild in nearly all parts of Northern Mexico. The plant, which has the appearance of a palm tree, flourishes on the dry waste lands of this country. The trunk grows to a height of from 6 to 10 ft., and is often 6 to 12 in. in diameter. The leaves, from which the fibre is extracted, are all produced within 2 or 3 ft. of the top of the tree, for the lower part of the trunk is quite bare. The inside leaves con-

tain the most valuable fibre, and are cut off and boiled, or steamed, for about four hours before being subjected to the extracting machine. A crop of leaves may be secured every three months, or oftener if the plant grows in a moist situation.

A suitable fibre-extracting machine has been invented by a local man, Mr. José Farias, of Monterey, and patented both in the United States and Mexico. The machine is mounted upon a light iron truck, and can be moved from one locality to another by a team of mules, which also furnish the power required to drive the machine when at work. One of these machines, with five men and a pair of mules, produces about 5 cwt. of cleaned fibre in ten hours, the quantity of fibre secured from the leaves amounting to about 18 per cent.

Monterey is the port of export, the fibre being shipped to the United States and Europe, principally Germany, where it is manufactured into ropes, cordage, bags and carpets. The price of the fibre in Monterey has lately been about £19 per ton.

Denje and Nzonogwe fibre grows abundantly in some parts of British Central Africa, and more especially in the neighbourhood of Zomba and throughout the Shiré Highlands. The British Central African Government have recently sent sample bales of these fibres to this country, where they have been examined by experts and spun into yarn by a firm of Dundee spinners.

The fibre received consisted of ribbons averaging 4 ft. in length, and varying in colour from pale grey to buff. The fibre was of fair strength, and fairly well cleaned, but seemed to have been insufficiently retted, and the spinners found that a six weeks' treatment in the "batch" was necessary before spinning could be attempted. A good level yarn was produced, which, however, had a harsh feel, and was weaker than jute yarn of corresponding size. This result may have been due to the long time during which the fibre was soaking in the batch. The fibre received was valued at only £16 per ton, but no

doubt it would be worth more were the plant pulled at an earlier period of its growth, and retted in a more intelligent fashion.

Bowstring Hemp (*Sansevieria zelanica*), *Sansevieria*, *murta*, or *moorva* is a fibrous plant which grows in India and in Queensland, Java, and South China. The leaves, which are from 4 to 8 ft. long, and from 2 to 3 in. wide, spring up directly from the root, the plant having no stem. The fibre which they contain extends of uniform quality from tip to root. The fibre is soft, silky, pliant, and very strong, and is readily extracted by existing decorticating machines. Fifty pounds of fibre may be extracted from 1 ton of fresh leaves, which yield $2\frac{1}{2}$ per cent. of fibre. One acre yields $13\frac{1}{2}$ tons of fresh leaves, or 6 cwt. of clean fibre. The plant is readily propagated from the roots.

Mauritius Hemp (*Furcroya gigantea*) is closely allied to the aloe plant. Its leaves are from 5 to 8 ft. in length, and weigh about 5 lb. The same mode of cultivation and extraction is practised as in the case of the agaves.

Pita Hemp or *Henequen* is produced from a certain species of agave which is grown in South America. It produces leaves of an average length of $3\frac{1}{2}$ ft., from which a coarse fibre, resembling sisal, is extracted.

Maguey is a fibre which finds its way to the London market in small quantities. It is extracted from the leaves of a species of the American aloe (*A. Americana*).

Istle, or Istle-grass, which is a commercial corruption of the Mexican name *ixtli*, is a valuable fibre obtained in Mexico and Central America from the henequen species of maguey, *Bromelia sylvestris*, and several species of agave, such as *A. ixtli*. It is at present exported to London and New York, and is used in the manufacture of cordage, nets, carpets, &c.

Aramina (little wire) is a fibre extracted from a plant which grows in Brazil. It is not unlike jute, and is locally manufactured into coffee bags, carpets, curtains, &c.

CHAPTER XII.

DECORTICATION.

DECORTICATION is the separation of textile fibres from the woody or pulpy matter with which they are generally associated. There are two distinct classes of fibrous plants, *i.e.*, those in which the fibre is found in the stem of the plant, and those in which the fibre forms the structural system of the leaf. To the first class belong flax, true hemp, jute and ramie, and to the latter most of the cordage fibres such as Manilla, New Zealand and Mauritius hems, Sisal, &c.

When found in the stem of the plant, the fibres usually surround the woody matter, to which they are bound by pectic or gummy matter and are generally covered by a skin of varnish which it is necessary to remove.

When the fibre is found in the leaves of the plant it is usually covered up by a succulent pulp which must be removed before the fibre can be seen.

The separation of stem fibres is much more easily accomplished than is the separation of leaf fibres. In the former case it is only necessary to dissolve the gummy matter which binds the fibre to the boon or harl and then to break up and knock or shake out this woody matter.

The gummy or pectic matter which binds the fibre to the woody core of the flax, true hemp and jute plants, is dissolved and decomposed by fermentation or retting. In the case of flax and hemp the retting process may be done in two ways; the quicker method being known as water-retting and the other as dew-retting. Jute is always water-retted. Water-

retting is done in either still or running water. Flax and hemp steeped in rivers is usually of a nice yellow colour and much appreciated by spinners. Flax and hemp steeped in still water is of a darker colour, but of good spinning quality if the water be soft and stagnant and free from mineral salts in solution. The best results are obtained when the straw or stems are protected from contact with the earthy sides of the dam or from floating scum, by straw, and placed in openwork crates or baskets. Ten to fifteen days, according to the temperature, is required by the steeping process.

In the Courtrai district of Belgium, where the finest flax which the world produces is steeped in the sluggish waters of the River Lys, the factors prefer to steep their flax for a comparatively short period the first year and then to dry and store it until the following year, when they complete the retting process. The greatest care is necessary lest the retting process go on too long, as the fibre is thereby weakened. When it is found that the fibre separates easily from the woody matter, the stems are removed from the water and spread out to dry upon the ground.

In India, jute is steeped in a like manner either in running water or in retting dams. Fermentation in this case occupies about ten days, when the bundles of stalks are withdrawn. Jute fibre can be separated from the stalk by hand at the same time as it is being lifted from the dam. The natives, standing waist deep in the water, strip off the bark, wash the fibre, wring it out and hang it up to dry on lines.

Dew-retting consists in spreading the freshly pulled flax or hemp straw lightly over the field and allowing it to remain there until the action of the sun, rain and dew has accomplished the partial dissolution of the gummy matter which binds the fibre to the wood.

Even when the straw is water-retted it should be "grassed," or spread upon a meadow in a similar manner after it has

been removed from the water. Grassing causes the fibre to contract and leave the boon and renders the succeeding mechanical operation much more easily accomplished. In order that the process referred to may be easily and successfully accomplished, the straw must be perfectly dry and thoroughly retted. It is then quite easy to break up the "boon" by beating the straw upon a flat surface with a mallet or by the use of a primitive wooden press of intersecting bars, called a "break," and then to thoroughly clean the fibre by repeated blows of a wooden scratching blade. This primitive method is still practised in many a cottage home in Ireland, Belgium, Holland, Russia, Germany and Italy, upon flax and hemp straw, but especially in the case of flax, farmers now generally bring their retted and dried straw to a scutch mill where it is cleaned in large quantities by steam or water power.

Scutch-mill machinery consists first of all of a "breaker" which has a series of pairs of fluted rollers which crush the straw and break up the boon into small pieces, which, if the stems have been sufficiently retted, are easily separated from the fibre by the strokes of a beater. The best breakers have six or seven pairs of comparatively small rollers fluted rather finely to different pitches, so that they may break the boon into as small pieces as possible. The efficiency of the machine is further increased by turning the rollers backwards and forwards alternately by means of cranks, connecting rods, ratchet wheels and detents. The crank producing the forward motion has the longer stroke, so that the straw passes through the machine.

The broken-up woody matter is then knocked out of the fibre, as it is held in handfuls in a notch in an upright plank or stock, by revolving beaters or "handles" of wood or light iron which strike it repeatedly.

Decortication should be practised upon the stems of the ramie plant just after they have been cut down and while

still in a green state, because when they become dry the outside skin becomes hard and brown and most difficult to remove. Up to the present time no machine has been found to give such good results, as regards yield and clean fibre, as the manual processes practised by the women and children in China, who produce from the ramie or rhea plant the fibre known as China grass. Hand decortication is a long and costly process, because a woman can produce only a few pounds of fibre per day. This she does by placing a few green stems on a flat board and scraping them with a piece of wood, in order to remove the woody matter with as much of the gum as possible. The best cleaned fibre still contains from 20 to 30 per cent. of gum, which must be removed before it can be spun into fine yarns.

Especially in the case of water-retted flax and hemp straw, a good deal of gum still remains in the fibre, and must do so until after the yarn is spun, for the ultimate fibres of the flax and hemp plants are short as compared with those of ramie and are held together by the pectic matter referred to. In the wet spinning process this gum is softened by the action of the hot water so that the fibres may be drawn out, but hardens again when the thread has been twisted and dried, binding the fibres together and giving the yarn strength and a smooth hard surface.

To make ramie or rhea, which has not been scraped, fit for spinning at all, and to render China grass fit for spinning into fine yarns, it must be subjected to chemical treatment to dissolve out the gum. Perhaps the best process for the purpose is that of Boyle. It consists in passing the material through a trough containing weak soda lye and then through a feeble solution of hydrochloric acid which acts upon the soda remaining in the fibre and sets up fermentation. The material is then passed on to a third tank similar to the first and then to a fourth containing a solution of permanganate of potash. The fifth tank contains a mixed solution of hypo-

sulphite of soda and hydrochloric acid, the sixth hyposulphite of soda and the seventh a solution of hydrochloric acid alone. On leaving the latter bath the fibre is washed in pure water and then steeped in a weak solution of soap and water, in order to give it back a little of the oleaginous matter extracted by the action of the soda. The material should be passed through these successive baths between endless openwork travelling aprons, in thin layers, in order that the fibre may preserve its parallelism and not become too much matted. Between each bath it passes between wringing rollers to remove superfluous moisture.

- True China grass, from which much of the gum has been removed by hand scraping, does not require such severe chemical treatment as that just described; it is sufficient to boil it in soda lye, to steep it in chloride of lime solution and then in an acid bath, repeating these two latter processes, with a washing in pure water between each, until the gum has completely disappeared and a pure white filasse is produced. The fibre should be placed in a kier or boiling pot between trays of wire network one above the other to prevent the matting of the fibre. The trays of fibre are placed in the pot with the lye at 3° Tw. and allowed to boil for about seven hours. The fibre is then taken out, rinsed in pure water to remove all traces of soda and then steeped for ten or twelve hours in chloride of lime solution at $\frac{1}{2}^{\circ}$ Tw., contained in a stone trough. When taken out of this steep it is again rinsed in pure water and placed in a solution of sulphuric acid or vitriol at 1° Tw., where it is left for some hours and then again thoroughly washed. If all traces of gum have not completely disappeared, the two latter processes are repeated as frequently as required.

Chemical treatment has also been frequently tried in connection with the separation of flax and hemp fibre from the straw, but without any real success except as regards shortening the time occupied in the process. An energetic chemical treat-

ment tends to weaken the fibre and render it hard and brittle and lacking in the spinning quality which characterises water-retted fibre. The *London Commercial Intelligence* recently described such a process, which is being tried in Australia to convert flax straw which is going to waste, into good fibre.

"Sheaves of straw are immersed in a hot neutral solution for about an hour, after which they are sprayed by steam force with a special solution and then with clean water. The flax is then dried and the straw broken and scutched in the usual manner. Each bath holds about 336 lb. of fibre and the cost of the solution in Australia does not exceed 48 cents. Frequent use of the same bath somewhat darkens the fibre. The light-coloured fibre can be used for many purposes without further bleaching. It is claimed by the inventors that their process can be carried out continuously, independent of weather conditions, and also that the fibre is produced so cheaply that it will ultimately to some extent take the place of other fibres."

Any real improvement in the direction of hastening the retting process, in the separation of textile fibres from the straw which contains them, can only be looked for by aiding and not forcing natural fermentation, and at the same time in keeping the fibre clean. The success of the Courtrai flax trade may be attributed not only to the superior retting properties of the sluggish waters of the river Lys, but also to the skilful manner in which the flax is handled, and steeped in crates lined with straw.

Considerable success has recently attended the steeping of flax and hemp in tanks under the Loppens and Deschwarte system, and also under the Legrand patents, the straw thus treated producing better fibre than the same straw treated in the ordinary way. The Legrand process, as carried out near Antwerp, consists in putting the straw to be retted upright in an open crate, which is lowered mechanically into a tank filled with water for scouring purposes, in raising and lowering the

FIG. II.

crate repeatedly to wash away the slime, and then in introducing the crate full of straw into a second tank of water—the retting-tank proper. The crate is again raised and lowered repeatedly, and is finally immersed in a third tank for washing and rinsing. Fresh water is admitted through a filter into the rinsing tank and caused to flow by means of syphons successively through the retting and scouring tanks. The water enters the first two tanks underneath a horizontal canvas partition and is thus more evenly distributed. The temperature of the water is slightly raised and the retting more quickly accomplished than in the usual way, the resulting fibre being of a golden yellow colour, much prized by spinners. The process is based on the assumption of the inventors that the pectose, which unites the fibres together and to the harl of the stem, comprises two distinct kinds of glueing materials, viz., one a gum which is soluble in water, and the other a resin, insoluble in water, which must be decomposed by the retting action before becoming soluble. Retting by the action of the so-called granulobacter or retting bacillus causes fermentation and decomposition, and produces a glutinous substance soluble in water.

In order that the retting process may be quickly and efficiently accomplished, the raising and lowering of the straw in the scouring tank is indispensable, so that the gum may be washed away. If the stalks be not properly scoured at this stage, the microbe of lactic acid will be developed, the said microbe being an enemy of the retting ferment. The straw crate is raised and lowered in the retting tank in order to wash away the secretion of the retting bacillus, which retards its development. It is further claimed that air or oxygen is introduced into the water by the raising and lowering of the crate, and the action of the retting ferment thereby highly increased.

All fibrous plants have special characteristics of their own, which must be closely studied if success is to be obtained in

extracting the fibre in a practical and profitable manner. The various processes of fibre extraction may be divided into three general heads, viz., (1) Obtaining the fibre after subjecting the raw material to some simple chemical process; (2) the extraction of the fibre without subjecting the material to any operation beforehand; and (3) the separation of the fibre

FIG. 12.

with the aid of a machine. The first process, viz., retting and scutching, we have already described. As regards the second, many a fibre may be separated from either the stem or the leaf by simply pulling the filaments one by one. Manilla hemp is hand-cleaned by native labour, the pulp being scraped from the newly-cut leaf-stalks by drawing them under a rudely

constructed scraper knife fixed in a bamboo framing, or merely by scraping them with a flat piece of wood. The Maories extract the fibre from the leaves of the New Zealand hemp plant in an extremely primitive fashion. They select full-grown leaves, and after cutting them off the plant, proceed to remove the fibre while the leaves are still green. The only appliance used, if such it may be called, is a large shell. With this an incision is made, just through the skin on each side of the leaf, and the epidermis removed. The fibres which are thus exposed are then scraped free of gummy and pulpy matter with the shell and subsequently dried in the sun.

The natives of Mexico often separate the fibre of the Sisal hemp plant by hand, after thoroughly beating the fresh leaf with a mallet on a wooden block, by drawing the leaf between two metal blades held in contact under a slight pressure. After drawing, the fibre is washed and dried in the sun.

Like stem fibres, the separation of many leaf fibres is considerably facilitated by fermentation and washing.

Apart from primitive native methods, the long flat leaves of the New Zealand hemp plant are cut down and subjected to the action of a stripper similar to the flax scutcher's handles, which detaches much of the bark. The partially cleaned fibre is then put into a trough through which water circulates and is washed and scraped with a flat piece of wood. The fibre is then grassed and partially bleached by the action of the sun and air, after which it undergoes a further scutching process which softens, cleans, and renders it a saleable article. The separation of the fibre from the leaves of several plants of the aloe species is also facilitated by soaking the previously crushed leaves in water in order to separate the soft parts *en masse*.

The purely mechanical separation of leaf fibres is resorted to in the case of several tropical plants, either because the supply of water is limited, or because the succulent pulp

FIG. 13.—Crusher.

which covers the fibres is comparatively easily removed. Mechanical fibre extractors, or decortivating machines, usually consist of a scraper wheel and fixed blocks, between which the previously crushed leaves pass. Water streams constantly upon the blocks from an overhead reservoir and washes away the woody pulp as it is removed by the scrapers. Planters have always found it most difficult to hit upon the right machine, either because such does not exist, or because machines which suit one sort of leaf do not suit another.

FIG. 14.

What energetic fibre cultivators in the colonies want is a machine small and light enough to be at least as portable as the ordinary grain-threshing machine, an effective machine which can be drawn by a mule. The machine must be run with a comparatively small amount of power, as the power plant must accompany the machine. These qualities are generally essentials, as the fibre must be cleaned within a short time after the plants are cut, it not being practicable to have large central works to which the heavy leaf sheaths can

be carted or shipped. Inventors must remember that all parts of the machine coming in contact with the fibre immediately after it is cleaned must be free from steel or iron surfaces, which would discolour the fibre. The distance from the scraping knives to the grip holding the leaf must remain practically constant, and must not exceed 8 or 10 inches, otherwise the fibre is likely to be strained and broken.

Decorticating machines which have been more or less successful are provided with organs for crushing, scraping or beating, or both. Some of these machines bear the name of the Favier, the Todd, the Landtsheer, the Andrew, the Weicher, the Villamore, the Aquilla, and the Prieto.

The Favier machine has a series of pairs of crushing rollers and beaters. The Todd fibre-cleaning machine has been much used in the cleaning of Sisal hemp. It is said to produce from 700 to 1,000 lbs. of clean fibre per day. The Landtsheer machine consists of two pairs of fluted crushing rollers and two sets of beaters. Andrew's patent machine has been successfully used in the extraction of New Zealand hemp, the fibre being cleaned by a hammering process, and the gummy matter removed by jets of water. The principal organ of the Weicher machine is a drum fitted with beaters. The Villamore and Prieto machines have been successfully used in Mexico. They are fitted with scrape wheels which, acting against a wooden block or shoe, scrape off the woody pulp from the fibre.

Figs. 11 and 12 give two views of the Prieto Machine Co.'s Irene No. 31 Machine, which has a capacity of 30,000 leaves per day, and requires 15 h.p. to drive it.

The crusher, fig. 13, is used to prepare the leaves for this machine.

Fig. 14 shows Lehmann's fibre extracting machine.

CHAPTER XIII.

COTTON.

COTTON is now so largely used for ropes and twines that it must be regarded as a cordage fibre. The cotton fibre is the hair which grows around the seeds of the various species of the cotton plant. The longest fibred cotton is only about 2 in. in length, and the shortest about 1 in. When placed under the microscope the fibres look like narrow ribbons having a small spiral twist. It is the natural twist of the fibre that increases the value of the fibre for spinning purposes, since the fibres interlock the one with the other and produce a stronger and more elastic thread than fibre of similar length which is perfectly straight in its formation.

Cotton is grown in America, India, Egypt, &c. In cultivating the fibre, the first step to be taken is the preparation of the ground for planting. In the southern part of Texas this begins as early as the middle of January; in Florida about the third week in January; in Alabama, Georgia, Mississippi, and Louisiana about the beginning of February; and in South Carolina about the beginning of February to the beginning of March. According to latitude, actual planting begins from the middle of March to the middle of April, and ends in the first half of May. Picking usually begins about the beginning of August. The plant goes on fruiting as long as the weather is mild, and does not close in the late districts till the middle of January. In India, picking begins and ends almost three months later.

Cotton is plucked from the plant in the form of bolls of

fibre, which grow upon, surround, and conceal the seeds. A machine called a gin is used to remove the seeds and husks from the fibre, preparatory to the latter being made up into bales for transit. There are several types in use, but the most universally adopted is the "Macarthy," or roller gin, and the "Eagle," or saw gin.

The Macarthy gin is specially adapted for long cottons, such as Sea Island or Egyptian. It cannot get through as much work as the saw gin, but leaves the fibre undamaged and straight. The machine is usually made about 40 in. wide, and consists of a roller covered with leather washers, or a wooden roller covered with leather, against which is pressed a "doctor," or knife blade. They are self-feeding, the cotton being merely thrown into a hopper, whence it is drawn by friction between the leather roller and the doctor knife. The cotton is then operated upon by a reciprocating beater-knife, which strikes the seed and separates it from the cotton, the seed falling through a grid provided for the purpose. The cotton is fed to the roller by the action of an automatic feeder having a reciprocating motion.

The Eagle or saw gin is usually made with sixty to seventy saws, arranged on bars in sections of five saws each. The cotton bolls are placed in a box behind the saws. The front of the box is formed by an iron plate, which is slotted and placed in such a manner that about one-third of the periphery of the saws is within the box. As the saws revolve, their teeth carry the cotton fibre with them, and the slots in the iron plate being too narrow to permit the seeds to pass, the separation is effected. The bottom of the box is formed of grids or wire netting, the interstices being just sufficiently large to permit the naked seeds to fall to the ground. The cotton from the gins is packed and formed by a hydraulic press into a square-shaped bale, which is covered with gunny cloth, or else into one of the newer cylindrical bales, in which form it is delivered to the Liverpool or Manchester market.

CHAPTER XIV.

CHEMICAL CHARACTERISTICS OF THE
CORDAGE FIBRES.

FLAX fibre when treated with iodine and sulphuric acid is coloured blue, whereas jute when treated in the same bath is coloured yellow, and hemp green. The flax fibre consists of pure cellulose, and is not lignified. It swells by treatment with Schweitzer's reagent, but, unlike cotton, does not completely dissolve in it.

The following analysis shows the approximate composition of the flax fibre of commerce :—

	Per cent.
Hydroscopic water	9·7
Aqueous extract	4·8
Fat and wax	2·4
Cellulose	77·0
Ash (mineral matter)	1·0
Intercellular matter	5·1

Thus the ordinary commercial flax fibre contains about 5 per cent. less cellulose than cotton, the difference being made up of impurities present in the form of intercellular matter and specific bodies such as a wax-like substance which may be extracted from the fibre by means of benzene or ether. Its melting point is 143° F., and its specific gravity 0·9 at 60° F.

According to Hoffmeister this wax consists of about 81½ per

cent. of unsaponifiable waxy matter and nearly 19 per cent. of saponifiable oil. Of the latter, $54\frac{1}{2}$ per cent. is free fatty acid. The principal constituent of this waxy matter resembles caresin, and there are also present ceryl, alcohol, and phylosterin. The saponifiable matter appears to contain small quantities of soluble fatty acids, like caproic, stearic, palmitic, linolic, linolenic, and isolinolenic.

In its chemical composition jute seems to be quite different from linen and cotton, being composed of a modified form of cellulose known as ligno-cellulose or bastose. Bastose is a compound of cellulose with lignin. It behaves quite differently from cellulose towards various reagents, its chief distinction being that it is coloured yellow by iodine and sulphuric acid, whereas pure cellulose is coloured blue. According to Müller, pure cellulose may be isolated from jute by the following method :—Take 2 grammes of the material and dry it at 112°C . Next treat it with a mixture of alcohol and benzol, and then boil it with dilute ammoniacal water in order to remove wax. The softened mass is then pulverized in a mortar, and placed in a large glass-stoppered flask with 100 cc. of water. From 5 to 10 cc. of a solution of 2 cc. of bromin in 500 cc. of water are added, until a permanent yellow colour is obtained, after standing twelve to twenty-four hours. The substance is then filtered, washed with water, and heated to boiling point with water containing a little ammonia. After this it is filtered, washed, and again treated with the bromin solution as above indicated, until a permanent yellow colour is obtained. The fibre is then boiled with dilute ammonia, and on filtering and washing leaves a residue of pure white cellulose.

Cross and Bevan consider that jute fibre may be regarded as an anhydrous aggregate of three separate compounds, *i.e.* (1) a dextrocellulose allied to cotton; (2) a pentacellulose, yielding furfural and acetic acid on hydrolysis; (3) lignone, a quinone which is converted by chlorination and reduction into derivatives of the trihydric phenols.

The chief chemical difference between jute and pure cellulose fibres is in the ability of the former to combine directly with basic dyestuffs. In fact, it acts in this respect similarly to cotton which has been mordanted with tannic acid. Jute is also more sensitive to the action of chemicals in general than cotton or linen. On this account it cannot be bleached with much success, as treatment with alkalies and bleaching powder weakens and disintegrates the fibre to a considerable extent.

The European hemp fibre is not composed entirely of pure cellulose, as it gives a green coloration with aniline sulphate, and iodine and sulphuric acid. It appears to be a mixture of cellulose and bastose. The behaviour of isolated hemp cells with ammoniacal copper oxide solution is quite characteristic. The cell membrane acquires a blue or bluish green colour, and swells up like a blister, showing sharply defined longitudinal striations. The inner cell walls remain undissolved in the form of a spirally wound tube contained inside the strongly swollen mass of the fibre.

Müller gives the following analysis of a sample of the best Italian hemp :—

	Per cent.
Ash	0·82
Water (hygroscopic)	8·88
Aqueous extract	3·48
Fat and wax	0·56
Cellulose	77·77
Intercellular matter and pectic bodies	9·31

Manilla hemp is a lignified fibre, and gives a yellow colour with aniline sulphate; iodine and sulphuric acid give a golden yellow to a green colour; ammoniacal copper oxide causes a blue coloration and a slight swelling.

The chemical compositions of Manilla, New Zealand, and Sunn hemp respectively are :—

Manilla Hemp.

	Per cent.
Ash	1.02
Water	11.85
Aqueous extract	0.97
Fat and wax	0.63
Cellulose	64.72
Incrusting and pectic matter... ..	21.83

New Zealand Hemp.

	Per cent.
Ash	0.63
Water	11.61
Gum and other soluble matter	21.99
Fat	1.08
Pectic constituents	1.69
Cellulose	63.00

Sunn Hemp.

	Per cent.
Ash	0.61
Water (hygroscopic)	9.60
Aqueous extract	2.82
Fat and wax	0.55
Cellulose	80.01
Pectic bodies	6.41

CHAPTER XV.

PHYSICAL STRUCTURE OF VEGETABLE FIBRES
AS SEEN UNDER THE MICROSCOPE.

THE flax fibre as it is obtained from the plant and as it appears in trade, is in the form of filaments of various length. These filaments are composed structurally of small elements or cells, which may be isolated by treatment with a dilute chromic acid solution. These cells are cylindrical in form, and taper to a point at each end, their average length being about $1\frac{1}{2}$ in. The ratio of the length of the fibre to its breadth is about as 1 : 1,200. Under the microscope the surface of the fibre appears smooth and marked longitudinally with frequent transverse fissure lines and jointed structures. On treatment with chloriodide of zinc the latter are coloured much darker than the rest of the fibre, and are thus rendered more apparent. The lumen appears in the centre of the fibre as a narrow yellow line, and it is usually completely filled with protoplasm. In cross section the fibres of flax are polygonal, with rounded edges, show a large lumen and a relatively thin cell wall. In these respects they are very similar to hemp, but may be distinguished from the latter, however, in that they do not aggregate in thick bundles, but are more or less isolated from each other, so that the cross section frequently shows but one fibre, and seldom more than three or four. Other differences from hemp, exhibited by the flax fibre, are (1) the lumen of the hemp fibre is seldom filled with yellowish protoplasm like that of the flax fibre; (2) flax fibres end in sharp points, whereas those of hemp do not.

Under the microscope, hemp fibre is seen to consist of cell elements, which are unusually long, averaging about $\frac{3}{4}$ in. in length. The ratio between the length and diameter is about 1,000. The fibre is rather uneven in its diameter, and has often fragments of lignified tissue attached to it. In its linear structure the fibre exhibits frequent joints, longitudinal fractures and swollen fissures. The lumen is usually broad, but becomes like a line towards the end of the fibre. It shows scarcely any contents. The ends of the filaments are blunt and very thick-walled, and often possess literal branches. The cross section generally shows a group of cells, which nearly always have rounded edges, and are not so sharp-angled and polygonal as in the case of jute. There is also a median layer between the cells, which is evidenced by it turning yellow on treatment with iodine and sulphuric acid. In the section the lumen appears irregular and flattened, and does not show any contents. The cell walls frequently exhibit a remarkable stratification, the different layers yielding a variety of colours on treatment with iodine and sulphuric acid.

Hemp is somewhat difficult to distinguish microscopically from flax, but there is a difference in the appearance of the cross section, which is of service in discriminating between these two fibres. Again, the parenchymous tissue which frequently occurs as attached fragments to hemp fibre is rich in straw-shaped crystals of calcium oxalate, and this is scarcely ever to be noticed in the case of flax. A peculiarity to be noticed in the examination of hemp is the occasional presence of long narrow cells, filled with a reddish brown matter. These cells occur between the fibres as well as in the bast, and probably contain tannin. They are not found in flax.

The appearance of Sunn hemp under the microscope is very similar to hemp proper. The essential distinction between the two is in the cross section, which shows the

presence of a very thick median layer of lignin between the individual cells. The lumen of the cross section is also usually rather thick, and often contains yellowish matter, differing in these respects from hemp, in which the lumen is flat, narrow, and always empty.

The microscopical characteristic of the New Zealand flax or hemp fibres is their remarkably slight adherence. The fibre elements average about $\frac{1}{8}$ in. in length, which is about fifty-five times greater than their breadth. They are very regular and uniformly thickened, and the surface is smooth, exhibiting no markings or joints. The lumen is very apparent, and is generally narrower than the cell wall, and is very uniform in its width. The ends are sharply pointed, and not divided. The cross section shows rather loosely adhering elements, and is very round in contour, the lumen being either round or oval, and is empty. The purified fibre of New Zealand hemp is rather difficult to distinguish microscopically from aloe hemp or from *Sansevieria* fibre, except by the rounded and separated cross sections.

Manilla hemp, as seen under the microscope, shows fibre elements about $\frac{1}{4}$ in. in length, and $\frac{1}{1000}$ in. in diameter. The bundles of fibres are very large, but by treatment with an alkaline bath are easily separated into smooth, even fibres. The fibres, which are very uniform in diameter, are lustrous and rather thin walled. The lumen is large and distinct, but otherwise the fibre does not exhibit any markings. The cross sections are irregularly round or oval in shape, and the lumen in the section is open and quite large, and distinct. The fibre bundles often show a series of peculiar, thick, strongly silicified plates, known as stegmata. Lengthwise these appear quadrilateral and solid, and have serrated edges and a round, bright spot in the centre. The lumen often contains a yellowish substance, but no distinct median layer is perceptible between the fibres.

In their microscopical appearance the fibre bundles of

Sisal hemp often shows an interlaced formation, with a peculiar spiral thickening. The fibre elements are only about $\frac{1}{8}$ in. in length, and about $\frac{1}{1000}$ in. in diameter. They show a remarkable broadening towards the middle. The width of the lumen is frequently greater than that of the cell walls. The ends are broad, blunt, and thick, but seldom forked. The cross sections show no evidence of a median layer between the elements. The sections are polygonal in outline, but often have rounded edges, and the bundles are usually close together. The lumen in the cross section is large and polygonal in shape, though the edges of the lumen are more rounded than those of the walls.

Mauritius hemp, or aloe fibre, has fibre elements only about $\frac{1}{10}$ in. in length. Under the microscope it is hard to distinguish it from Sansevieria fibre. The fibres are usually cylindrical, and the cell walls thin and of uniform width. The fibres show occasional fissure-like pores. The cross sections are polygonal, with slightly rounded edges. In the Sansevieria fibre the lumen in the cross section is usually larger, and the cell walls consequently thinner; furthermore, the lumen has a sharp-edged, polygonal form.

In its microscopical characteristics Pita fibre is very similar to Sisal hemp.

Silk grass, or pineapple fibre, may be distinguished from all other leaf fibres by the extreme fineness of its fibre elements, which are about $\frac{1}{4}$ in. in length. The lumen is very narrow, and appears like a line. The cross sections are polygonal in outline, and often flattened. The sections form compact groups, which are often crescent-shaped, and are enclosed in a thick medial layer of lignified tissue.

Coir fibre possesses marked microscopical characteristics. The fibre elements are short and stiff, being only about $\frac{3}{100}$ in. in length, and $\frac{1}{200}$ in. in diameter. The cell walls are thick, but rather irregularly so, in consequence of which the lumen has an irregular outline. The points are blunt, and there are a number of pores penetrating the cell wall.

The ultimate fibres of the jute plant, as seen under the microscope, are relatively short, being only about $\frac{1}{8}$ in. in length and $\frac{1}{500}$ in. in breadth. In cross section the jute fibre shows a bundle of several elements bound together, these being more or less polygonal in outline, with sharply defined angles. Between the separate elements is a narrow medial layer. The lumen is usually of about the same width as the cell wall, and in cross section is round or oval. Longitudinally the lumen shows remarkable constrictions, though towards the end of the fibre the lumen broadens out considerably, causing the cell wall to become very thin. Externally the fibre is smooth and lustrous, and has no jointed ridges or transverse markings such as are seen on flax or most other bast fibre.

Microscopically the ramie fibre is remarkable for the large size of its bast cells. These are, on the average, about 6 in. in length and $\frac{1}{400}$ in. in breadth. Joints and transverse fissures are of frequent occurrence along the fibres. The lumen is quite broad and easily noticeable. The ends of the ultimate fibres have a thick-walled, rounded point, and the lumen is reduced to a line. The cross section of the fibre shows usually only a single element or a group of but a few members. The cross section is elliptical in shape, and the lumen appears open, and frequently contains granular matter. The fibres are frequently very broad, and at these parts are flat and ribbon-like in form, and are never twisted.

In its microscopic characteristics Gambo or Ambari hemp is very similar to jute. The length of the ultimate fibres is about $\frac{1}{6}$ in. The median layers of lignin between the cells are broad. The lumen presents the same appearance as with jute, having such very marked contractions that in places it is discontinuous. The ends of the fibres are very blunt and thick-walled.

Cotton fibre may be readily differentiated from other fibres on account of its pronounced microscopical characteristics.

Under the microscope it presents the appearance of a flat, ribbon-like band, more or less twisted on its longitudinal axis. The cell walls are rather thin, and the lumen occupies about two-thirds of the entire breadth, and shows up very prominently in polarized light. Between its thickened edges the fibre exhibits the appearance of a finely granulated surface. Fibres of dead cotton, or those which have not reached maturity, are seldom spirally twisted, and do not have a lumen, but are thin, transparent bands. Immature and over-ripe cotton fibres exhibit a smooth, straight, flat appearance, and the external walls of the fibre are very thin.

APPENDIX I.

THE RUSSIAN FLAX TRADE.

IN Russia, flax is chiefly cultivated in the northern departments. In two of these—namely, in the governments of Pskoff and Jaroslav—it is the chief crop and source of revenue to farmers and peasants. These two governments, together with the governments of Kovno, Wilna, Witebsk, Smolensk, Novgorod, Kostroma, Viatka, Vladimir, Moscow, Tver, and Kaluga, where flax culture holds sway, extend from west to east and pass just north of Moscow. It is in this huge region that practically all the flax which is exported from Russia is produced.

Russia is the largest flax producer in the world. The bulk of the flax produced is exported to England, France, Belgium, and Germany. The fibre exported may be divided into two sorts—dew-retted and water-retted. The latter is the quicker method of treating the flax straw, and may be accomplished in either still or running water. Flax steeped in rivers is usually of a light yellow colour and much appreciated by spinners. Flax steeped in still water is of a darker colour, but of good spinning quality if the water be soft and stagnant, and free from mineral salts in solution. Ten to fifteen days, according to the temperature, is the time required by the steeping process. The greatest care must be taken that the retting process does not go on too long, as the fibre is thereby weakened. When it is found that the fibre separates easily from the woody matter, the stems are removed from the water and spread out to dry upon the ground.

Dew-retting consists in spreading the newly-pulled flax straw lightly over the field and allowing it to remain there until the action of the sun, rain, and dew has accomplished the partial dissolution of the gummy matter which binds the fibre to the wood. The one objection to dew-retted flax is that weavers and bleachers find that yarn spun from dew-retted fibre turns a dark colour when boiled. When fully bleached, however, linen made from dew-retted flax has a more brilliant whiteness than that made from water-retted fibre.

Dew-retted flax is exported from Archangel and St. Petersburg by ship and rail. Reval, Riga, Pernau, and Libau are the chief ports of export for water-retted fibre, large quantities of which also leave by rail and pass through Germany. While flax cultivation has been dwindling away in Ireland and in France, it has been increasing in Russia. During the last twenty-five years the area under flax in Russia has doubled itself, attaining in 1902 the enormous surface of 1,400,000 hectares. During the same period the number of flax-spinning spindles running in Russia has also nearly doubled itself, being reckoned in 1900 as 296,000. Russian spinners use home-grown flax almost entirely, their consumption being about 40,000 tons, or one-fifth of the total output of the country, which exceeds 200,000 tons annually. The peasants use a three or six years' rotation of crops, and sow 40 to 50 lb. of seed per acre when seed is desired, and 56 to 160 lb. of seed per acre when the best fibre is the object aimed at. Water-retting is practised in the west and north-west districts. In the other districts the dew-retted system prevails. "Slanetz," or dew-retted, is produced in rather larger quantities than is "motchinetz," or water-retted. France is probably the largest importer of dew-retted fibre. The water-retting regions are the governments of Pskoff, Livonia, St. Petersburg (Longa and Gdof districts), Novgorod (Staraia-Roussa districts), Wilna, Witebsk, Kovno and Courland. The dew-retted regions are the governments of Tver, Smolensk, Kaluga

(Jisdra, Likhvin, Medyn, Mossalsk, Mechtchovsk districts), Moscow (Volokolamsk district), Jaroslav, Vologda, Vladimir, Kostroma, Nijni-Novgorod, Viatka and Perm. A good deal of tow, as well as flax, comes from the five dew-retting districts of Kashin, Kama, &c.

Considering its importance, the Russian Government has very rightly taken measures to promote the prosperity of the industry. It has established experimental farms in the governments of Pskoff, Kostroma, Tver, and Viatka. It propagates the best brands of seed and gives instructions in the most modern methods of flax culture.

German spinners seem to believe that the Russian flax trade will be a declining industry in future years, for they have approached their government to assist financially in the direction of improved methods, as well as in a scheme for the purchase of German-grown flax on foot from farmers. By reason of the low price Russian flax commands, the peasants can only make anything out of it by reason of their low working expenses, owing to the unscientific and rough methods of cultivation. Flax is grown at present in practically all the Russian districts where the climate is favourable, without due regard to manuring and rotation of crops, so that soil exhaustion will be the inevitable consequence.

The Russian peasants bring their flax to market in the winter-time, when the roads are covered with snow and in good order for the sledges. Since the lots are rather irregular in quality, classers, attached to the market, separate the various qualities and put a price upon the lot. It is then sold to small agents, often Russian Jews, who resell it to the export houses. In this way it will be seen that the fibre passes through the hands of several middlemen before the spinner gets it, its price being, no doubt, considerably increased in consequence.

Dishonest dealing in the way of mixing foreign substances with the flax, watering it, and stuffing the heads with tow, became so notorious that in 1899 the Russian Government

made a law that (1) Flax must contain no admixture of refuse, and must not be damped to increase its weight. (2) The bundles of flax must not weigh more than 20 lb., and must consist of fibre of like quality and scutching. (3) They must be tied with one band only, at a distance of one-third from the top, so that the ends of the fibre will hang down freely, and so that the fibre may be examined without loosening the bundles. (4) The bands with which the bundles are tied must be of flax.

These rules have had a good effect, and it is now not so common as it was to find stones, sand, and pieces of metal in the heads of Russian flax.

Riga flax is generally exported in mats, weighing about 1 cwt., with a tare allowance of 3 lb. per mat. Other flaxes are exported in "bobbins" or bundles, without matting, and weighing rather more than 1 cwt.

The Russian weights used in the flax trade are the berkowitz = 10 pouds = 400 Russian pounds = $356\frac{1}{2}$ English pounds, and the poud = 40 Russian pounds = $35\frac{1}{2}$ English pounds. The money used is the rouble, which at par is equal to $3\frac{1}{2}$ d.

Contracts are usually made from September to December, the flax being delivered as required, and paid for ninety days after delivery. The usual conditions of sale and expedition are as follows:—

F.O.B.—The seller must put the flax on board at the port of shipment; the buyer must furnish the ship for the time of delivery arranged.

C. and F. (cost and freight). The selling price includes the cost of the fibre and freight. The buyer must insure it.

C.I.F.—The selling price covers all cost, insurance and freight. The insurance is usually made according to the conditions of the picking clause when the insurance company agrees. It is made at the risk and peril of the buyer, on whom falls the responsibility of the solvability of the insurance company. He has a right to demand a policy of insurance.

In the C. and F. and C.I.F. arrangements the freight is

deducted from the invoice and paid to the captain by the buyer on the arrival of the bales. In the F.O.B., C. and F. and C.I.F. arrangements the fibre travels at the risk and peril of the buyer. The mats for stowing the flax on the ship, the harbour dues at the port of arrival, the duty (if any), and the statistics are at the cost of the buyer. The invoice is made out at the place of shipment, and the quantities allow a latitude of 5 per cent., more or less.

Delivery on the Quay.—The cost of discharge, weighing, and putting on the quay is paid by the seller.

Delivery at the Station.—All cost and risk are borne by the seller until the bales arrive at the station.

Delivery on Wagon.—The cost and risk are borne by the seller until the bales are put upon the wagon.

In the three latter cases the invoice is made out according to the weight found by a sworn weighmaster at the port of arrival. The weighing is done in draughts of not less than 3 cwt. The cost of lading by the railway company is included in the cost of transport. In the case of shipwreck or fire the seller is not bound to replace the fibre lost or destroyed.

When flax to be sent by rail is sold "free on rail" or on wagon at the place of expedition, the seller must put the bales on the wagon and furnish a receipt for the same. The cost of lading is, of course, included in the cost of transport.

When the sale price includes the cost of the flax and its transport, the seller deducts the cost of transport, in conformity with the terms of the International tariff, from the invoice, the buyer having to pay it on the arrival of the bales. In this case the flax travels at the risk of the buyer.

When the bales are to be delivered at the station at the place of destination, the risks of the road are run by the seller, who must pay the cost of transport, duty, and statistics.

The sending of the bales in a fixed time only involves the obligation to put the fibre on board the ship or train before the expiration of the appointed time.

The tare usually allowed upon Russian flax and tow is as follows: At Archangel the tare allowed corresponds with the weight of the mats surrounding the flax, tow, or codilla. At St. Petersburg the tare is the actual weight of the mats and thick ropes. For flaxes in bobbins, such as Pskoff, Longa, and Soletsky, which are sent from St. Petersburg, the actual weight of the large ropes is allowed. At Riga, and at the stores of Riga houses in the interior, a tare of $3\frac{1}{2}$ Russian pounds, or nearly 3 lb. avoirdupois, is allowed per mat. For Reval, Narva, Pernau, and Ostrow in bobbins or mats no tare is allowed for cords.

For sales F.O.B., payment is made by bills at three months from the putting on board, or at three months from the time arranged for delivery, if the ship does not arrive at the proper time for loading.

The most usual conditions of sale concerning the quality of Russian flaxes are: At St. Petersburg the average quality of the deliveries of the dealer is indicated in the contract of sale. The average quality of a growth, Vologda, Jaroslav, Ouglitch, Rjeff, &c. At Archangel, the average quality of the "bracque" at that place. At Riga, Pernau, Reval, Pskoff, Ostrow, Narva, &c., the average quality of the bracque of the seller. Raw flax may enter free of duty into almost every country. The few exceptions are: (1) The United States of America, which impose a duty of $\frac{1}{2}$ d. per lb. on raw flax, and of \$20 per ton on tow; (2) Switzerland, where flax pays the small duty of 3s. per cwt. to enter.

The base of transactions in Riga flax is the mark K (the initial letter of the Russian word Kron, which means Crown). The other marks are PK, SPK, HK, HPK, HSPK, GK, GPK, GSPK, WK, WPK, WSPK, ZK, HZK, GZK, R, HR, GR, and WR, the other letters meaning respectively: P = puik or picked; S = sanft or sweet, superior; H = heel or yellow; G = grau or blay; Z = zins or extra; W = weiss or white; R = Risten.

The marks of the wrack flaxes are: W, PW, HPW, CPW, and WPW. Here W means wrack and white, and the other letters as the Crown flaxes. The Drieband marks are D, PD, SD, PSD, LD, PLD, and DW. S here means Slánétz, and L Livonian.

Pernau "district" flax is grown in the neighbourhood of Pernau and shipped in the state in which it is marketed by the peasants, with a good deal of shove in the top end. Pernau flax is this district flax opened out in Pernau and partially rescutched, making it worth £2 per ton more. Flax shipped from Pernau comes from either of two districts, Livonia or Fellen, the latter being of a finer quality, and fetching £2 per ton more. The Pernau marks are LOD, O, OD, HD, R, and G.

For Dunabourg or Kowns flaxes the Riga marks are usually employed. For Ostrow the marks of both Riga and Pskoff are used, and sometimes figures also. Pskoff flax is usually classed as OD, PWW, OW,O, OO, OOO, PI, PII, PIIL. Flax from Reval and Dorpat is exported in bobbins, and has usually been re-scutched. The following are the ordinary marks: GR, HD, D, OD, and OOD.

The principal districts from which the flax known as Archangel comes are Vologda, Ustjuga, Jaroslav, Kama, Tolma, and Viatka. It is usually classed in six marks: 1st Crown, 2nd Crown, 3rd Crown, 4th Crown, Zebrack No. 1, and Zebrack No. 2.

Archangel flax is dew-retted, and is usually of a silver-blau or reddish-foxy colour. It is exported in bales weighing each about 500 lb. The tare at Archangel varies according to the weight of the mats. The weight of the cords is not deducted. Navigation on the White Sea is open only from June to October. The "bracque," official and compulsory, exists in Archangel. Flax which has not been bracqued cannot be exported from this port.

St. Petersburg flax may be divided into "classed" and

Siretz. The "classed" fibre, which is becoming scarcer every year, and which is in reality re-scutched Siretz, comprises Fabrichng and Otbornoy 1st and 2nd Crown. Siretz flax, which forms the bulk of what is exported from St. Petersburg, may be divided into non-classed and superior fibre. Superior Siretz comprises Groesovitz, Kostroma, Vologda, and Jaroslav, and is frequently classed as Polochno, Fabrichng, and Otbornoy 1st and 2nd Crown. Siretz of medium quality is not classed at all, and is made up of Bejetsky, Ouglitch, Kashin, and Krasniholm. Common or inferior Siretz comprises Jwashkofsky, Rjeff, Yaropol, and Systchewka, and is classed as Otbornoy 1st and 2nd Crown.

For all "classed" flax the price is made for average 1st Crown, and varies according to the composition of the lots.

At Königsberg, part of the flax is classed on the present Riga method and part by the old classment, which is:—

FWPCM = fine white picked Crown Marienburg.

FGCPM = fine grey picked Crown Marienburg.

WPCM = white picked Crown Marienburg.

LPCM = light picked Crown Marienburg.

FPCM = fine picked Crown Marienburg.

PCM = picked Crown Marienburg.

P₁ = picked No. 1.

P₂ = picked No. 2.

The "rise" in price for the various marks varies with different years. Take Riga, for instance, with K as base, at £18 per ton. The "rise" in pounds per ton for the several marks is: H = 1, P = 3, S = 4, G = 3, W = 4, and Z = 10.

The principal centres of consumption for Russian flaxes are:—In Scotland: Dundee, Arbroath, and Kirkcaldy. In England: Bridport, Crewkerne and Cockermouth. Ireland: Belfast and Newry. France: Lille and Armentières. Germany: Bielefeld. Austria: Trautenau. Belgium: Ghent and Roulers.

APPENDIX II.

HOW TO DISTINGUISH ONE FIBRE FROM ANOTHER IN ALL STAGES OF THEIR MANUFACTURE.

NOWADAYS the finishers of textile fabrics, &c., have become so expert that it is sometimes by no means easy for the man in the street to say with any degree of certainty if a handkerchief is linen or cotton or if hemp twine consists largely of jute.

The object of the present paragraph is to give a few tests, which are not difficult to make, and which may be found useful to our readers.

Cotton is much more easily spun than flax, and in the ordinary way produces a much more regular thread free from the slubs and naps which are generally found in linen yarns. Consequently if a handkerchief, &c., be held up to the light it is generally pretty easy to judge from the appearance of the warp and weft threads if one or both are linen or cotton. When the cloth is a union, weavers generally prefer to use a cotton warp and a linen weft, as the former yarn is more elastic and weaves better. No matter how well a cotton cloth is stiffened and glazed by the finisher, its linen-like appearance disappears, and after the first washing it becomes a cotton rag.

An admixture of jute with hemp or flax yarn in cords, ropes, or woven fabrics may be detected in the following manner. Prepare a saturated solution of chloride of lime,

hydrochloric acid, and ammonia. Untwist the cord or unpick the fabric and untwist the threads so that the fibres separate one from the other. Place the threads thus prepared in a saucer, sprinkle and saturate with the chloride of lime solution. A few drops of hydrochloric acid are then added, when a slight effervescence is produced, the liquid taking a yellow-green colour, and the fibres bleaching almost instantaneously. The yarn is then at once washed and wrung, and then put into a clean saucer and moistened with a few drops of ammonia. The colour of the fibres must then be at once examined, for the jute fibres take a blue red colour, whilst the flax or hemp takes a yellow tint streaked with pink.

Jute may also be distinguished from flax and hemp by testing in an aqueous solution of iodine. Under this test the jute fibre assumes a deep brown colour, while to flax and hemp fibre a blue or violet colour is given.

Jute also gives the lignin reaction of a yellow colour when treated with iodine and sulphuric acid.

APPENDIX III.

THE CORDAGE FIBRES OF QUEENSLAND.

THE Agricultural Blue Book published by the Queensland Government gives a great deal of interesting information about the fibre plants of the Colony. The native fibre plants for the most part carry the fibre in their bark; examples of this being the wild hibiscus and the Moreton Bay fig. The aerial roots of the pandanus, the native bread-fruit tree, also contain excellent fibre. This tree grows freely in the poorest soil, and flourishes without moisture. The leaves and rough rind of the pine-apple are also fibre-bearing, the former containing a fine silky fibre which would be a valuable textile material if suitable extracting machinery were available. Sisal and Mauritius hemp are being largely planted in many parts of Queensland. In the Burnett districts especially plantations are in full swing, and the plants are ready for cutting on many plantations; one of the larger types of scutching machines is being introduced by a Queensland planter. The true Sisal agave and the Fourcroya or Mauritius hemp plant thrive luxuriantly on all the suitable coast lands of Queensland, so that there is every indication that Queensland will become an important centre for the production of Sisal fibre.

The Colony of Queensland has become a nursery for the production of Sisal hemp. The Agricultural Department and private planters have supplied about 500,000 plants to

growers, and the plants have been imported to the other colonies of Australia, New Guinea, Fiji, and the Solomon Islands. The principal part of these consignments consists of the Sisalaneous plant botanically known as *Agava rigida*, and the remainder is *Merva sanseveira lelelaucia*, or bow-string hemp. The latter variety is not much cultivated outside the Bahamas, owing to the difficulty of treatment, but the Sisal species has been very largely grown in Queensland for the past fifteen years as a commercial industry. At the early stages of hemp culture the fluctuation of its market value was a great drawback to the industry. The present market value is fairly stationary at £40 per ton. The cultivation of sisal hemp is profitable and very applicable to poor lands. There is very little labour required in planting sisal or any of the fibre-producing cacti. The planting resembles that of sugar-cane. Rows are made about 8 ft. apart, and the plants are placed from 4 to 6 ft. from each other, in holes usually sunk by a mattock to the depth of from 8 to 12 in., where the soil or nature of the land will permit. The fibre-producing cacti from which the largest quantity of fibre may be obtained are plants grown on barren land, *i.e.*, of a rocky nature. It has been proved that a deep, moist soil produces a lot of pulp and very little fibre in the plant. It takes about 1,000 plants to lay down an acre, the plants taking between three and four years, according to circumstances and conditions, before the crop is ripe for cutting; when cut, 2 tons per acre is a very good average. The cost of planting, treating, &c., runs with white labour on the Queensland plantations to about £17 10s. per ton. At a market value of £40 per ton the crop gives the farmer a fair margin of profit. The plant is exceptionally hardy, and can endure exposure to the sun out of the ground for months, and when replanted springs into life once more. It is claimed to be immune from frosts, draughts, and the ravages of insects. There is no particular season for harvesting. When the leaves are ripe for cutting they will not lose

any weight or value in fibre if they are allowed to stand for a month or two. When the cutting commences the outward ring of leaves may be removed, and by the time the last of the crop is once treated the second ring of leaves can at once be operated on, until the whole crop is dealt with. Each day's cutting must be treated, if possible, at the scutch mill, as the leaf must not get dry before the fibre is extracted.

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