satisfactory spun into a yarn nor woven into a cloth. Italian hemp is so carefully prepared that it can be spun into a fine yarn. The resulting fabric is very soft and lustrous, quite similar in appearance to the flax fabric.

Hemp is used where strength is more important than beauty as in carpet warp, canvas, tarpaulins, webbing, sacking, twine, rope, cables, artificial sponges and a host of other articles. In recent years, hemp in conjunction with flax has been widely used for the manufacture of yarn and twines. Short fibres or 'tow' and ravellings or entanglings constitute 'oakum', used mainly for caulking the seams between the planks used in shipbuilding, barrel making and as a packing material for pumps and engines. In addition, hemp waste and woody fibres from the stem serve as a raw material for the paper industry.

Hempseed oil is a good substitute for linseed oil, much used in the paint, varnish and soap industries. The seeds are also used as caged bird's feed.

Jute

***Corchorus* spp. (x = 7)**
Family: Tiliaceae

Jute is the least expensive, but most important of all the bast fibres. It comes second to cotton in production among all natural fibres. The fibre is obtained from the stems of two cultivated species of *Corchorus*, namely *C. capsularis* L. (white jute) and *C. olitorius* L. (tossa jute). It occupies an important place in the Indian economy, being the largest earner of foreign exchange.

HISTORY AND ORIGIN

The early history of jute is not known definitely. The plant is mentioned as food in the Bible as well as in ancient Egyptian and other early Mediterranean literature, but its use as a textile fibre is somewhat obscure. The generic name *Corchorus* is believed to have been derived from the word 'korkhoros' used by the Greeks for pot-herb. In India, jute fibre has been used since ancient times but became important as a sackcloth during the late sixteenth century. The first shipment of jute fibre from India to England was made in 1791. The term jute is probably the anglicised form of the Oriya word 'jhout' or 'jhut'.

The genus *Corchorus* consists of about 40 species, of which 36 have been recorded in Africa. According to Kundu (1959), the primary centre of origin of *C. olitorius* is Africa with a secondary centre in India or Indo-Burma. *C. capsularis* is, however, not found in Africa and Australia; its centre of origin is believed to be Indo-Burma.

PRODUCTION

Jute is second only to cotton in terms of world's production of textile fibres. Around 97 per cent of the world's jute production of 3.46 million tonnes (2012) comes from the Gangetic Deltas of India (West Bengal) and Bangladesh, accounting for about 1.9 and 1.4 million tonnes, respectively. China comes third with a production of 45 000 metric tonnes. Other minor producers are Uzbekistan, Nepal, Myanmar, Bhutan, Vietnam and Thailand. In the African region, jute cultivation is confined to Sudan, Zimbabwe and Egypt while Brazil is the only producing country in the tropical America. India is the biggest consumer of jute in the world, and exports only the jute products to the international market, while Bangladesh is the largest exporter of raw jute and some manufactured items. The best quality of jute still comes from the districts of Mymensingh, Dhaka, Tangail and Comilla

in Bangladesh. At one time, jute was a monopoly crop of India, which produced 99 per cent of the world's production. However, after the country's partition in 1947, India retained only the jute mills, while most of the area producing the superior quality jute (districts of Mymensingh, Dacca and Tippera) went to Pakistan (now Bangladesh). Since then, there has been a considerable extension of acreage in India.

MORPHOLOGY

Both the cultivated species are woody, little branched annuals having simple, ovate, serrate margined leaves with peculiar curved bristles (auricles) near the base [Figure 2.6 (A)]. Flowers are either solitary or arranged in a few flowered cymes [Figure 2.6 (B)]. The two species are quite similar botanically but differ in a number of ways. *C. capsularis* is a tall, little branched annual (3-3.7 m tall) with ovate, glabrous leaves containing a bitter glycoside 'corchorin' (Figure 2.7). Hence, it is often referred to as 'tita' or 'bitter pat'. Small yellow flowers at maturity give rise to small, more or less globular, much-wrinkled capsules flattened at the top and enclosing chocolate brown seeds (300 to 1 g). Although the fibres of *C. capsularis* are normally whitish, they are considered inferior to *C. olitorius* and sell at a lower price. The plant can withstand waterlogging in the later stages of growth (lowland species).

Unlike white jute, *C. olitorius* is a much taller species having leaves with a shining upper and a rough undersurface. With no bitter taste, the leaves are almost tasteless when chewed (known as 'mitha' or 'sweet' pat). The yellowish flowers are larger in size than *C. capsularis*, each developing into a long, cylindrical, ridged capsule with an elongated beak. Seeds are small (500 to 1 g), bluish green to steel grey or even black in colour. Fibres of *C. olitorius* are usually finer, softer, stronger and more lustrous than those of *C. capsularis* but are either yellow, red or grey, depending upon the nature of retting water. The plant is an upland species, quite susceptible to waterlogging.

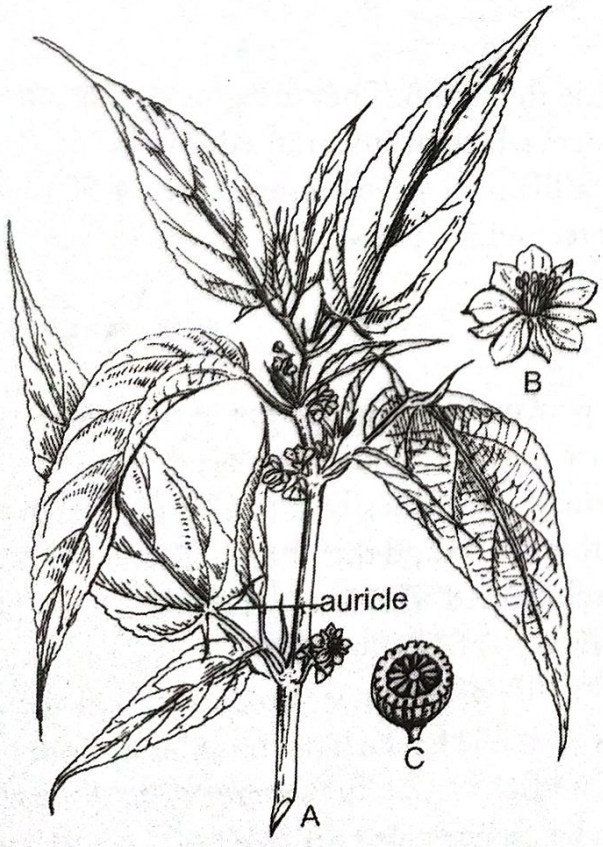

Figure 2.6 (A) Diagram of a portion of *Corchorus capsularis*, showing auricles at the base of leaves, (B) a flower and (C) cross section of fruit.

Figure 2.7 Close-up photograph of the fruiting shoot of *Corchorus capsularis* – the golden fiber of India.

CULTURAL PRACTICES

In India, about 75 per cent of the jute crop is *C. capsularis*. It is primarily a rainy season crop, thriving best on warm, humid and rich loamy or alluvial soils where annual rainfall ranges from 150-250 cm; with an average temperature between 17 and 38 °C and a relative humidity of around 70 to 90 per cent. The fertile alluvial soils of the extensive river delta of the Ganges, the Brahmaputra River and their tributaries are ideally suited for jute cultivation. Jute cannot withstand waterlogging in the early stages of growth. *C. capsularis* is very adaptable, growing equally well in both upland and lowland areas, whereas *C. olitorius* cannot withstand flooded conditions and is cultivated in the highlands.

Seeds are sown broadcast. In the large jute fields of West Bengal, the seeds are sown close together so as to produce unbranched stalks. Weeds are hand-hoed. The plant matures within three to five months.

HARVESTING

Plants are harvested when nearly 50 per cent of them are fruiting. At this stage, both the yield and quality of the fibres are good. Early harvesting is likely to give a poor return, and although the fibre has a good white colour, it lacks strength. Late harvesting, on the other hand, increases the yield but produces coarse fibres. Plants are cut close to the ground with a sickle or pulled out by hand when growing under water. In flooded areas, particularly in many parts of Assam and Bangladesh where the flood water rises very high, the cutters often have to dive under water to cut the stem. A trained cutter cuts as many as six to eight plants at one time. The cut stems are tied in small bundles and left in the fields for two to three days during which the leaves wilt and finally drop off. Further removal of leaves and fruits is accomplished by drawing the bundle through a comb-like device without inflicting any damage to the stem and fibres.

LOCATION OF FIBRES

The fibres occur in long wedge-shaped bundles outside the xylem. They are grouped in concentric rings alternating with the thin walled tissue of the phloem which disintegrates during retting (Figure 2.8). Each of the fibre bundles represents one strand or filament (reed) composed of 4-50 cells. The individual fibre cells are seldom longer than two or three millimetres.

PROCESSING

The bundles of stems are taken to the nearest stagnant pool or ditch and laid flat in the water, arranged side by side so as to make a regular platform. Another layer of bundles is placed on top at a right angle to the first. A third or fourth layer of bundles may sometimes be added if the water is deep. The surface of the bundles is covered with weeds or other refuse and then heavily loaded with stones, bricks, logs of wood, banana stems, etc. to keep them submerged. The retting process usually takes 10 to 30 days, depending upon the maturity of the crop, the type of retting water and its temperature and the depth of immersion. Because of the more woody nature of the lower or 'butt' end of the stem, it takes longer time for complete retting. It is, therefore, desirable to stack the bundles upright in about 0.6 m of water for two to three days before they are laid flat.

Retting is considered complete when the bark can be easily peeled off. For stripping, the workers stand in waist-deep water. At first, the root or 'butt' ends of the stems are beaten with a wooden mallet to loosen the fibres. Then, the free ends of the loosened fibres are wrapped firmly around the fingers

and the stems are jerked backwards and forward in the water, thereby separating the fibres from the stick. Afterwards, the stripped fibres are lashed, on the surface of the water, to remove the adhering bits of periderm and pith. Finally, the fibres are washed in clean water and wrung out. They are then spread out in the sun on bamboo racks for two to three days and rolled into bundles. The average fibres yield is about six per cent of the green (fresh) weight of the stem. *C. capsularis*, on average, yields 900 to 1350 kg of fibre per hectare, while the outturn from *C. olitorius* is 1350 to 1880 kg per hectare.

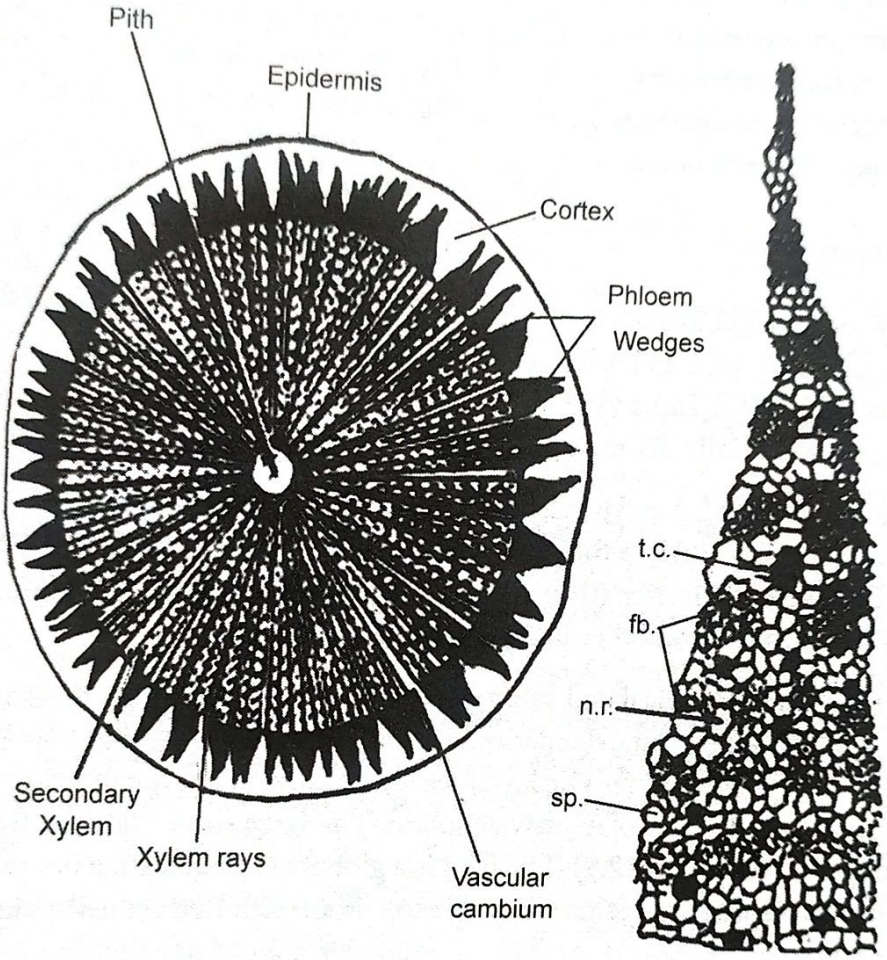

Figure 2.8 (Left) Cross section of a jute stem showing the wood and phloem wedges, (right) a pholem wedge – *fb.*, fibre bundles; *n.r.*, new secondary rays; *sp.*, soft phloem tissue; *t.c.*, tannin-containing cells.

FIBRE CHARACTERISTICS

The strands of jute fibre range from 1.83 to 3.05 m in length, are pale yellow or yellowish white in colour and possess a silk-like lustre. They are weaker than hemp and flax, perishable and tend to deteriorate when exposed to dampness. Even under normal conditions, they are stiff, brittle and coarse, with low stretchability and elasticity. During processing, the ends of some of the individual fibres in the bundle are loosened, resulting in a varying amount of hairiness – a property quite desirable in the manufacture of bagging, as it tends to prevent slipping.

The individual fibres vary from 2 to 5 mm in length, are polygonal in cross section and have a smooth surface free from markings or striations. They have a relatively wide lumen but show characteristic constrictions at irregular intervals, and sometimes the lumen is completely obliterated. They take dye quite well, but jute is difficult to bleach.

Jute fibres contain 63 per cent cellulose, a relatively low content compared to that of hemp (77 per cent), flax (82 per cent) or cotton (86 per cent or even more). They also have a high proportion of lignin which makes them less durable. An average sample of jute, on chemical analysis, gives the following values: cellulose, 56-63 per cent; hemicellulose, 22-26 per cent; lignin, 11-12 per cent, plus minor components such as fats, waxes, gums and minerals.

Despite many defects, jute is the world's most important bagging and wrapping textile. Nearly three-quarters of the jute produced annually is manufactured into sacks and bags. It also finds wide application in the manufacture of rugs, blankets, carpets, tarpaulins, cloth backing, carpets, linoleum and oil cloth, twine, rope, upholstery, curtains and coarse cloth. The leaves and young shoots are an important source of vegetable food in Egypt, Sudan and Greece. Jute 'butts' are used for the manufacture of paper and paperboard.

JUTE SUBSTITUTES

There are about 40 other vegetable fibres that can be considered as potential competitors of jute. Of the estimated world supply of 1 151 870 t of jute-like fibres, Thailand produces about 400 000 t, followed by China (397 800 t), India (193 000 t) and the CIS (57 000 t).

In this section, we will briefly discuss some of these more important vegetable fibres.

Kenaf (*Hibiscus cannabinus* L.) and roselle (*H. sabdariffa* L.), of the family Malvaceae, are used on a fairly large scale, mixed with jute, in the manufacture of bags, sacks, cordage, netting, coarse canvas and fishing nets. Because of their strength and durability, kenaf fibres are now used in the manufacture of tags, abrasives (sand paper) and other heavy duty paper.

H. cannabinus, a native of tropical and subtropical Africa, has been grown in Egypt and India for centuries as a fibre plant. It has a long, slender, unbranched, glabrous or prickly stem which may reach a height of 2.4 to 3.6 m or even more. The lower leaves are cordate but the upper ones are palmately divided (five to seven oblong-lanceolate, serrate lobes). The large showy flowers are borne singly in the axils of the upper leaves (Figure 2.9). The fruit is a globose capsule with a pointed tip, producing large brown, nearly glabrous seeds at maturity. The seeds are rich in a semi-drying oil, very similar to the cottonseed oil.

Kenaf (also known as Deccan hemp, Mesta, Bimlipatam Jute or Java Jute) has been successfully grown in many countries throughout the tropics and subtropics as a commercial crop. It is less exacting in its climatic and soil requirements than jute. At present, India, Thailand, Brazil, China, the United States (Florida), Cuba, Mexico, South Africa and the USSR are the major kenaf producers.

In order to obtain a higher yield and good quality of fibres, the crop is harvested at the flowering stage. The bulk of the fibres is found in the lower portion of the stem. The fibre extraction process is similar to that used for jute. Mechanical decortication with or without retting has been attempted in South Africa and Western countries.

The fibre strands are 1.5-3.5 m long and are comparable to jute in lustre. They are somewhat coarser and less supple but are tougher and stronger, that is, resistant to rotting. The primary fibres obtained from the inner cortical cells are tightly packed, glossier and more flexible than the secondary fibres originating as a result of cambial activity.

Roselle (also known as Jamaican sorrel), probably native to West Africa, has been cultivated throughout India and parts of Asia for centuries. Currently, it is being grown throughout the tropics, especially Indonesia (central and eastern Java), India, Bangladesh, Sri Lanka, the Philippines and the West Indies, however, the quantity of fibre produced in the areas other than Indonesia is small.