28 Jute

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Jute, *Corchorus capsularis* L. and *C. olitorius* L., is a subtropical crop which produces fine fiber of commerce from its bark. *Corchorus capsularis* originated from Indo-Burma and *C. olitorius* from Africa (Singh, 1976).

The crop is cultivated mainly in India, Bangladesh, Brazil, and Taiwan between 20°N Lat and 30°S Lat. It is usually sown between February and June in the northern hemisphere (Finlow, 1939). In Brazil, two crops may be grown in a year, the first in May to June and another in November to December.

The plants normally attain the height of 4 to 5 m. Plant height in this crop is positively correlated with fiber yield (Shukla and Singh, 1967; Singh, 1971).

The crop is harvested for fiber between 120 and 140 days after sowing. The plants are cut at the ground level, tied in 20 to 30 cm diam bundles and left in the field for 2 to 4 days for shedding of leaves. During this period, the tissues of the main stem shrink and rupture, facilitating the entry of micro-organisms to rot the stem (Kundu and Mukherjee, 1954; Mukherjee et al., 1954).

Retting is accomplished in slow moving and clean water with the process being completed in 10 to 12 days at 30 to 35 C. The fiber is separated from the main stem by hand, washed, and dried. This fiber serves as a raw material for jute mills.

I. PARENTAL MATERIAL

The species of jute are herbaceous annuals belonging to the family Tiliaceae. Cultivars of *C. capsularis* normally have branches, but some non-branching types have been collected from Brazil. The *C. olitorius* cultivars collected from African countries, such as Sudan, have helped the Indian

plant breeders in developing high-yielding photoperiod-insensitive cultivars. Many cultivars also have been collected from China, Taiwan, Japan, Philippines, USSR,and Pacific regions.

Scientists from Taiwan also have selected some useful cultivars of *capsularis,* like 'Shu-Shang Green Bark' and 'Tainang 1'. Tainang 1 is regarded as being resistant to anthracnose, a high yielder, and insensitive to day length (Chi et al., 1967). Mutation breeding also has helped in widening the source of germplasm in this crop (Singh et al., 1973; Singh, 1970).

Interspecific crosses among the two cultivated jute species are highly incompatible. Initial studies on the reasons for the incompatibility have shown that pollen tubes in interspecific crosses normally grow through the styles (Srinath and Kundu, 1952). Fertilization takes place, and some young embryos and free endosperm nuclei also are formed. However, the embryos degenerate early in development and seed fails to set (Ganesan et al., 1957; Patel and Dutta, 1960). Recently, some interspecific hybrids between *capsularis* and *olitorius* have been reported (Bhaduri and Bairagi, 1968; Islam and Rashid, 1960, 1961).

All the genetic collections of this crop are being maintained at the Jute Agricultural Research Institute (I.C.A.R.), Barrackpore (W.B.), India.

II. PLANT CULTURE

A. Field

The effect of soil fertility on hybridization and seed set in both species of jute has not been studied critically. A sandy loam soil with an application of 2 to 3 q/ha of manure is considered good for growing the crop. The application of 20 kg of N, 30 kg of P, and 30 kg of K per ha 30 days after planting helps in getting good fruit set and seed yield.

The soil should have enough moisture to help the plants grow properly. Low moisture in the soil adversely affects the formation and opening of buds. In such cases, the buds are shrunken and unhealthy and develop into inferior fruits.

Fig. 1—A *Corchorus olitorius* branch with flowers.

Plant populations of 0.2 to 0.3 million per ha are enough to get good seed production. The crop is normally sown in rows 40 to 50 cm apart.

Photoperiod plays a major role in this crop. A short photoperiod induces early flowering, while a longer period delays it. For hybridization and seed set, a photoperiod of 11 to 12 hours is good.

An open sky with good sunshine is considered ideal for hybridization. Cloudy and rainy days are not good for proper pollination and seed set.

A temperature ranging from 28 to 32 C and a relative humidity of 40 to 90% are considered standard for hybridization.

B. Growth Chamber and Greenhouse

To add a generation of crossing each year, jute has been grown in South India below 20°N Lat during winter months (November to March) where the winters are more or less similar to the summers prevailing between 20° and 30°N Lat. Growth chambers and greenhouses have not been used in breeding this crop.

III. FLORAL CHARACTERISTICS

Jute is predominantly self-pollinated, but cross-pollination of 10 to 15% occurs in *olitorius,* mainly by insects. The percentage of cross-pollination in *capsularis* is negligible (up to 5%) and does not require any treatment to enforce selfing.

The jute flower is perfect and small in size. The inflorescences occur on the terminal and lateral branches. The flowers are in groups of two or three in *olitorius* and in groups of two to six in *capsularis* (Fig. 1 and 2). Although the flowers in both species are small, those in *olitorius* are about twice the size of those in *capsularis.* In both species, the number of sepals and petals is usually five. In *olitorius,* there may be six to eight sepals and petals, but in *capsularis* flowers with six sepals and petals rarely occur. Stamens are variable in number from 20 to 60 and surround the stigma. The ovary usually has five locules and often six or more carpels, particularly in *olitorius.* In *capsularis,* there are two rows of ovules in a locule, each row usually consisting of five ovules. In *olitorius,* there is a single row of about 40 ovules.

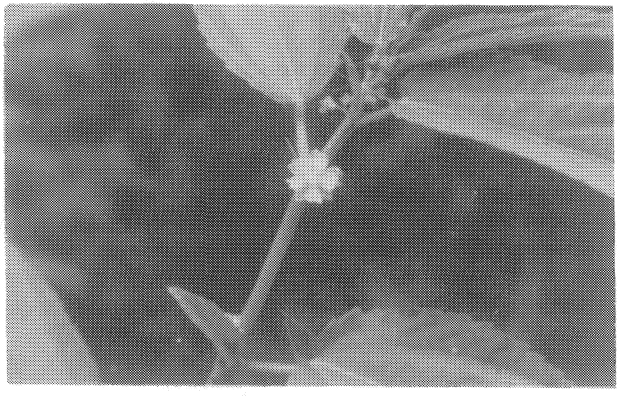

Fig. 2—A *C. capsularis* branch with a flower and young buds.

IV. ARTIFICIAL HYBRIDIZATION AND SELF-POLLINATION

A. Equipment

It is not necessary to protect *capsularis* flowers against natural crossing, but it is important to control pollination in *olitorius.* Mesh cloth bags of cylindrical shape (60 × 30 cm) generally are used to protect the plants against foreign pollen (Fig. 3). The bags are fitted inside with two bamboo or iron rings, each about 20 cm from the end so that they divide the bags into three more or less equal portions. One end of the bag is closed and tied with strong, 45 cm-long string. The other end is threaded with the same length of another string, so that it can be closed whenever needed. Sometimes cages of the same size made by 16-mesh wire netting are used instead of mesh cloth bags. In wire net bags, both ends of the cage are closed with two cloth cylinders of 30 cm length, and the remaining arrangements are similar to those for mesh cloth bags.

Emasculation, pollination, and bagging require a pair of forceps, a hand lens, cellophane paper bags 16 × 7 cm, and small paper tags. A lens is used most easily if tied to a string and draped around the neck of the worker.

B. Preparation of the Female

In preparing for hybridization or self-pollination, one must be sure that the plant is free of disease or insect injury because unhealthy plants normally do not survive for a long period and the pods do not develop

Fig. 3—Flowers of jute plants enclosed in mesh cloth bags that are tied to a scaffolding.

properly. When a plant is to be selfed, a bamboo cane higher than the plant is placed in the soil. A bag is suspended from the cane over the flowers to be selfed. The drawn string at the open end of the bag is tied to the plant. The rings in the bag prevent the walls from collapsing and prevent injury of the flowers. When a large number of plants are to be selfed, a scaffolding or a framework, with upright and horizontal bamboo canes, has been found to be economical (Fig. 3). The string connecting the bag to the scaffolding should not be too taut because the wind may move bags and cause strain on the plants and damage them.

The flowers which appear first in the spike always set better. For hybridization, all buds are removed from the spike, except the one to be emasculated. Immature and young buds should never be used for emasculation. Emasculation is normally attempted between 1500 to 1800 hours on the day before pollination.

A bud that is ready for emasculation usually has pale yellow anthers and petals. An immature bud has whitish petals, and the anthers are slightly reddish. The filaments in an immature bud are short, and the anthers are below the level of the stigma.

The bud to be emasculated is held at its base between the thumb and index finger of one hand. The sepals and petals are separated with a pair of fine-pointed, straight forceps. Jute flowers are very sensitive to the removal of calyx and corolla, particularly the former. Seed set is poor when the calyx is removed. The anthers are removed with the forceps, then the buds are examined with a hand lens for complete removal of the anthers. The bud is enclosed in a cellophane bag having small perforations that permit the movement of air, but not the entrance of insects (Fig. 4). The bags are tied with a length of light twine to the base of the inflorescence that contains the emas-

Fig. 4—Inflorescences enclosed in the cellophane bags.

culated flowers. On the day of pollination, the emasculated flowers may be identified without difficulty because they usually have their sepals and petals wide open.

C. Pollination

The male flowers are enclosed in cellophane bags on the evening before they are used to avoid contamination from foreign pollen. The male flowers are removed between 0500 and 0700 hours on the day of pollination and placed in covered petri dishes. The buds start opening in the dishes and the anthers dehisce by longitudinal splitting.

Fresh pollen normally is used in jute for pollination. Pollinations attempted under rainy conditions do not result in good seed set. Under such cases, the collected male flowers can be stored in covered petri dishes for 1 or 2 days at 8 to 10 C.

The flowers of *capsularis* close at 1530 hours and those of *olitorius* at 1330 hours. The emasculated flowers usually become receptive the next morning between 0700 and 0800 hours, if the temperature is more than 20 C. Receptivity is delayed by 1 or 2 hours at lower temperatures. The best time for pollination is in the morning up to 0930 hours. In *capsularis,* it may extend to 1100 hours.

The male flower is held with a pair of forceps, and the base of the emasculated flower is held between the thumb and index finger of the other hand. The stigma is lightly touched with the anthers of the male flower until it is covered with pollen, which can easily be observed with the help of a hand lens. A paper tag bearing the cross number is tied onto the pollinated flower before enclosing it in the cellophane bag.

The cellophane paper bags function well in withstanding light showers or wetting by dew during the night. Bags should be removed 24 hours after hand pollination. The pollinated flowers start withering and a small fruit develops about 24 hours after pollination.

If emasculation and pollination have been properly conducted, the expected success may be as high as 90%. Failures may be detected best with the help of a hand lens on the third or fourth day after pollination. Fruits resulting from unsuccessful pollination appear discolored and shrivelled. In some cases, the pruning of the other pods on the branch provides stimulus to the crossed pods, enabling them to develop normally.

D. Factors Affecting Efficiency

Sowing of the cross nursery is in blocks or ranges of rows. The row spacing distance is 45 to 50 cm with plant spacing within the row of 8 to 10 cm. A population of 0.2 to 0.3 million plants per ha is considered sufficient for use in hybridization. The plants are not allowed to grow taller than 120 to 150 cm because it is easier to handle short plants for crossing purpose. Sometimes the tip of the plants are pruned at 40 to 50 days after sowing to induce more branching for production of more flowers.

To secure simultaneous flowering of parents of both *capsularis* and *olitorius,* the early parents may be sown about 30 to 45 days after the late parents.

Cold treatment of seeds at 8 to 10 C before sowing delays germination and results in more vigorous seedling growth in both the species. In such cases, *capsularis* cultivars flower 15 to 18 days earlier than the controls, while flowering is delayed by 10 to 15 days in *olitorius.* Vernalization alters the effects of the photoperiod treatment applied after it (Kar, 1943; Kundu, 1956).

Several genetic markers like pigmentation patterns, leaf shape, size and color, flowering period, branching habit, pod shape and size, seed coat color, and seed size help in identifying hybrid plants and seeds in this crop.

In *capsularis,* the distribution of anthocyanin in an individual plant varies to a great extent. Plants range from full green to full red, through a series of well defined and distinct forms. Plants have been classed into three broad genetic groups: full green, green pigmented, and red (Patel et al., 1944). Three loci control pigmentation: *C* is required for color production regardless of the genetic make up of the other two loci; *A*, A^L, and A^R are a multiple allelomorphic series affecting the distribution, as well as the intensity of the pigments; and *R* causes dilute coloration, and *r*, intense coloring.

In *olitorius,* the plants are either red or green. The expression of the pigments depends on the sunlight and the age of the plants. It is first observed as a dark red blotch at the base of the stipule. A ring of color slowly is formed around the base of the stem and gradually extends upwards as the plant grows. Genetically the gene for red pigment is dominant over the gene for green.

Cultivars possess different types of leaves, such as narrow lamina, crumpled surface, palmate, undulate, yellow, red, etc. These characters are mostly monogenic and recessive to normal green leaves (Das Gupta and Ghosh, 1954; Singh, 1974).

Some cultivars of jute flower early, while others are late. Early flowering is recessive to late (Ghosh and Sarma, 1965).

Cultivars differ in their branching behavior. Some cultivars are severely branched, while others have no branches. The branching behavior is dominant over nonbranching (Patel et al., 1945).

The pod surface may be smooth or ridged, its shape being oval or round. Such variations exist mostly in *capsularis.* In *olitorius,* only the elongated and stumpy pod shapes are common. Rough pod surface is dominant over smooth, and oval and stumpy pod shapes are recessive to normal (Patel et al., 1945).

In *olitorius,* the cultivars have seeds with different seed coat colors like leek green, steel grey, blackish grey, greyish steel, etc. This character helps in identifying hybrids. Seed coat color is governed by a single factor (Patel et al., 1945).

V. NATURAL HYBRIDIZATION

Jute has a low degree of cross-pollination, and is not good material for natural hybridization.

A monogenic male-sterile line has been identified in an x-ray induced mutant (Rakshit, 1967; Singh et al., 1973). This male-sterile gene has pleiotropic effects and causes several undesirable characters; therefore, it is unsuitable for any hybrid seed production program. Efforts to break this complex have failed, and no recombinant has been isolated that has the male-sterile gene disassociated from such undesirable characters as ribbon leaf and short height of the plant (Mitra, 1976). Efforts are underway to break this pleiotropic complex or to develop a cytoplasmic-genetic male-sterile.

The amount of outcrossing in jute is highly variable and nonrandom (Basak and Gupta, 1972). Because jute is cross-pollinated only by insects, reasons for the variation in outcrossing are attributed to the activity of insects (Bateman, 1950). The insects cross-pollinate only a few plants here and there in the plot, which results in highly variable cross-pollinated population. Under these circumstances, it has not been possible to follow any field layout for natural cross-pollination. An isolation of 10 to 15 m is recommended to minimize cross-pollination.

VI. SEED DEVELOPMENT, HARVEST, AND STORAGE

The time interval between the blooming and maturity of the pods is nearly 6 weeks. The appearance of brown spots, streaks, or patches on healthy pods indicate that the pods are mature and possess healthy seeds. The crossed pods should be collected as soon as they turn brownish black.

In a crop grown for its seed, one should ascertain if the plants have developed a yellow color on their stems. Such coloration indicates a stage when nearly 60 to 80% of the fruits are mature in *olitorius.* In this species, pods shatter and lose seeds at this stage, so it is always advisable to harvest the crop immediately. The problem of shattering does not exist in *capsularis,* and in some photoperiod-insensitive cultivars of *olitorius.* If it rains during this stage of maturity, the quality as well as quantity of seeds is affected adversely. The rain soaks through the pods and some of the seeds germinate in situ or become infected by fungi.

Crossed pods are harvested individually, and the seeds are threshed by hand. Harvesting of naturally pollinated plants or plants from cross-pollination plots is done in bulk. Plants are cut at their base or at mid-stem length and spread on a canvas under the sun. The plants are beaten by sticks or bamboos to shatter the seeds out of the pods. The seeds are winnowed, cleaned, and dried on the canvas in the sun for 4 days. Seeds harvested in bulk are analyzed for germination percentage.

Freshly harvested seeds contain nearly 21% moisture. Seeds stored at this moisture lose viability within a year. After drying, the seeds are treated with organo-mercury preparations against seed-borne fungi. This treatment prolongs viability in storage and controls seedling diseases. After exposure to moisture, treated seeds lose viability more rapidly than untreated seeds (Ghosh et al., 1951). Seeds should be stored in burlap bags with polyethylene under dry room conditions, otherwise they lose viability in less than 1 year (Kundu and Sarma, 1955). Seeds stored properly with 7% moisture retain viability up to 4 years.

VII. TECHNIQUES FOR SPECIAL SITUATIONS

Plant breeders have wished to develop an interspecific hybrid combining the desirable characters of both *capsularis* and *olitorius*. In most cases, the cross *olitorius* × *capsularis* has given very poor fruit set and no viable seeds. The reciprocal cross also gives negative results because the flower aborts shortly after pollination. Sulbha and Swaminathan (1959) used hormones in reciprocally grafted plants and increased the seed set. Islam and Rashid (1960, 1961) applied 300 ppm solution of indole-acetic acid to the pedicels of flowers soon after pollination and reported success in getting the hybrid. Islam (1964) combined hormone application and embryo culture to rear hybrid seedlings of the cross *capsularis* × *olitorius*. A medium supplemented with 0.1% yeast extract and 0.05 ppm each of kinetin and indole-acetic acid proved best for the germination of hybrid embryos which grew into transplantable seedlings.

Moistening the style and ovary with nearly 38% sucrose solution containing 0.01% thiamine hydrochloride or 40 ppm of napthoxy acid just after pollination also has increased fruit set (Roy, 1968).

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