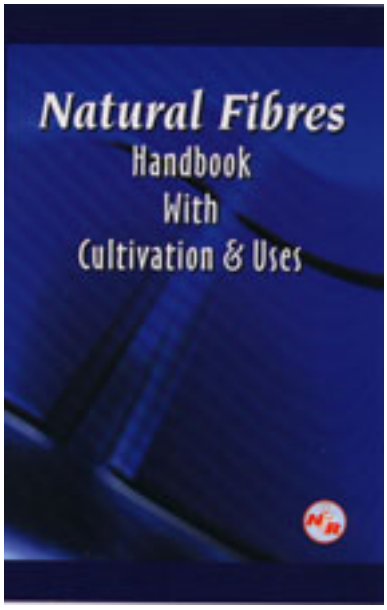
106-E, Kamla Nagar, New Delhi-110007, India.
Tel: 91-11-23843955, 23845654, 23845886, +918800733955,
Mobile: +91-9811043595.
Email: npcs.ei@gmail.com ,info@entrepreneurindia.co

Website: www.entrepreneurIndia.co

# Natural Fibers Handbook with Cultivation & Uses

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Natural fibers production, processing and export are vital to the economies of many developing countries and the livelihoods of millions of small scale farmers and low wage workers. Almost all natural fibers are produced by agriculture, and the major part is harvested in the developing world. It is convenient to classify natural fiber in two ways; morphologically, according to the part of plant from which they are obtained and practically according to the uses to which they are put, which in turn depend on their properties. From the view point of the uses vegetable fibers may be classified into following groups; textile fibers, cordage fibers, brush and mat fibers, stuffing and upholstery materials, paper making materials etc. Fibers from the view point of the part are classified as hair fibers, leaf fibers, woody fibers, bast fibers, etc. The use of fibers for paper making differs completely from their use in textiles, in that in papermaking it is ultimate fiber cells which are used; thus in papermaking process consists in breaking down the strands of fiber into the ultimate fibers. Jute, the most important textile fiber apart from cotton, is obtained from two species of corchorus(white jute) and C.olitoriusL. (tossa jute). Farmers around the world produce a wide variety of natural fibres, planting crops and rearing animals. Plant fibres may be from the plant fruit (e.g. cotton), stems (e.g. flax and jute) or leaf (e.g.sisal). Natural fibres are generally considered more environment friendly than synthetics in their production and disposal. However, there is great variation depending on the fibre and the growing conditions. Many chemicals are used to contain pests and weeds. Chemicals are also used in the processing and dyeing which can lead to water contamination. Processing of some natural fibers can lead to high levels of water pollutants, but they consist mostly of biodegradable compounds, in contrast to the persistent chemicals, including heavy metals, released in the effluent from synthetic fiber processing. Farming and production of natural fibres also plays a significant role in eradicating poverty as an important source of farming income and contribution to food security in developing countries. Demand for natural fiber composites are largely driven by increasing environmental awareness. Due to low cost, low density, acceptable specific properties, ease of separation, enhanced energy recovery, CO2 neutrality, biodegradability and recyclable properties, natural fiber use in composites is gaining as demand grows for component materials that are durable, reliable, light weight, with mechanical properties better than those of traditional materials. Total global natural fiber composite market expected to grow at 11% CAGR.

Some of the fundamentals of the book are the occurrence and nature of vegetable fibres, conditions necessary for growing flax, mulberry family (moraceae), lime family (titliaceae), experiments on mechanized production of jute, mallow family (malvaceae), kenaf production in various other countries, the use of unretted kenaf ribbons for sack manufacture, pea family (leguminosae), sterculia family (sterculiaceae), agave family (agavaceae), structure of the sisal industry, narcissus family (amaryllidaceae), lily family (liliaceae), pineapple family (bromeliaceae), fibres from other species of musa and a related genus, brush making fibres, etc.

The book contains process and other parameters for the manufacturing of fibers arrive from natural sources. Due to eco friendly nature there is very good domestic and export potentiality for natural fiber. This is very useful book for new generation entrepreneurs, consultant institutional libraries, and existing units.

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**Sample Chapter:**

# MULBERRY FAMILY (MORACEAE)

## HEMP (CANNABIS SATIVA)

Cannabis sativa L. (hemp) is today considered by most systematic botanists to be the only species in the genus Cannabis. However, it has many varieties, strains, types, or lines, which differ from each other with regard to their size, colour, degree of branching of the stalk, shape and size of leaves, flowering periods, and other characteristics. True hemp must not be confused with the very different Mauritius hemp, Manila hemp and some other fibres which are erroneously called hemps.

Hemp, also known as Italian hemp, Russian hemp, soft hemp, and by a large number of other names in many countries, is one of the oldest cultivated plants known to mankind. Today, the fibre is usually called Italian hemp because Italy was, until quite recently, the chief exporter of the fibre. Yugoslavia is now the most important exporter of hemp, though more than three-quarters of the total world production is in the U.S.S.R., Italy, and Poland.

Although the original home of the hemp plant appears to have been in Central Asia, from which it spread to China (where more varieties are to be found than in any other country), hemp has been cultivated, at least to some extent, in nearly all the countries of the temperate zone. It is supposed to have been cultivated in China for more than 4,500 years. In the U.S.A. the 'Kentucky' variety is grown, which appears to have originated in China. The plants spread from Central Asia to the regions north of the Black Sea and the mouth of the Danube, and consequently Russia and the Baltic States were important producers of the fibre at an early date. The plants also spread to Italy and France, and these countries, too, became centres of production. A good deal of hemp is grown in Europe, especially in the U.S.S.R., and in Italy where the best quality hemp is produced. It is also grown on a small scale in Kashmir and in the region of the Himalayas. The Northern varieties of hemp differ from the Southern varieties in that they have short growth and mature early, whereas the Southern varieties grow taller and mature later.

The form of the plant and the yield from it of fibre vary according to the climate, and also according to the particular variety. Varieties cultivated particularly for their fibre have long stalks, branch very little, and yield only small quantities of seed. On the other hand, varieties which are grown for the oil from their seed, and which yield large quantities of seed, are short in height and mature early. The variety of Cannabis sativa which is known as Indian hemp, and which is cultivated for the sake of the drug 'hashish', is short, much-branched, and has small dark-green leaves. Between these three main varieties there are numerous varieties which differ from the main ones in height, the extent of branching, and other characteristics.

The plant is grown for fibre in temperate regions, whereas in tropical regions, it is grown for the drug. The stalks, leaves, and flowers, produce a resinous juice from which the drug is obtained, and the drug is known under many forms, such as 'charas' (the name given to the resin), 'ganja' (which consists of the dried flowering tops of the cultivated female plant), 'bhang' (the dried leaves and flowering shoots of either the male or female plants, or of both), and 'hashish' (which is the name given to a Turkish preparation of the leaves). Owing to the presence of the drug in the plant, the growing of hemp is forbidden in many tropical countries.

The oldest use of the hemp plant seems to have been for fibre, and it was not until later that the seeds began to be used for culinary purposes. The fact that the plant yielded a drug seems to have been first discovered in India, where it appears to have been cultivated for medicinal purposes as early as 900 to 800 B.C., and it was not until medieval times that hemp was brought to North Africa, where today it is cultivated exclusively for 'hashish'.

In the temperate zones there are two series of varieties of hemp, namely the Northern varieties and the Southern varieties. The former varieties require comparatively low temperatures for growth, have a short

vegetative period, and are consequently short in stature. Moreover, as they are adjusted to the length of summer days in northern and central Europe, they are able to complete their development and mature fruits there. If these Northern varieties are planted in more southern latitudes, where the summer days are shorter, they develop much faster from planting time to flowering time than do the Southern varieties, but complete their growth and flower very quickly, so that they yield short stems and little fibre. The Southern varieties, on the other hand, require high temperatures and a long vegetative period, and consequently grow taller and mature later. Most of these Southern varieties, however, are adapted to the short days of the summer in southern latitudes, and if they are cultivated in the long days of central Europe they grow well, but flower and bear seed so late that it does not ripen. In particular cases, if the varieties which are adapted to the length of day in lower latitudes are brought to the higher ones, even the fibre does not mature properly, so that the fibre content of the stems is low and of inferior quality.

## BOTANY

Hemp is an annual, herbaceous plant; it has a slender, erect stalk which may very in height from 3 to 14 ft. according to the variety and climatic conditions. The stalk varies between 1/6 and 5/6 in. in diameter, and when the plants are sown close together the stems do not branch-so that for fibre purposes the seed is always sown closely. The leaves of the plant are palmately compound and have seven to eleven leaflets each.

The plants are dioecious, the staminate or pollen-bearing flowers and the pistillate or seed-bearing flowers being borne on separate individuals. The male and female plants are much alike, except of course for their flowers and the presence of seeds only on the female plant, and provided the crop is harvested at the right time there is no apparent difference in the fibre from the two sexes. The male inflorescence is a large 'ear' composed of numerous axillary clusters and forming small yellow panicles, while the female inflorescence is a false car which is large, straight, and tuft-like; it is much more leafy, compact, and robust than the male, and has short green spikes. Both male and female inflorescences are borne in the axils of the leaves or in clusters along the branches.

The plant should be harvested when the staminate plants are in flower. In any one field the proportion of male to female plants may vary from 40 to 60 per cent, but the average ratio is about 50:50. Where the crop is being grown for fibre only, both the male and female plants are harvested together, but where it is desired to obtain both fibre and seed, the male plants are first collected by hand pulling, and the female plants are left thereafter for as much as three weeks or even longer to enable the seed to ripen.

Where the plant is grown both for fibre and seed, the fibre from the male plants is stated to be superior to that from the female plants, as by the time the female plants are harvested the fibre has become overmature. The reason for this may be because lignification in the male plants does not take place so quickly as it does in the female plants. Experiments carried out in Armenia showed that, at the end of their period of growth, whereas the male plants had a lignin content of between 13 and 16 per cent of dry-weight, the lignin content in the female plants was between 23 and 25 per cent. The quantity of seed sown yer acre varies somewhat according to the type of fibre which is desired.

## BREEDING EXPERIMENTS

Until fairly recently it was only the wild forms of the plant which were used for fibre production, and few attempts had been made to select and cultivate improved varieties. Hemp was, in effect, a wild plant brought under cultivation.

Experiments by G. Bredemann in hemp breeding with a view to increasing the fibre content of the plant started in Germany before the second World War. All male plants of low fibre yield were eliminated before flowering, and in this way plants were bred that had a fibre content which was twice that of the original plants, namely about 24 per cent of dry-weight instead of 12 per cent.

H. Neuer in Germany began experiments to eliminate dioeciousness in wild hemp plants, and a variety of hemp was bred which always possesses both male and female blossoms, i.e. was a monoecious variety; with such varieties all plants blossom at the same time. A plant was evolved which no longer had a decreased yield of low-quality fibre (such as results from dioecious hemp owing to the early death of the male plants). The new strains were not, however, altogether satisfactory from the point of view of yield or quality, and nor were the strains with an increased fibre content which had been bred by Bredemann.

The next step in the breeding process was to try and combine monoeciousness with high fibre content, and also to create useful monoecious and dioecious varieties of high fibre content for the different districts in which hemp is cultivated. After a study had been made of the special characteristics of existing varieties, cross-breeding was started of (a) monoecious plants of low fibre content with dioecious plants of high fibre content; (b) dioecious plants of low fibre content with dioecious plants of high fibre content; (c) dioecious plants of low fibre content; (c) dioecious plants of low fibre content and late maturity with dioecious plants of high fibre content.

The different varieties were tried out in the field in Germany, France, India, the Netherlands, and Sweden, and it was shown that an average net yield of about 1,800 to 2,250 lb. of fibre per acre could be obtained from a straw harvest of about 9,000 to 11,000 lb. per acre, and that a fibre yield of about 24 to 25 per cent could be obtained. It was then proposed to undertake experiments to improve the quality of the fibre by breeding.

Another important problem which can be solved only by actual breeding is that of eliminating or reducing the 'hashish' content of these new varieties, so that varieties can be bred which contain a low content of the drug or none at all. Work on this aspect of hemp breeding is still going on, but it looks as though the work will take some time and will be costly.

## CULTIVATION

When it is being produced for fibre, hemp requires a mild, temperate climate, a humid atmosphere, and a rainfall of at least 27 in. per annum, with abundant rain while the seed is germinating and until the young plants are well-established. Where the plants have been sown close together, as when the seed is broadcast, they suffer very little damage from wind, rain, or hail; but if they are planted wide apart, as for seed-production purposes, they may be beaten down and injured in bad weather

.

The plants grows best on rich and fertile, neutral or slightly alkaline, well-drained clay-loam or silt-loam soils in which the subsoil is fairly retentive of moisture. It does not do well on acid sandy soils, on heavy clay, or on soils which dry out quickly. If, during the growing period, there is any prolonged drought, the plants are impeded in their growth, and the fibre form them is harsh and woody.

On the other hand, as has been mentioned, there are so many types of hemp, and these are able to adapt themselves so effectively to different climates and terrains, that it is difficult to define what are the best climatic conditions for hemp as a whole.

The plant can endure considerable changes in temperature, and this is one reason why it is so widely distributed in both the northern and southern hemispheres. Frost for any long period will destroy young hemp plants, but once the plants are ready for harvesting they do not seem to suffer from cold.

During its growing-season, hemp tends to exhaust the soil, but much of what is taken from the soil is put back into it after the plants are cut. On soils which are not very fertile, a dressing of farmyard manure or a greenmanure crop should be dug in. Sometimes chalk, gypsum, and potash manures are applied to the ground, and, in the United States, experiments have shown that sodium nitrate, ammonium sulphate, or a mixture of both of these with potassium sulphate, has a beneficial effect. For the best results, plants that are being grown for fibre should always have plenty of the proper nourishment, and nitrogen is the most

important requirement. Provided the leaves or refuse obtained during rettig are ploughed back into the soil, the crop can be grown for several years in succession on the same ground without exhausting the soil, but a rotation with other crops in nevertheless considered desirable. However, in Italy, for example, hemp is grown on the same ground year after year, apparently without any harmful effects on the yield.

As with other fibre plants, proper preparation of the land before sowing is essential if a good crop of hemp is to be obtained, and it has been stated that no other crop reacts better than hemp to proper husbandry and proper fertilizing. The land is usually ploughed in the autumn several times to a depth of about 8 or 9 in., and repeatedly harrowed so that the ground is level; in the following spring it is harrowed again and rolled, so as to make a fine uniform tilth over the whole field. In the Campania area of Italy, the first ploughing is done in the autumn, to prepare the soil for 'manure grasses' (such as red clover or lupin), which are then sown. In January or February a second ploughing is made, so that the 'grasses' are turned into the ground as green-manure.

Hemp seed is sown as early in the spring as possible, and is then covered, by means of a light harrow, with not-more than one inch of soil. Often, after harrowing, the soil is raked to level the ground. In Italy, hemp is generally sown in March-never later, except in unusual circumstances, as otherwise there may be danger of periods of drought just as the seeds are ready for germination, or when they are in the early stages of growth. The seed will germinate at low temperatures, but not below 1Â°C.

Too sparse a sowing means too great a distance between the plants and consequent branching of the stems, whereas if sowing is too dense, competition among the young plants is too great and early development is therefore retarded. Rolling the land after the seed has been sown is stated to be beneficial.

The quantity of seed sown per acre varies according to the type of fibre it is desired to produce. To produce fibre for cordage or coarser textiles, about 1 bushel per acre is used; but to produce the finest fibre as much as 3 to 4 bushels per acre may be sown. In Italy, where the seed is sown by machine the distance between the rows varies from 12 cms. upwards. The seed is placed at a depth of 3.5 cm., at the rate of about 40 to 60 kg. per ha. (according to the degree of viability of the seed). In other countires seed is generally sown broadcast; but where the plant is being grown for seed and not for fibre, the seed may be sown by means of drills. When this is done the plants sometimes reach a length of 16 ft., and have thick stems as large as 2 in. in diameter, with many branches. For fibre purposes, the ideal size of stalk is stated to be about 6 ft. high and 1/5 in. in diameter. If the stalks are much larger than this they tend to contain more wood and to have a lower fibre content and, moreover, they are more difficult to handle in the harvesting, retting, and scutching operations.

The seed weighs between about 1.5 and 2.5 gm. per 100 seeds. The best results are stated to be obtained if the seed used has been selected and grown for at least three successive years in the country where it is to be sown for the production of fibre. Imported seed is less certain to produce satisfactory crops. As a hemp plant may flower over a period of several weeks, and as the seed does not all mature at the same time, some of the carpels often contain immature seeds which will not germinate when sown. Good seed should have a germination capacity of at least 90 per cent; it should be stored in a cool, dry store, where it should remain viable for up to two years.

After the seed has been sown the plants require little cultivation except for weeding in the early stages of growth, though if the seedling come up too thickly they must be thinned. Hemp grows quickly and soon covers the ground, choking out the weeds. After the plants have attained a height of about 8 in., weeding can usually be discontinued. If, however, the weather in the spring is cold, the hemp does not grow well and tends to turn yellow and remain stunted. In Italy, two or three applications of nitrate have been found beneficial in such circumstances, in order to revive the growth of the plants. Irrigation is hardly ever practised in Italy.

## HARVESTING

The time for harvesting depends on climatic conditions, on the particular variety of hemp used, and on whether the crop is being grown for fibre or seed. In temperate countries hemp is normally ready for harvesting from four to five months after planting, but some of the early strains from Manturin seed may mature in three months, though in this case the yield of fibre is smaller. In Italy, hemp harvesting generally begins between the second half of July and the first week in August, according to the area and to the climatic conditions of the particular ye
ar.

Both male and female plants look alike until flowering time, when the male plants turn yellow and die. The female plants, however, remain dark green for another month or so until the seeds ripen. Male plants are ready for harvest when their colour changes from deep green to light brown, and the best yield of fibre of the best quality is obtained from hemp that is harvested when the staminate flowers are beginning to open and shed pollen. The seed is harvested when most of it is ripe enough to fall if the plant is shaken. The best time of the day for harvesting seed is during the early morning mists, as if the crop is left until later in the day, the seed cases burst open in the hot sun and seed may be lost. The cut stems are put on canvas sheets and beaten with sticks to extract the seeds. If the plant is cut before it is mature, the yield of fibre is diminished, and the fibre is weak but fine and soft, whereas if the plants are too mature, the fibre is harsh and brittle.

In Italy the following signs are said to be looked for when deciding whether hemp plants are ready for harvesting for fibre:

1. The stalk should have lost its green colour and shiny appearance, and have turned green and then white, especially near the root.
2. The lowest tiers of the stalk should have shed their leaves.
3. If the plant is blown by the morning breeze, or is shaken by hand, a blue mist of pollen should escape from the top of the plant.

The above points, however, apply chiefly to the male plants, as the female plants mature later and do not produce pollen.

Generally, as with other such fibre cops, hemp should be harvested between the time of blossoming and that of the formation of seed, which gives a harvesting period of at least three weeks.

Cutting is done by hand with a hemp knife, which resembles a long-handled sickle. The plants are cut off about 2 to 3 cm. from the ground. After cutting the stems are spread on the ground to dry. In some areas, however, such as in Campania and Piedmont-where, owing to the nature to the ground, the stems can be pulled up easily-pulling, instead of cutting is the normal method of harvesting. Hand-cutting is slow, and one man will not be able to harvest and spread more than Â½ an acre per day; but in such hand-harvesting the plants can be cut very near to the root, so that the yield of fibre per acre is higher, and there is less risk of breaking the stalks, than with machine cutting. Harvesting starts from the peripheral parts of the field, as the plants in this area are the first to ripen, possibly because they receive more light than those in the middle of the plot.

In the U.S.A., where over 120 million lb. of hemp were produced per year during World War II, machines were used for harvesting, and a specially designed harvester cut the stems and spread the stalks on the ground in a single operation. This machine harvester, with a tractor and two operators, was able to harvest up to 10 acres per day. In some places the crop was cut with a self-rake reaper which placed the stalks on the ground, but in other places the machines used were similar to those employed for harvesting wheat, although they had been modified for harvesting hemp. These, however, were not satisfactory if the hemp was more than 5 ft. high.

In central Russia hemp is grown as a late crop, but this has disadvantages in that the hemp matures when root-crops such as potatoes have to be lifted and there is consequently a big demand on labour, and when the water for retting is cold, so that retting takes longer. Sometimes retting is left until the winter, or in some years a large proportion is not retted at all, so that there is often a loss in yield, or the fibre produced is of inferior quality. To avoid this, experiments have been carried out with varieties of hemp which mature at different dates, so that the harvesting could be spread. Three varieties were grown: one, the main variety, was a dual-purpose crop maturing between 28 and 30 July; another, grown for fibre, matured between 12 and 15 August; and the third, also grown for fibre, matured between 27 and 29 August. The main variety, however, when left for seed purposes, was harvested between 12 and 15 September. The plants were harvested and transported in these four periods, so that some 65 per cent of the labour force was used for harvesting the main fibre crop in July and 35 per cent for the two other varieties in August while only 50 per cent was required in September when the balance of the main crop sown for seed was reaped, and when other crops, such as beet, potatoes, etc., also had to be harvested.

By spreading harvesting in this way, a considerable part of the demand for labour was transferred from September to August, and there was also a considerable saving of labour in October, November, and December, when under the old system retting would normally have been done. Moreover, as much of the retting could thus be done in warmer weather, the quality of the fibre was better, and the time and space required for retting were less- so that, whereas under the normal system 7,400 cubic metres of retting space were required, under this system only 3,700 cubic metres were needed. By spreading the harvesting times, much more efficient use was made also of the machines employed-and of the tractors needed to draw them. In view of the success of these experiments, it was proposed to extend them to other hemp-growing areas in the U.S.S.R.

This problem of spreading the harvest of a stem fibre crop is always an important one where machines are used for the harvesting and preparation of the fibre, or where supplies of labour are limited. It explains why the attempts to produce jute or Kenaf in countries where labour is scarce or too expensive have not met with success, and also accounts for the large amount of effort which is being devoted in various countries to the development of varieties of Kenaf which mature in different months of the year and which also give satisfactory yields of fibre of the right quality.

## YIELD

The yield obtained per acre will vary according to the climatic conditions, soil, and the spacing of the plants. The weight of dried stems of hemp per acre is usually between 1Â½ and 3 tons, and the yield of fibre is about 25 per cent of the dried stalks. In Italy, about 1,000 lb. per annum per acre of fibre are obtained, and, in the best areas, about 1,500 lb. per acre. A general average yield is about 800 lb. per acre. In Russia, however, yields of fibre per acre are not so high; they average less than 500 lb., partly because no attempt seems to have been made to select good seed, and partly because cultivation is not so carefully carried out as it is in Italy. The roots of air-dried plants amount to about 10 per cent of the total weight, the leaves to 30 per cent, and the stems to 60 per cent.

Other things being equal, the taller the stem of the plant, the longer will be the fibre and the greater will be the yield of fibre per plant. Anything which increases the length of the stem, therefore, is important from the point of view of commercial production. In this connection it is of interest to mention some work done with hemp at the University of Parma, Italy, using an aqueous solution of giberellic acid as a growth stimulater. Thirty-five days after the first treatment, plants which had been treated with the solution showed an increase in length which was about twice that of untreated hemp plants which were grown as controls. Giberellic acid, however, produces a number of effects in plants besides stem elongation, and more work would be needed to ascertain whether treatment of this kind would be worth while or economic.

## RETTING

The fibre is extracted from the stems of hemp by a retting process which is similar to that used with many other stem fibres. In this process the green colouring matter is decomposed, and the thin-walled tissues which surround the fibres in the inner bark are freed from the inner woody pith of the stalk. The gums and pectin which cement the fibres together are also dissolved or broken down, so that the strands of fibres are freed from one another. Sometimes the stalks are dried before they are retted-as, for example, in Italy, where the stalks are laid on the ground in the shade and left exposed to the air for from four to six days, being turned over occasionally, or alternatively are hung up on a frame. The roots and crop or flower ends of the stems, which contain little in the way of fibres, are then cut off and the branches and leaves are beaten off by means of a stick. After this, the stems are sorted according to length, and are made up into small bundles containing about ten to twelve stems each. These bundles are then placed with the root end downwards, in cone-shaped shocks, and are left for further drying.

For retting, bigger bundles, containing fifteen to twenty-five of these small bundles, are made with the butt or root end of one bundle lying on the top end of the next bundle, so that the final bundle is cylindrical and roughly the same thickness at each end.

In Emilio and Veneto, Italy, the dried stems are sorted and pulled. Small bundles are formed of about fifteen to thirty stems of almost equal length, and these are then collected into a larger bundle, which larger bundle is then 'topped' so that all the stems are of equal length. In some countries, however, as in France, the stalks are not dried before retting, but the green stems, after the roots and tops have been cut off, are made into bundles and retted at once.

The action which takes places during the retting of hemp is similar to that which takes place with other fibres, such as flax, jute, Hibiscus cannabinus, etc. Three different methods are used, namely water retting, dew retting, and snow retting-according to the climatic conditions which prevail in different countries. In the United States and the U.S.S.R., dew retting is usually practised, whereas in Italy and France, water retting is more common. In Russia and Sweden, however, snow retting is also sometimes used.

For dew retting, the stalks are spread on the ground in thin uniform layers, and are then left exposed to the dew. Dew retting may take from two to ten weeks, according to the climatic conditions. The stems are turned over at intervals, and, if there has been no rain or dew for some time, are given an occasional watering. The period required depends on the temperature and amount of rain and dew; in warm wet weather, retting is more rapid, particularly if such weather occurs at the beginning of the ret. Dew retting is, of course, cheaper than water retting, but the dew-retted fibre is considered to be a quality inferior to the water-retted fibre, as the process takes longer, and it is difficult to control the ret, whereas in water retting more control can be exercised.

For water retting the stems are usually placed in rivers, pools, or tanks, although river retting is considered to give better results than the others. The hemp is tied into bundles and placed in the stream, where it is covered with boards loaded with stones which submerge it under the water. Water retting is carried out most extensively in Italy, some parts of Russia, Hungary, and Yugoslavia. Where the temperature of the water is between 60Â° and 70Â°F., retting takes about ten to fifteen days, but with higher temperatures the period for retting is shortened. In Italy, the retting ponds are usually filled about one month before retting is to be carried out, so that the water can be warmed by the sun. In order that the water can become warm fairly quickly, the ponds are usually constructed to be not more than 5 ft. deep. Retting is considered to the finished when the fibre contained in the 'bark' can be separated easily from the woody inner portion of the stem. After retting, the bundles of stalks are taken out of the retting tank and set up in stooks to dry.

In snow retting, the dried stalks are spread out after the first fall of snow, and are then left to be covered by subsequent snow-falls until the spring, when, after the snow has melted, the stalks are usually found to be

sufficiently retted. However, if the stalks are buried under heavy falls of snow for too long, they are often over-retted and the fibre is ruined.

In China and Japan, the method of extracting the fibre from the stems differs somewhat from the methods described above. In Japan and Korea, for example, the stalks are tied into bundles, submitted to the action of steam, and then dried in the sun; they are then dipped into water and once more exposed to the sun. After this, they are made thoroughly wet by plunging into water, and are then heaped on a thick layer of straw mats in a barn and allowed to undergo a moderate fermentation process. The way in which these heaps are arranged, and the regulation of the fermentation process so that the best results are obtained, requires considerable skill. After the fermentation process the fibre is stripped off by hand and immersed in water. The epidermal and other tissue on the fibre is removed by scraping the fibre by hand with a special tool, and the fibre is then hung on lines to dry in a well ventilated barn or some other building. This method of extraction produces thin, smooth, pale straw-coloured ribbons. Although the material obtained is very stiff and strong, as it is more in the form of ribbons than fibre, it is not really suitable for spinning on ordinary hemp machinery, and there is a high loss on hackling.

As with many other fibres, chemical retting processes have been devised for hemp, have been used commercially, and from time to time have been given considerable publicity; however, none of them has so far been found to be really satisfactory, and the cost of such processing tends to be high. Some process which have also been devised involve the inoculation of the retting water with a specific retting organism. One difficulty with such methods, however, is that of keeping the culture pure on a commercial scale.

## BREAKING AND SCUTCHING

As with flax, the retted hemp stalks consist of the fibre in the rind and the woody interior portion of the stalk. The fibre is separated from the stalk by means of a breaking process similar to that used for the preparation of flax. The stalks are dried after retting and the woody shive is then broken into short pieces called hurds, by means of a wooden hand-break. This consists of a long wooden cradle or block, on to one end of which a movable, wedge-shaped, heavy wooden blade is attached by a hinge. The hemp straw is pulled between the block and blade, and the blade is dropped repeatedly, so that the dry stalks are crushed and the interior portions of them are broken into small pieces. These loosened pieces are then removed by beating the stalks across a bar, and the cleaning operation is completed by a hackling process which consists of drawing the fibre through coarse hackle pins which remove any remaining small pieces of wood or encrusting matter.

A really skilled worker using these methods can separate as much as 290 lb. of fibre per day. Today, however, the hackling process is often done by machine hackles in the spinning mill. Sometimes a breaking machine, consisting of one or more pairs of fluted rollers, is used. Attempts to devise machines for breaking, to take the place of the hand-break, have not been very successful, although machines have been used in cases where the cost of hand-labour was too expensive to enable the normal hand-breaking and scutching to be carried out.

In the U.S.A., for example, the bundles of dew-retted stalks from the farms were passed through a steam-heated dryer, and were then fed lengthwise through a number of fluted rollers which broke and removed most of the wood in the stalks. The fibre was then carried past large revolving drums with projecting bars which beat off any pieces of wood remaining and also removed any short and weaker fibres. One-half of the bundle of fibre was treated by one drum, and the bundle then went on by means of conveyor chains to another drum which scutched the other half of the bundle. This machine, of course, is similar to a flax scutching machine. The wood beaten out in the machine was carried by air into a furnace and used to produce steam-heat for the dryers and power for the machines. Machines of this type were able to handle 6,000 to 7,000 lb. of dried straw, which yielded 800 to 1,000 lb. of cleaned fibre, every hour. About one-half

of the fibre consisted of long fibre and one-half of tow, which is a high proportion of tow. With hand-breaking, however, the percentage of combed long spinnable fibre obtained varies between 65 and 90 per cent, the remainder being tow. This yield depends on the way the fibre has been prepared, the retting process, etc.

In Italy, a small portable machine is used for breaking and scutching water-retted hemp; in this machine, fluted rollers do the breaking of the stalks while revolving cylinders do the scutching. About 20 or more labourers are required to keep the machine going at its fullest capacity.

In Italy, about half of the total hemp crop was formerly grown in the district of Emilio in the north, and the remainder mainly in the Campania region in the south. Recently, however, hemp production in Italy has been declining, particularly in northern Italy, it was expected that only 2,500 tons would be produced in the north, compared with 13,000 tons. In the south, production in the same year was expected to be 14,500 tons, compared with 29,000 tons.

The chief reason for the decline in production in Italy is the low price of hemp, which makes other crops much more profitable from the farmer's point of view; consequently, they are being grown in preference to hemp. To cultivate one hectare of land under hemp requires about 1,000 to 1,200 working hours. This is double the number of hours required to cultivate the same area under wheat.

Bologna hemp gets its name from the city of Bologna in northern Italy: in this area, which adjoins the River Po, there are rich alluvial soils, and great attention is given to the cultivation of the crop, so that the plants grow to a height of as much as 12 ft. The plants are retted in the small rivulets which run into the river; the rivulets contain clean moving water, so that the retting is properly done. Consequently the hemp produced in northern Italy is of much better quality than that produced in southern Italy, and can be spun into finer yarns than hemp from other sources; indeed it is able to compete to some extent with the medium and lower grades of flax in Italy and elsewhere.

In Yugoslavia the chief areas producing hemp are Backa and Leskovats, and these two areas together account for about two-thirds of the total production in the country. In the Leskovats area, which produces the best quality hemp, the most important regions are Nish, Vranje, and Kosovo, and in the Backa area, Backa, Osijek, and Scram are the most important. Some of the hemp produced in the Vranje district is considered to compare well in quality with Bologna hemp.

## HEMP IN CHINA

Hemp is another fibre which has been grown in China for hundreds of years, and it is grown in almost all parts-in northeastern, northern, eastern, and southwestern China-but the best fibre produced in China is stated to come from Shandun Province of eastern China, and the highest yields per acre are obtained in eastern and southwestern China. In china there are many varieties, which mature at different times and give different yields per acre. One variety, for example, 'Sui-Matszun', which is grown in eastern China, is a late-maturing variety which gives a high yield of fibre and which is normally harvested before it flowers and when the stems are still green, whereas another variety, 'Homatszun', which grows in the same area, is an early variety.

There are also summer varieties and winter varieties of hemp in China, which are sown at different times of the year. One summer variety, 'Fu-ma', is sown in the middle of April and harvested in early August, whereas 'Tun-ma', a winter hemp, is sown at the end of November and harvested towards the end of July. Its seed, which is sown among other crops such as potatoes and soya beans, begins to sprout towards the end of March. The hemp grown in winter is stated to give fibre of better quality and also higher yields of fibre than the summer-grown varieties.

Hemp in China is usually grown in the fertile soils, on the banks of rivers and in areas where there are alluvial soils with a water-table near the surface. It is grown with other crops, and after the hemp has been

harvested, such crops as wheat and vegetables are sown. The yield of fibre obtained depends on the variety of hemp, soil conditions, time at which the crop is harvested, and so on. In the case of the variety 'Sui-Matszun', for example, yields of fibre of 500 lb. and 650 lb. per acre are obtained, according to whether the crop is harvested at seventy days or eight days, respectively, after the germination of the seed.

The stems of the plant are harvested by hand, usually when the plants are full flower, and the stems, after the leaves and roots have been removed, are retted in water in streams or ponds. The retting time varies according to the time of the year and the temperature of the water. In the summer, retting may take only two or three days, whereas in September it may take from five to six days. As with Abutilon in China, the hemp stalks are sometimes allowed to dry for two or three days before they are retted, as it is then easier to remove the leaves from them; but this practice is discouraged, as the resulting fibre is darker and more difficult to separate from the retted stems.

After retting, the stems are washed, left overnight on the ground, and then made up into bundles and stooked to dry in the fields. When they have become properly dry, they are put under cover, the actual separation of the fibre from the stems being carried out during the winter months. In order to separate the fibre, the stems are soaked in warm water, after which the fibre can be pulled off the stem. It is then dried, combed, and made into hanks ready for sale. In the southern part of eastern China, fibre from green, freshly harvested stems is used for paper-making.

## HEMP IN CHILE

Chile is the most important producer of hemp in the Western Hemisphere, and the plant has been grown there for over 400 years. It is grown as a dual-purpose crop, i.e. for fibre and for seed-partly because the sale of seed pays the farmer for the cost of growing the crop, so that the sale of the fibre provides the profit. Formerly the crop was grown almost entirely in the Province of Aconcagua, in the area north and west of Santiago. During the war, however, cultivation spread southwards to Santiago, O' Higgins, and Colchagua, but the soils in the Aconcagua region are better for hemp growing. The crop is grown on small farms varying in size from 8 to 40 acres, are owing to the long dry summers in central Chile it is always grown under irrigation. Only one variety of hemp, known as 'Chilean Hemp', is grown, and this was developed from one of the Italian varieties. It produces about as much weight of seed as of fibre, and consequently is most suitable for a dual-purpose crop. From the point of view of fibre quality, however, growing both seed and fibre is a disadvantage, as the dead male plants in which the fibre is over-matured are harvested with the female plants.

The hemp is sown in November at the rate of 150 lb. of seed per acre, and the plants are ready for harvesting in about March. The stalks are pulled, not cut, and left to dry on the ground for some days before being tied into bundles and placed in shocks to complete the drying process. Before retting, the seed is removed by flailing. Retting is done in pits and tanks, the bundles being submerged under water, and weighted with stones or rocks. The time taken for retting varies between six and twenty days. After retting, the stems are dried in the open-air and then stacked in the usual way.

Most of the hemp produced in Chile is used locally for the manufacture of twines and ropes. The best qualities are exported, when production warrants export. The possibilities of increased production, however, are limited, owing to the poor quality of the fibre for the reason mentioned above, and to the primitive, inefficient machines which are used to extract and process the fibre.

## QUALITY OF HEMP

The quality of hemp is judged mainly by its colour and lustre; good-quality fibre should be lustrous and give a decided snap when broken. Dew-retted hemp is grey, whereas water-retted hemp is usually creamy-white. White and pale-grey hemps are considered to be the best, greyish hemp next, while soft yellowish hemp is the least valuable. The best hemp is Italian, especially of the variety known as Bolognese, which

has excellent colour, a silky lustre, and a softness rather similar to that of flax; normally, it is about 6 or more ft. long. Next in quality is French hemp, particularly that from the Grenoble area. Russian hemp and hemp produced in the U.S.A. is coarser than the other two kinds mentioned, but has great strength and durability.

## PROPERTIES AND USES OF HEMP

Hemp fibre is longer than flax fibre, but is less flexible and more coarse. It does not bleach well, and as it lacks elasticity and flexibility it is not used for fine textiles. The ultimate fibre cells vary in length from 5 to 55 mm., and have an average length of about 20 mm.; their diameter varies between 0.016 and 0.050 mm., with a mean of 0.022 mm. The thickness of the cell-wall varies much more than it does in flax, increasing towards the end of the fibre so that the lumen is narrower there. When viewed under the microscope the fibre cells are seen to be irregular in shape, being flattened at some points along their length but cylindrical at others. There are striations on the surface of the fibre but no nodes like those found in flax. The ultimate fibres have forked ends, and these serve to distinguish them from flax.

Hemp has a cellulose content of 67 per cent and contains about 16 per cent of hemicelluloses. Hemp has a 'Z' twist, and this is one way of distinguishing it from flax, which has an 'S' twist.

Hemp can be used for ropes, twines, cables, nets, sail-cloth, canvas, tarpaulins, etc., but its main use is as a substitute for flax in the manufacture of yarns and twines. Today, however, its place as a material for ropes has to a large extent been taken by such other fibres as sisal and abaca, which are much stronger and more suitable for this purpose.



**NIIR PROJECT CONSULTANCY SERVICES**
106-E, Kamla Nagar, New Delhi-110007, India.
Tel: 91-11-23843955, 23845654, 23845886, +918800733955
Mobile: +91-9811043595
Email: npcs.ei@gmail.com ,info@entrepreneurindia.co
Website: www.entrepreneurIndia.co