JUTE—
FIBRE TO YARN

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Preface

THIS book is intended mainly for students but it is hoped that it will also be of interest and value to those engaged upon the technical side of the industry. Briefly, the intention behind the book is to give an appreciation of the more important aspects of the raw material, to show the basic principles involved in converting the raw material into yarn, and to demonstrate how the machinery does this.

I am deeply indebted to Dr. H. P. Stout, Director of the British Jute Trade Research Association for his continued interest and assistance, and to the Council of the Association for permission to draw from their Research Reports. My thanks are also due to Mr. P. G. Anderson and Mr. G. C. Stevenson, who were kind enough to criticize the text in a most helpful and constructive manner; to Messrs. James Mackie and Sons Ltd, to Messrs. Fairbairn Lawson Ltd, and Messrs. Giddings-Lewis and Fraser Ltd for their ready assistance in providing technical data and photographs of their machinery. Help with proof-reading and the preparation of the index was given by my wife. For this and for her constant encouragement while the book was being written, I thank her.

Dundee, 1964.

R. R. ATKINSON

The Place of Jute in World Textiles

JUTE is second only to cotton in the world's production of textile fibres. It is estimated that in 1960 about 31 thousand million pounds of fibres were processed throughout the world, cotton accounting for roughly half that quantity and jute following with a consumption of nearly five thousand million pounds. Table I shows the relative proportions of the principal fibres used in recent years compared with the pre-war period. The most interesting feature of the Table is the decline in importance of some fibres and the growth of others as economic and technological changes take place.

TABLE I. TEXTILE FIBRE PRODUCTION†
(Individual figures are percentage of total)

	Average 1934–39	1957–58	1958–59	1959–60
Cotton	57·2	47·6	48·5	49·3
Jute and allied fibres	16·5	16·2	18·1	15·6
Wool (apparel)	7·4	7·0	7·2	7·1
Wool (carpet)	1·5	1·3	1·3	1·3
Rayon (filament)	4·8	7·2	6·2	6·7
Rayon (staple)	2·2	9·0	7·8	8·2
Other man-made fibres	—	3·0	3·0	3·9
Silk	0·5	0·2	0·2	0·2
Flax	1·0	0·8	0·7	0·6
Hemp	8·9	7·6	7·2	7·1
Total (million lb)	20,219	28,482	29,326	30,901

† Sino–Soviet bloc excluded.

The major sources of supply of jute lie within the Commonwealth, chiefly in India and East Pakistan. When the Indian sub-continent was partitioned in August, 1947, the main jute-growing area, East Bengal, was awarded to the newly created state of Pakistan while about three-quarters of the manufacturing capacity fell within the boundaries of

the Indian Union. Thus at that time Pakistan had ample supplies of fibre but few mills while India had more mills than she had fibre for. Each country began to make the necessary alterations to its economy, Pakistan developing Chittagong and Chalna, its ports on the Bay of Bengal, so that she could export her raw fibre more easily while, at the same time, every effort was made to set up new mills. India, on the other hand, expanded her acreage under jute cultivation to supply her mills, the export of jute cloth being a powerful currency earner and playing a vital part in the economy of the country.

Jute is grown on a large number of peasant smallholdings and it is rather difficult to arrive at an exact figure for the total acreage but it is estimated that since 1955 about 3,600,000 acres each year have been used for jute growing throughout the world, India and Pakistan between them accounting for some 3,000,000 acres. Jute is also grown in Burma, Formosa, China, Brazil, and Nepal, but at present their production is negligible compared with that of the sub-continent. Fibres allied to jute, such as kenaf and Congo jute, are grown in India, Thailand, and the Congo but again output is comparatively small.

In recent years the world's production of jute and its allied fibres has been running at a level of between 2 and 2·7 million tons annually, true jute accounting for about 80 per cent of this. Though some of the minor growing countries are trying to increase their output, one of the difficulties about successful jute growing on a commercial scale is that plentiful supplies of both water and labour are required. From time to time various types of mechanical harvester have been tried but none are, at the moment, capable of handling the large quantities involved.

The largest centre of the jute industry is the Calcutta area of India where some 70,000 looms produce about 1·25 million tons of jute goods annually. Pakistan follows next in importance with an annual output of some 250,000 tons which, it is planned, will increase to 360,000 tons by 1965. After these two countries, the United Kingdom has the largest industry, capable of producing about 160,000 tons of jute goods each year. The manufacturing emphasis in the U.K. differs from that in India and Pakistan; these last mentioned countries being mainly concerned with weaving cloth for sacking and bagging. In Great Britain about one-third of the output is yarn for the carpet industry, and the weaving of speciality fabrics is carried on in preference to sacking fabrics. The combined 'Common Market' countries

process some 280,000 tons of jute annually and here again the emphasis is on jute for special purposes. Other countries such as Brazil, Japan, and the United States have smaller manufacturing capacities used mainly for internal trade. India is the world's major exporter of jute cloth, sending large quantities to America for baling cotton and to Australia for grain and wool packing.

Jute has long been recognized as a cheap, strong, durable fabric eminently suited for sacks and bags and many other purposes. On a world basis about 80 per cent of all the jute manufactured finds its way into packing of one sort or another. The actual weight of jute used per ton of transportable material depends on local variations in sack dimensions, whether the goods are for export, whether the bag is returnable or not and so on, but typical figures for the weight of jute used to pack one ton of various products are

Flour	(hessian bags)	15 lb
Flour	(twill sacks)	41 lb
Potatoes	(hessian bags)	22 lb
Potatoes	(twill sacks)	46 lb
Beet pulp		24 lb

In certain cases the contents of the bag must be protected against contamination by the jute itself, by other products stored nearby, or by the atmosphere. For such uses the bag may be lined with paper or polythene bonded to the jute. Alternatively a loose liner of paper or polythene can be used and after transporting the commodity the liner may be taken out and the bag re-used. One of the advantages which a jute bag has over a paper bag is the fact that it has a good second-hand value and in most countries of the world there is a considerable trade in second-hand bags.

Jute is used in woven carpets as weft, warp, or pile, in tufted carpets as the backing material, in linoleum as backing, and in carpet underlays and felts. A general indication of the amounts of jute used in different floor-coverings is given below

Woven carpet (wool pile)	1·2 lb/yd^2
Woven carpet (jute pile)	2·0 lb/yd^2
Tufted carpet	0·9 lb/yd^2
Linoleum	0·6 lb/yd^2

One of the outstanding developments in the carpet industry in recent years has been the rapid growth of the tufted carpet section and now large quanties of jute are sold for the backing fabric of these carpets.

Jute is also used in smaller quanties in a host of other applications. Small domestic ropes, parcelling twines, horticultural twines are examples of its use as cordage. Roofing felt and damp courses often have a base-cloth of jute; in the upholstery trade jute is used for covering the underside of chairs and as webbing for supporting chair seats; tailors' interlinings are often made from fine jute cloth; jute yarns are used in the electrical and cable-making industries as packing for power cables or telephone and telegraph cables; jute may be used for filter cloths, boot and shoe linings, and tarpaulins. It has even had some vogue as a dress fabric.

CHAPTER ONE

The Anatomy, Cultivation, and Marketing of Jute

JUTE is obtained from the stems of two plants grown mainly in the Indian sub-continent. All fibres which are extracted from the stems of plants are classified as bast fibres, others in this category being flax, hemp, kenaf, and ramie. The botanical names of the plants from which jute is obtained are *Corchorus capsularis* and *Corchorus olitorius*. About 40 species of *Corchorus* are known throughout the world, being found chiefly in the Tropics but *C. capsularis* and *C. olitorius* are the only ones which are cultivated for their fibre. In the wild state both plants are small and shrub-like but when they are cultivated they can grow up to a height of 15 ft. Both are herbaceous annuals, i.e. they grow from seed to maturity in one year and in doing so produce seeds for the following year's crop. Jute is grown in the rainy season in temperatures of 70–100° F with relative humidities of 65–95 per cent and requires a total rainfall of about 10 in. during the months of March, April, and May.

In general appearance *C. capsularis* and *C. olitorius* are similar, having long straight stems about 1·5 in. in circumference, unbranched except at the top. The main difference between the two species is in their fruits: *C. capsularis* has a rough wrinkled spherical seed-box about 0·3 in. in diameter and *C. olitorius* has an elongated pod like a miniature cucumber about 2 in. long. Besides the shape of their seed-boxes there are other differences: *C. capsularis* tends to be shorter than *C. olitorius*, rarely exceeding a height of 12 ft compared with 15 ft for *C. olitorius*; *C. capsularis* is grown on lower-lying ground than *C. olitorius*; *C. capsularis* yields the 'white' jute of commerce and *C. olitorius* the 'Tossa' and 'Daisee'. Tossa is grown on the higher ground because the crop withstands floods later than white and so does not need to be cut at the normal flood-threat time. Although Tossa has a higher yield per acre and commands a better price, some 60 per cent of the total jute crop is of white jute.

THE ANATOMY OF THE JUTE STEM

The jute fibres lie within the stem of the plant just beneath the bark and surrounded by soft tissue. Figure 1.1 shows diagrammatically what would be seen if a V-shaped wedge were cut out of a jute stem.

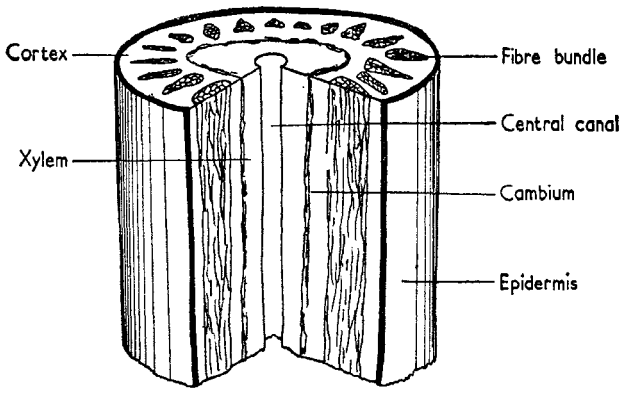

Figure 1.1. Anatomy of the jute stem

On the outside of the stem is the epidermis which in young plants is green and soft but becomes harder, particularly at the root end, as the plant matures. Immediately beneath the epidermis lies the cortex, imbedded in which are the fibre bundles. Continuing to move inwards to the axis of the stem the cambium is found, a continuous layer about five cells thick running completely round the stem. On the inside of the cambium lies the xylem which, as the plant matures, becomes more and more woody and finally, running down the centre of the stem is a canal which in mature *C. olitorius* stems is usually hollow but in *C. capsularis* stems still contains a soft pith.

The cambium plays an extremely important part in the life of the plant and is particularly interesting because it is from it that the fibre bundles develop.

In the young plant the stem is composed of a ring of unconnected bundles of cells, surrounded by the soft tissue of the cortex and encircling the pith, the whole being enclosed by the waxy epidermis which protects the young plant. The inner part of the cell bundles contain the elements of the woody xylem while the outer part will form the 'bast'; separating these two sections are the rudimentary cells of the cambium. As the plant grows, the cambium cells multiply and

divide until they join up with their neighbours in the adjacent bundles to form a complete ring round the plant. On the inside of cambium the cells enlarge and bundles of them become progressively more lignified and form the 'wood' of the stem. On the outside of the cambium interesting and important developments occur. Groups of cells known as medullary rays spread out from the cambium and between them certain cells begin to change by thickening their walls—these are the first fibres. Growth continues and more and more cells develop into fibres until the easily recognizable fibre bundles are formed. The bundles are roughly triangular in shape with their base towards the cambium and their apex towards the epidermis. In the bundle the oldest fibres are at the apex and the most recently formed at the base. Thus the oldest fibres are continually being pushed outwards by the newly formed ones.

These cells in the fibre bundles are, as it were, the building units of the fibres and are called 'ultimates' and are on average about 18 microns in diameter and 2·5 mm long (1 micron = 0·001 mm). The ultimates are cemented together to form the 'fibres' of commercial usage which run along the stem of the plant, branching and dividing, only to unite with their neighbours then divide again, making up a mesh of fibre networks lying in layers around the cambium. The outermost layers are more open than the innermost ones because of the outward growth from the cambium, and as the stem circumference grows the first-formed networks become stretched and open.

THE CULTIVATION OF JUTE

The jute crop is grown on small plots of land and in many districts half the growers have only about 800 lb of fibre to sell at the end of the season. With the normal outrun of fibre being 1,100–1,300 lb per acre, this means that many of the plots are only about three-quarters of an acre. Since it takes around 80 man-days (1 man-day = 1 adult working for 7 hours) to plough, sow, weed, cut, and extract the fibre from 1 acre of ground it follows that about 150 man-days are needed to produce 1 ton of fibre. Some idea of the large labour force required can be obtained when one remembers that about 2,000,000 tons of jute are grown each year.

Low-lying, slightly acidic, alluvial soils in river complexes are particularly suited to jute growing, especially when these soils are revitalized by flooding each year and a deposit of silt is left on them

when the flood-waters recede, but the fibre can be grown on lighter sandy soils provided large quantities of manure are fed into the ground. The characteristic feature of the main jute-growing areas of India and Pakistan is the low-lying nature of the terrain, any slopes are gradual and the river banks have an extremely small gradient. Dacca, in the centre of an important jute-growing region, is less than 50 ft above sea-level although it is 100 miles inland. These low lands, as would be expected, flood very easily when the heavy monsoon rains coincide with the melting of the Himalayan snows about the middle of June or July and even those parts which are not actually flooded may be under a few inches of surface water at times. The lower levels are inundated each year by the overflowing rivers which meander over the whole area and at harvest time parts of the crop may be under several feet of water. Apart from the beneficial effects of this large supply of water from the botanical and agricultural points of view, the widespread river systems provide a very useful means of transporting the fibre as road and rail communications in the country districts are not good.

The time when both types of jute cease strong growth and enter upon their reproductive phase of life by flowering and then forming seed-pods is influenced by the hours of daylight in each day. When the length of the day reduces to about 12 hr at the end of August and the beginning of September the plants flower soon afterwards no matter when they have been sown. *C. olitorius* is more sensitive than *C. capsularis* in this respect and since growth and the yield of fibre depend critically upon the time of flowering the former variety is always sown later than the latter. Most of the more commonly met *C. capsularis* is sown in February, March, or April, whereas the *C. olitorius* type is sown in April and May. Apart from these differences the two species are cultivated in similar ways.

The land is ploughed to a depth of a foot and the soil worked down to a fine tilth by successive harrowings or 'ladderings'. Laddering consists of drawing a rough bamboo ladder or a log of wood about 7 ft long across the plot with the worker standing on it to apply pressure. This breaks up the lumps of earth, levels off the soil, and removes weeds. Since jute seeds are very small (about the size of turnip seeds) they need a fine seed-bed. As jute is a strongly growing plant it requires plenty of nourishment from the soil. Where flooding occurs the fresh silt brought down each season is a ready supply of fresh

nutritional material but where flooding does not occur the land must be manured.

Sowing is usually done by the broadcast method at the rate of 10 lb of seed per acre for *C. capsularis* and 6 lb per acre for *C. olitorius*. The sower walks across the field scattering the seeds to either side, then when the ground has been covered in one direction he repeats the process by walking at right angles to his original line; in this way a uniform distribution of seeds can be achieved. A light covering of earth is then drawn over the seeds until they are 1–1·5 in. below the surface, and the surface is consolidated by laddering. Line sowing, which gives a better yield of fibre is being encouraged by the various jute-growing authorities by means of field demonstrations, etc., but at the moment most seed is sown broadcast.

Within 2 or 3 days the seeds germinate and about a million plants per acre are formed. This high seed-rate is necessary because the individual seedlings are very delicate and this large number makes it easier for the plants to burst through the firm crust of earth which forms when rain follows soon after sowing. The plentiful supply of plants ensures that some will survive if periods of drought occur before the monsoon starts at the beginning of June. Weeding and thinning are carried out manually, usually in two stages when the plants are 3–6 in. tall, until a final count of around 150,000 plants are left, spaced 4–6 in. apart. Weeding is by far the most laborious part of jute growing, accounting for 30–40 per cent of all the labour involved. Depending on the district, the plants are ready for harvesting from the middle of June to the end of September.

The optimum time for harvest is just after the plant has flowered and before the fruits form since at this stage the plant has reached full height, the bark is easily retted, and the fibres are at their best. If the crop is cut early, perhaps because of heavy rains and flooding early in the season, then the yield is low, the fibre short and pale in colour; late harvesting, when the fruits are well set, gives a higher yield but the quality of the fibre deteriorates.

The plants are cut off close to the ground with a sickle and in the plots which are flooded the workers must dive beneath the water to do this. Where the water is only 2–3 ft deep the plants may be simply pulled up by the roots and then the roots cut off when the stems are on the banks. On the higher ground the stems are stacked for a few days to let the leaves fall and then they are bundled ready for the next

stage in fibre extraction. Jute harvested from low ground has its stems bundled immediately after cutting.

As jute is an annual, some of the plants must be left to produce seed for the next year's crop; depending on the district some 3–5 per cent of the land is used for this purpose.

FIBRE EXTRACTION

In the living plant the fibre bundles lie beneath the bark, surrounded by gummy materials; these encircling soft tissues must be softened, dissolved, and washed away so that the fibre can be obtained from the stem. This is done by steeping the stems in water and is known as 'retting'. The bundles of stalks are laid in ponds, ditches, or slow-moving streams, weighted down with stones, leaves, or clods of earth, and left for 5–15 days. A plentiful supply of water for retting is another of the reasons why jute can only be grown on a large scale in certain regions of the world (approximately 2,800 gal are needed to pond-ret 1 ton of green stalks which will yield some 112 lb of fibre). The optimum water temperature for retting is 80° F. Retting is caused by micro-organisms which soften the tissues and gums, starting at the cambium and extending outwards so that the outer cells of the cortex are the last to disintegrate. Retting is better if the stems are uniform in thickness since large differences in diameter mean that the thin stems will be retted before the thicker ones and by removing the stems at an average time poor quality arises from the thin stems being over-retted and the thick stems under-retted. Similarly at the root end of the stem the bark is stronger and more resistant to the micro-bacterial attack than the middle of the stem which, in turn, is more resistant than the top end. The type of water which is used for retting has an influence on the value of the fibre, for instance stagnant pools where the same water is used over and over again become loaded with iron salts and the fibre is discoloured to a metallic grey shade. The best place for retting is in slow-running streams which are as free from pollution as possible. Retting, therefore, is a critical stage in the production of jute where good cultivation can be completely undone by carelessness or inattention.

When the daily examination of the stems shows that the bark can be removed easily from the rest of the stem the fibre is taken from the water as soon as possible. This stage is called 'stripping'. A bunch

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