CHAPTER I

GENERAL INTRODUCTION
CHAPTER I

GENERAL INTRODUCTION

1. CHARACTERISTICS OF JUTE PLANTS

Jute, the golden fibre of commerce is obtained from the bark of two species of Corchorus, namely C. capsularis L (White jute) and C. olitorius L (Tossa jute). The two species are very similar in general appearance, but can be distinguished by certain differences (Kirby, 1963). The main difference is in the fruits, which in case of C. capsularis is more or less globular pod, whereas in C. olitorius the pod is cylindrical. The seeds of C. olitorius are smaller than those of C. capsularis, are bluish green to grey or black, whereas in case of C. capsularis the seeds are chocolate brown in colour.

From the point of view of cultivation, the great difference between the two is that C. capsularis can withstand water-logging in the latter stage of its growth whereas C. olitorius cannot withstand water-logging and for this reason is usually grown on higher ground where the land is not inundated by flood waters.
Another difference shows itself in the leaves, which in case of *G. Olitorius* are almost tasteless whereas those of *G. capsularis* contain corchorin, a bitter glucoside.

*G. capsularis* and *G. olitorius* differ from each other in many other respects such as colour, fineness of their fibre etc. and it would be useful if, by crossing the two species the best qualities of both could be produced in one plant (Kirby, 1963).

2. **SOIL, CLIMATE AND NUTRITION**

Both jute species grow well on slightly acid to slightly alkaline 'sandy loam' soils rich in organic matter and nitrogen. The best soils for jute are those associated with riverine areas which are frequently flooded and enriched with silt, and have pH values of 6.0 to 6.5. Though most lateritic and gravelly soils are unsuitable, jute can be grown on almost all other types of soils from 'sandy loam' to 'clay', provided texture and pH values are adjusted (Finlow, 1939; Kundu, 1959).

High humidity (60 to 95% R.H.) is necessary for the crop. The crop can withstand a temperature of 17° to 41°C and a temperature of 34°C is optimum for the crop-growth. An annual rainfall of 1270 mm to 2032 mm is necessary for good growth of
plants, 1500 mm of rainfall being optimum (Mondal et al., 1974). Young jute plants are very sensitive to water-logging, which also interferes with hand-weeding. The sowing date, therefore, should be such as to allow weeding to be completed and the plants to reach a height of 90-120 cm before the heavy monsoon rains begin (Kundu, 1956 and 1959).

Soils in jute growing areas of India are usually poor in organic matter and in soil nitrogen. For the maintenance of tilth and fertility in such soils, the addition of organic matter is essential. Since organic manures such as compost or farm yard manure are bulky, their handling is difficult and are also not available in plenty, chemical fertilisers have become popular now-a-days. But the use of chemical fertilisers alone year after year in such soils may lead to ultimate impoverishment of the soil. It is advisable, therefore, to fertilise jute with both organic and inorganic fertilisers (Arakeri et al., 1967).

Manuring is mainly done during preparation of soil using both organic and inorganic (artificial) fertilisers. Cow-dung, ashes, compost-house sweepings are used, cow-dung being used at the rate of 2-4 tonnes per acre. Amongst
chemical fertilisers, urea, ammonium sulphate, muriate of potash and superphosphates are mainly used.

Of the major nutrients, nitrogen is the most important for jute and nitrogenous fertilisers have the greatest influence on the vegetative growth of the plants (Sengupta, 1953; Sen et al., 1960). With nitrogen deficiency growth is poor, leaves are pale-green and drop prematurely. With high rates of N the overall growth increases resulting in net increase in fibre yield, although the fibre content per unit weight of green matter decreases (Salisada, 1955; Kundu, 1956). The effect of N has differed from region to region but high rates of N has been beneficial to *C. capsularis* than to *C. olitorius* (Choudhury, 1942-43, 1944-46 and 1951; Lin, 1959; Saha, et al., 1967). In most districts of West Bengal, yield responses to N or N plus K have been significant but has been influenced by soil type (Gupta, 1959). Under experimental conditions, suitable levels of N are reported as 67-90 kg/ha for *capsularis* and 45-50 kg/ha for *olitorius* (Pandey et al., 1965; Pandey et al., 1967; Saha et al., 1967). Nag and Sharma (1971) reported that the doses up to 40 kg N/ha are mostly effective in *olitorius* and those beyond are generally uneconomic.
Yield responses to P and K have not been found in all trials; C. *capsularis* has been found to show a greater response to P than C. *olitorius* and the latter a greater response to K (Sengupta, 1953). Fertiliser P and K are not usually effective without N (Choudhury, 1942-43; Das, 1958; Kundu *et al.*, 1956) and may sometimes reduce yield (Kundu, 1959; Pandey *et al.*, 1967). It has been reported, however, that fertiliser P reduces lodging, improves fibre quality and helps the plants to make better use of N (Kundu *et al.*, 1956; Mukherjee *et al.*, 1956). Fertiliser K reduces disease incidence (Ghosh *et al.*, 1966; Kirby, 1963; Lin, 1959) and occasional slight increases in yield have been attributed to K applied alone or in combination with N (Das, 1958 and 1966; Kundu, 1956; Jain *et al.*, 1967). In most trials, the highest yield responses from both *capsularis* and *olitorius* jute grown in non-acid soils have usually been obtained from applying NPK followed by NP, NK and N (Das, 1966).

Application of calcium as lime in acidic soil is beneficial to jute crop but in non-acidic soils its main use appears to be protecting the plants to some extent against diseases (Kundu, 1956). Liming reduces the acidity.
of soil, increases the rate of decomposition of organic matter and also increases the availability of P in acidic soils (Black, 1957; Kar, 1974). With *C. capsularis*, calcium(Ca) applied alone has been effective, with Ca plus N being better than N alone (Das, 1966). It is reported that magnesium (Mg) can increase the fibre yield to the extent of 2-3 q/ha when it is applied at 20 kg MgO/ha along with N, P and K in a soil deficient in Mg (Mondal *et al.*, 1974). In some acidic soils, 2.8 q/ha fibre yield (*capsularis*: JRC 212) increased at 40 kg MgO/ha in Mg-deficient soil (Anon., 1970).

The net uptake of nutrients (excluding defoliated leaves) per quintal of fibre production in case of *olitorius* jute (JRO-632) has been reported as 2.06 kg N, 1.65 kg P$_2$O$_5$, 5.18 kg K$_2$O, 4.07 kg CaO and 1.04 kg MgO whereas that in *capsularis* jute (JRC-212) as 3.14 kg N, 1.54 kg P$_2$O$_5$, 7.94 kg K$_2$O, 4.99 kg CaO and 2.15 kg MgO (Mondal *et al.*, 1970).

3. **CULTIVATION**

Depending on the date of arrival of pre-monsoon showers, jute is sown from February to June in the jute producing states in India (Sharma, 1969). With *C. capsularis* sowing between 16 March and 1 May is most satisfactory whereas with *C. olitorius* high yields are obtained when the seed is sown between 15 April and 16 May. In most areas the seed of
C. *capsularis* is broadcast at 9.0 to 11.2 kg/ha and that of *C. olitorius* at 5.6 to 6.7 kg/ha (Choudhury and Ali, 1962; Kundu *et al.*, 1955; Sanyal, 1953). It has been found that sowing the seed in rows and using hand-wheel hoes for interculture has given satisfactory results. In order to encourage line sowing, a hand-operated seed-drill was devised by the Govt. of India. With drilling, seed rates are reduced by 50% and yields are increased by upto 25% in *C. capsularis* and 16% in *C. olitorius*. The cost of cultivation is also reduced by about 20% (Das, 1958; Das *et al.*, 1962; Kundu *et al.*, 1955; Sanyal, 1952). However as sowing by hand-operated drills requires good soil preparation and is slower than broad-casting, row-sowing is not very popular and on most farms jute seed is still broadcast (Sharma, 1969).

The crop is weeded 3-6 times during the first 7-8 weeks and the first weeding is done when the plants are 10-20 cm tall. The first 2-3 weeding operations are accompanied by thinning. Best yields are obtained when thinning is completed within three weeks from sowing (Anon., 1950). The optimum spacing for jute is 10 cm x 10 cm for broadcast crops and about 7 cm between plants in the row, and in rows 30 cm apart, for drilled crops (Sanyal, 1953; Sharma, 1969). Closer spacings than these favour diseases (Ghosh, 1963) while more spacings result in taller plants, thicker stem and excessive
branching, which has an adverse effect on fibre quality (Kundu, 1959; Nodder, 1946).

Jute can be harvested at any time after it is 90 days old or until the fruit is mature (Kundu, 1956; Sanyal, 1963). The best quality fibre is obtained by harvesting at flowering stage; with later harvest the yields are higher but quality deteriorates progressively (Anon., 1949-50 & 1950-51). Harvesting at the small pod stage gives the best combination of yield and quality (Sen, 1957).

The jute plants are normally cut with a sickle close to the ground. The cut stems are tied in bundles 20-30 cm in diameter and left in the field. After 2-3 days, the leaves drop, thus increasing soil fertility, the tissues of the stems shrink and their cells rupture, facilitating the entry of micro-organisms during subsequent retting in the pond, pool or ditch (Kundu et al., 1954; Mukherjee et al., 1954).

4. RETTING

Retting is the process whereby the fibres in the bark are separated from adjacent tissues and woody core by removal of pectins, gums and other mucilaginous substances (Roy et al., 1965; Roy et al., 1967). Retting is effected by chemical and microbial methods (Chatterjee et al., 1944, Anon., 1953-54), although chemical methods are expensive
Retting in water (steep-retting) is usual since stack-retting results in poor quality fibre (Roy et al., 1967). The most important characteristics of jute fibre such as colour, lustre, cleanliness and strength depend on retting (Anon., 1940-41). As a basically micro-biological process steep-retting is influenced by a number of factors, such as temperature and pH of retting water, depth of immersion, the relative volume of water and plants, fertilisers applied to plants, their maturity stage and other factors (Kundu, 1964).

Steep-retting usually takes 10-30 days depending on temperature of water. The optimum temperature for retting is 30°C-32°C and the optimum pH value is around the neutral region. Urea and ammonium sulphate have been found to hasten the retting process and to improve the quality of fibre particularly in case of tossa jute (Bose et al., 1973). Hemicelluloses, pectins, reducing sugars, tannins and proteins are the principal substances removed during retting. Loss of hemicelluloses and reducing sugars is greater in C. capsularis (Roy et al., 1965). The retting time is shorter in C. capsularis than C. olitorius because the former supports a large population of bacteria and fungi (Anon., 1963-64). The presence of periderm in C. capsularis interferes with uniform retting and reduces its quality. C. olitorius is therefore
considered to be of better quality than *C. capsularis* (Rao *et al.*, 1961).

The colour of jute depends to a considerable extent on the amount of iron present in retting water (Nodder *et al.*, 1942). It is reported that 'phenolic acid lignin' in the jute stems reacts with iron to form dark coloured derivatives which impart dark colour to fibre (Sengupta *et al.*, 1958).

After retting, the fibre is taken out from the retted stem by jerking backwards and forwards in water so that fibre is separated from sticks and other extraneous matters. The fibre is then squeezed by hand and hung on a frame for 2-3 days to dry after which it is tied in bundles ready for marketing.

5. QUALITY CHARACTERISTICS

The quality characteristics of jute fibre is determined on the basis of its strength, colour, lustre, fineness, density (or heavyness), root content and defects (Anon., 1975a). Strength is the most important quality desired in jute. Weakness of fibre suggests that it has been over-retted, not properly dried or possibly obtained from over-matured plants. In general, jute with high gloss and lustre has good strength. The higher density is a characteristic of better quality fibre. Density is a measure of mass per unit volume including air-spaces.
Fig. I - A portion of the transverse section of a mature jute stem (microscopic view).
The fineness of fibre is a measure of diameter or mass per unit length of the fibre filament. The finer the fibre the better is the spinning quality and higher is the yarn strength (Mazumdar and Bondopadhyay, 1976). The moisture content of jute also plays an important role towards determining its quality. Jute with too high a moisture content deteriorates in strength and sometimes also in colour.

6. MORPHOLOGICAL STRUCTURE

Jute fibre as obtained from the bast of several species of Corchorus is embedded in the outer tissues of the bast. The outermost layer of fibres develops from the protophloem, while all the inner layers, forming the bulk of the fibre cells, develop from the cambium (Sharma, 1969). The fibres are arranged in pyramidal wedges which taper towards the cortex and alternate with the medullary rays of soft tissues. A portion of the transverse section of a mature jute-stem is given in Fig. I. The fibre strands in the wedge consist of groups of fibre cells or ultimate fibres, each group separated again by soft tissues. The wedge thus consists of fairly regularly arranged radial layers of strands in which both the individual strands are separated by soft tissues. In tangential longitudinal sections of the bark, the outermost fibre groups form a
loose mesh, which becomes more compact towards the cambium. The mesh-like character of the fibres depends on the activity of cambium, the formation of secondary rays and re-union of fibre bundles; it increases from the peripheral to the interior layer, from the top to the basal regions and is more evident in G. capsularis than in G. olitorius. The protophloem fibres at the apex of the wedge do not normally exceed 10% of the total fibre weight (Kundu, 1942; Patel et al., 1943).

The pyramidal wedges of secondary phloem usually consist of layers of fibre bundles, 10-20 in G. capsularis and 8-19 in G. olitorius. The number and size of fibre bundles are dependent on cambial activity and vigour of the plant (Sharma, 1969). Fibre bundles consist of groups of fibre strands and the fibre strands in a cross-section are composed of 4-25 fibre cells which can be separated by maceration. The ultimate fibres vary from 500 to 6500μ in length and 10-30μ in diameter. The average length of fibres from outer part of the wedge is 3200μ and from inner parts about 1500μ only, but there is little difference in fibre diameter (Kundu, 1956). The number of ultimate fibres in a fibre strand is higher in G. capsularis than in G. olitorius (Kundu, 1959; Rao et al., 1955). The length : breadth ratio of ultimate fibres for fine yarn production should preferably
be about 1000-2000 (Turner, 1949). In jute this rarely exceeds 120, so that its fibre is suitable only for making coarse fabrics. The middle and top parts of a plant contain longer ultimate fibres and have higher quality ratios in both species. As in other natural fibres, higher length:breadth ratios of ultimate fibres in jute are associated with greater strength (Rao et al., 1961). The secondary wood generated by cambium activity forms a thick zone and occupies the bulk of the radial depth in the stem cross-section. The pith of C. olitorius collapses early and the mature stem is hollow. In capsularis, the pith persists and consists of large thin-walled cells (Kundu, 1956).

The lumen of ultimate fibres remains large in diameter up to the bud stage and then generally decreases. The length and average thickness of the wall are not affected by maturation after the bud stage (Rao et al., 1955). Harvesting at this stage gives fibre of superior quality; as maturity advances yields increase to some extent but fibre quality deteriorates. Periderm formation also increases with age and affects retting (Patel et al., 1943).

A single filament of jute has a very irregular cross-section and usually consists of large numbers of biological
cells (ultimates) cemented together laterally by means of intercellular materials (middle lamella). The ultimates of jute are characterised by irregular polygonal cross-section (Osborne, 1935). Each ultimate has a primary cell-wall within which there is a thick deposition of layers called secondary wall. There is a cavity called lumen running down the centre of each ultimate. The secondary wall is not a continuous stretch of mass but exhibits under electron microscope innumerable fibrils arranged in annular layers (Preston, 1953).

Lignin, hemicellulose and pectin are known to be incrusting substances. The cell wall is strongly impregnated with lignin in a fairly uniform manner. Pectin appears to be distributed throughout the wall, though it is more abundant in the middle lamella. During retting, the primary wall and the outer layers of the secondary wall lose a considerable amount of their lignin while the inner layers remain strongly lignified. The pectin however, disappears almost completely from the cell-wall (Roy, 1958).

7. CHEMICAL COMPOSITION OF JUTE FIBRE

The chemical composition of a bast fibre of which jute is a typical member, can be broadly divided into two main categories, viz. lignin and carbohydrates,
Jute fibre

Proximate chemical composition of

---

![Diagram of chemical composition of jute fibre]
though a number of minor components such as wax, pectin, inorganic substances, nitrogenous and colouring matters occur in small quantities. The isolated carbohydrate portion is generally designated as 'holocellulose' (Ritter and Kurth, 1933) which can be further subdivided into two groups, namely, $\alpha$-cellulose and hemicellulose. Although $\alpha$-cellulose from jute is mainly composed of cellulose chain, it has been found to be associated with small amounts of other sugar residues. Hemicellulose components of a fibre are built up of various sugar units of which the major constituent is xylose. The proximate chemical composition of jute fibre as described by Macmillan (1957) is shown in Fig. II.

A brief account of the physical and chemical characteristics of the important components of jute fibre is given below to provide basis for subsequent discussions on properties of jute fibre.

**Lignin**: It is the most important part of the non-carbohydrate component of jute fibre and has a great influence on the physical and chemical properties of fibre. It is known to contain both methoxyl and hydroxyl groups corresponding to a molecular weight of 840; the presence of phenolic hydroxyl groups in lignin building unit has also been shown (Brauns, 1939).
The yellowing of jute on exposure to light is known to be due to the presence of lignin (Mukherjee and Radhakrishnan, 1972). The high tensile strength of jute fibre in comparison to other textile fibres is attributed to the presence of cross-linkages between lignin and cellulose in the amorphous regions of the fibre (Bhattacharya, 1961). Lignin however, increases the irregularity of yarn (Bandopadhyay et al., 1959).

**Alpha-Cellulose:** The $\alpha$-cellulose content of jute appears to be the major contributing factor towards its strength, although the length of the cellulose chain molecule is more important than the quantity of cellulose (Bandopadhyay et al., 1955 and 1959). Pure $\alpha$-cellulose consists of long chains of $1:4\beta$-anhydro glucose units (Cellobiose) through oxygen bridge arranged in zigzag way (Fig. III). But the $\alpha$-cellulose isolated from jute fibre is always associated with considerable amounts of other carbohydrates and non-polysaccharide components particularly xylan (Adams and Bishop, 1953; Das et al., 1954; Macmillan, 1957).

**Hemicellulose and holocellulose:** The term 'hemicellulose' is generally used to comprise a number of polysaccharides of comparatively low molecular weight such as glucosan, xylan, polyglucuronic acid etc. One group of hemicelluloses consist of mainly xylan which forms an integral part of true cellulose and has a chain structure very similar to
Fig. III - Structure of cellobiose unit.

Fig. IV - Structure of xylan.

Fig. V - Structure of polyuronide.
cellulose (Fig. IV), the only difference being that the projecting carbinol group (—CH₂OH) of cellulose is replaced by a hydrogen atom (Hawley and Norman, 1932). Another group of hemicelluloses are not closely associated with cellulose and consist of hexose residues and polyuronides. The polyuronides are known to be encrusting substances with chain structure similar to collulose, but the carbinol group (—CH₂OH) is replaced by carboxyl group (—COOH) (Macmillan, 1957) as shown in Fig. V. High yarn-irregularity is correlated with higher values of hemicellulose content of jute (Bandopadhyay et al., 1959).

The term 'holocellulose' is applied to the product obtained after delignification of dewaxed fibre by chlorination. It therefore, contains not only all the cellulose, but also all the xylans, polyuronides etc. comprised in the 'hemicellulose'. The terms alpha, beta and gamma cellulose relate to the fractionaction of 'holocellulose' by treatment with 17.5% (w/w) sodium hydroxide at 20°C whereby α-cellulose remains undissolved, β- and γ'-cellulose dissolve but the former can be precipitated by neutralisation of the alkaline extract. These differences are due to the variation in the length of the molecular chain (Ott, 1943).
Pectin: Only a small amount of pectin (0.2 - 0.5\%) is present in jute fibre, the major portion being removed during retting. It is essentially a long chain polygalacturonic acid, the carboxyl groups of which are partially or fully esterified with methyl alcohol or metallic ions. In matured plants, pectin exists mainly as calcium salts in the cell wall where it appears to have a cementing effect. Calcium pectate is soluble in hot ammonium oxalate solution and it is the basis for chemical retting of bast fibre with ammonium oxalate (Chatterjee et al., 1944; Roy, 1958).

Amongst the other minor constituents of jute fibre, nitrogen content though only 0.2\% on average bears a negative correlation with the yarn strength both in \textit{capsularis} and \textit{olitorius} jute (Bandopadhyay and Mukhopadhyay, 1959).

8. \textbf{AIM OF THE PRESENT WORK}

Since industry requires a steady flow of standard quality jute, it is imperative to clearly delineate how far the soil properties (both physical and chemical) influence the quality of fibre and how far the soil in question will accommodate judicious and economic application of fertilizers to boost the yield without adversely affecting the fibre qualities. Influence of several factors such as variety, fertilizer, interculture and climatic conditions have masked
the influence of soil and have so far failed to clearly indicate the actual contribution of soils in the test results of fibre quality from different defined areas. It was therefore, considered necessary to make a fresh approach to study the influence of soil factors alone on the yield and quality of jute fibre.

Chemical composition and physical properties of the soil are among the most important factors controlling the yield of a plant. The soil constituents have a direct effect on the change in the plant metabolism and its growth. With increased nutrients the yield reaches a maximum but with excess of the nutrients the yield again decreases (Flaig and Schmid, 1966). Hence it is necessary to ascertain the nutritional status of the soil before application of any fertilizer in order to get the maximum benefit of the fertilizer by its economic use.

Though a considerable amount of work has been done on the effect of major nutrients viz. nitrogen, phosphorus, potassium, calcium and magnesium on the yield of jute, sufficient data regarding the effect of these nutrients on physical and chemical characteristics of jute fibre are not available. Hence a study on the effect of these nutrients not only on the yield but also on some of the important physical and chemical properties of fibre was undertaken.
The importance of micro-nutrients for efficient maintenance of physiological functions and for vigorous and balanced growth of vegetative and reproductive organs of plants has received wide attention (Kar et al., 1961). Amongst the various micro-nutrients, zinc is known to be necessary for certain enzymatic reactions; it plays an important role in carbohydrate metabolism, development of chlorophyll in leaves and also in turnover of organic phosphorus compounds (Anon., 1971). Molybdenum is reported to significantly increase the number of non-symbiotic bacteria and nitrogen fixation in soil. Thus it may help towards nitrogen economy and is also known to help nitrogen transformation into plants (Bear, 1965; Dey et al., 1975). The effects of these micro-nutrients on jute plants are not yet clearly known. Exploratory trials were, therefore, undertaken to study the soil status of these two elements in the local jute producing areas as well as the effect of their input in the existing soil status on the yield and some properties of jute fibre.