Jute—The Golden Fibre of India

by

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JUTE is the cheapest of all textile fibres. The quantity of jute used every year is larger than the total of all the other plant fibres except cotton. It is most widely used in the manufacture of gunnies, hessians, cordage and twines.

About 2.4 million tons of jute fibre are produced annually, mainly in the Indo-Pakistan sub-continent. Jute manufactures form one of the most important commodities of export from India. They accounted for 38.5 per cent of the value of the total exports in 1951-52, for 23.4 per cent in 1952-53 and for 22.08 per cent in 1953-54. The export duty earned by Indian Government from jute has varied from as low as Rs. 75 million in 1947-48 to as high as Rs. 593 million in 1951-52. Successive reductions in export duty provided stimulus to the trade but the duty realized has gradually gone down though the share of jute goods in Indian export has risen considerably. Jute manufactures now account for 60 per cent of the total export earnings and amounted to Rs. 1400 million in 1961-62. Jute mills used to provide direct employment for over 300,000 workers. At present about 200,000 workers comprising about 8 per cent of the total factory labour in India are engaged by the industry. No statistics for indirect employment exist but the number is near about two million. The capital invested in Indian mills in 1950 was about Rs. 668.5 million. The annual output of jute products from Indian mills is valued at about Rs. 1500 million.

Jute fibre is obtained from two species of plants, botanically known as *Corchorus capsularis* and *Corchorus olitorius*. The former gives the 'white' jute and the latter, *tossa* jute of commerce. It is not known when exactly jute came to be recognized as a textile fibre of great utility. Even in the biblical times, *C. olitorius* was used as a pot-herb and called *Olus judiacum Jews Mallow* or the food of the wretched. The fibre-yielding property of jute plants was unexplored till comparatively recent times. Rumphius (1743 A.D.) is of opinion that the Chinese were the first to appreciate the fibre producing nature of *C. capsularis L.* However, there are references in the *Ain-i-Akbari* (1590 A. D.) of trade in *tat* —a sort of coarse fabric used as clothing by the poorer classes. In the early Bengali literature *Kavi-kankan Chandi* (1590 A. D.) there are refrences of jute fibre and gunnies made of jute cloth. This shows that jute fibre must have been known to us during the sixteenth century or even earlier.

Handloom Industry of Jute

Spinning of jute fibre was an important source of employment among the poorer classes of cultivators and helpless women in Bengal even up to the end of the last century. Three devices, *Takur*, *Dhera* and *Ghurghura* were used for spinning and it is said that a bundle of loose jute used to hang near the door of every village home and any one that passed used to spin a little thread out of it. Yarn made by *Takur* was very fine and was used for *tat* cloth. *Dhera* was used when the yarn was required for coarse cloth (*choli*) used for gunny bags and sails for boats. Yarn produced by the third implement was used for making cordage. In spite of the fact that this was the only source of employment for some, the price of spun thread was low. The yarn was woven into cloth by handlooms by a class of people known as *Kapalees*. The cloth was strong and considered to be more durable than mill made cloth produced by the jute mills in the initial stages of the industry. Among the products of the cottage industry of jute were cordage, gunny cloth, gunny bags, etc. After the establishment of mills in India, however, the handloom industry deteriorated within a very short time. It now exists in a moribund condition in a few of the rural areas of Bengal, Assam and Orissa.

Jute Industry

The East India Company were actively in search of a suitable substitute for European hemp, the supplies of which used to be uncertain, especially in times of war. Roxburgh, the then Superintendent of the Botanical Gardens at Sibpur, Calcutta exported in 1793 a sample of 100 tons of raw jute under the name of *Pat* to England. The report on this fibre was favourable and from then on, a small but irregular trade in jute began. It was used in making backings for heavy carpets and union yarns composed of flax and jute. The real impetus to jute trade came in 1838 when the trials for adaptation of flax mill machinery for spinning jute were successful at Dundee. From then on, jute became a recognized textile material with wide uses for packaging, cordage and other purposes. The exports of raw jute rose from only 18 tons in 1828 to 29,000 tons in 1851 (excluding gunny bags), and to 897,900 tons in 1928. The export of raw jute in 1946-47 was 306,246 tons but it fell to 526 tons in 1950-51, after which exports were banned.

Jute mill owners in Dundee had already made fortunes by 1855 when by a singular course of events the first mill was established in India. An Englishman, George Acland, came to India to establish a ramie spinning plant but he was later advised by his friends in England to turn his attention to jute and "to take jute machinery to Bengal where the jute comes from and spin it there." He established a small mechanically driven spinning mill at Rishra (at the site of the present Wellington Mills) with an output of 8 tons per day. This was the foundation of an industry, which in the course of only three decades, became the producer of one of the most important commodities of export. The first power-operated looms were established in

1859 by the Borneo Jute Company, later known as Baranagore Company. This was the second jute mill to be set up in India and had 192 power and 200 hand operated looms for the manufacture of jute cloth. The number of mills and the loomage steadily increased. The number of looms increased to 1250 by 1873, to 6700 by 1885 and to about 9700 by 1895. Demand for jute goods in overseas markets far outstripped production and during this period investment in jute industry was considered to be more sound than investment in established trades like tea, coal, etc. Rapid increases were made in the number of mills and their loomage and by 1909 there were 38 mills with a total of 30,685 looms. In the years following, further progress was made by establishing new mills and extension of the existing mills. The number of looms rose to 50,354 by 1927 and by 1962 there were 113 mills with a total loomage of 72,916.

Uptil 1919, all the jute mills, except Serajganj jute Mill which was destroyed by earthquake in 1897, were located on the two banks of the Hooghly near about Calcutta. After this, a few mills have been opened in other parts of India.

After the partition of India in 1947, East Pakistan also established three mills. At present there are 14 mills and the loomage is reported to be 8726 and there are plans to increase it.

In the initial stages of the industry, the mills produced only sackings and the production of hessians was a monopoly of Dundee mills. With increase in the number of mills in India, the production of gunnies exceeded the demand and attention was turned to the finer jute fabrics—hessians. The first hessian looms were established in 1870 and from about 1895 the production of hessian cloth exceeded that of sacking. The proportion of looms producing this finer fabric also increased. Since 1900-1910 period more than 50 per cent of the looms have been used for hessians and from 1944, 65 per cent of the total loomage is utilized for this purpose.

In recent years there has been a great increase in the demand of non-standard goods, particularly canvas, ropes, twines, etc., besides carpet backing. Export of jute goods, other than hessian and sacking, have increased from 28,800 tons in 1951-52 to 144,000 tons in 1961-62. Carpet backing cloth alone is expected to go up in exports by 50,000 tons each year. India is gradually losing ground to Pakistan in the export of sacking, while she is gaining ground in non-standard goods.

Though India has the largest number of jute mills and about 56 per cent of the total world loomage, other countries like Britain, France, Germany, Brazil, etc., have also their own jute mills; Britain with 9.1 per cent of the total world loomage has the oldest established jute industry. The Indian sub-continent has, however, the advantage of working with raw material produced locally whereas the foreign jute industry has to depend almost always on imports of raw jute.

Origin of the Two Cultivated Species

There are about 40 species of the genus *Corchorus* which are distributed throughout the tropics, the largest number of species being found in Africa and only eight in India. In finding out the origin of the two species *C. capsularis L.* and *C. olitorius L.*, their distribution in different parts of the world, as recorded by the previous workers, is of great importance. J. F. Royle in his publication *Fibrous Plants of India* published in 1855, states that the ancient Greeks used to call a pot-herb as *Korkhoros*, from which the generic name *Corchorus* is probably derived. The *Chorchorus* (*Koskhoros*), still cultivated in the neighbourhood of Aleppo and described by the travellers in the East as a pot-herb in Egypt and Arabia as well as in Palestine, is supposed to be *C. olitorius*. It is small and herbaceous in the dry soil of Syria, a little taller in Northern India and attains its maximum size only in the warm moist climate of Bengal. According to some Botanists this species is found in North Australia and that it is common in Asia and Africa. The occurrence of *C. olitorius* under wild and cultivated conditions in tropical Africa has been reported in 1868 by Oliver in his *Flora of Tropical Africa*. Masters (1874) and Prain (1908) record it as indigenous to India. George Watt, on the other hand, states in his publication *Dictionary of Economic Products of India* (1889) that it is indigenous in many parts of India and distributed by cultivation to all tropical countries. The author of this article has come to the conclusion from available data that the primary centre of origin of *C. olitorius* is Africa and the secondary centre may be India or Indo-Burma region.

C. capsularis is not found in Africa or in Australia. It has been regarded by many early Botanists as of Chinese origin. After careful study of the types available in the Calcutta Herbarium and from study of the types of *C. capsularis* collected by him from Bombay, Saurashtra and the district of Surguza in Madhya Pradesh, Watt (1908) came to the conclusion that *C. capsularis* was not wild in India, Malaya or China. The author of this article is of the opinion that *C. capsularis* is not an immigrant as stated by some authors, but its centre of origin is Indo-Burma, which according to Vavilov's map includes South China.

Description

Though the two species from which jute fibre is obtained are similar in

C. olitorius

C. capsularis

general appearance, the leaf of *olitorious* has a shining upper surface and a rougher under-surface and is almost tasteless, when chewed. The leaves of *capsularis* contain a bitter glucoside, *corchorin* and taste bitter on chewing; hence it is often known as *Tita* (bitter) *pat* and *olitorius* as *Mitha* (sweet) *pat*. There are, however, some non-bitter types of *capsularis*. The flowers of *olitorius* are larger than those of *capsularis*. The pod of *capsularis* is roughly globular, while that of *olitorius* is cylindrical. Among the *capsularis* varieties, "Dhaleswari" and "Fuleswari" and *capsularis var. oocarpus*, described by Burkill and Finlow (1911), have pearshaped or oval pods or capsules. The seeds of *olitorius* are bluish-green to steel-grey in the cultivated varieties and steel-grey to black in the wild varieties. *Olitorius* seeds are smaller than those of *capsularis* which are copper-coloured. *Olitorius* also tends to grow taller than *capsularis*.

The detailed descriptions of the two species are presented below for comparison :

	C. capsularis L.	*C. olitorius* L.
General	Plant 5 to 12 feet tall, can withstand water-logging in later stages.	Plant 5 to 12 feet tall, cannot normally withstand water-logging; flowers prematurely if sown very early.
Plant	Herbaceous annual, 3 to 5 months duration depending on the time of sowing.	Herbaceous annual, 4 to 5 months duration depending on the time of sowing.
Stem	Cylindrical, green or coloured dull coppery red to pink.	Cylindrical, green or coloured light red or dark red; Shades of colour fewer than in *capsularis*.
Epidermis	Breaks off in the older parts with the development of periderm.	Persists throughout.
Periderm	Always present, distinct, consisting of several layers of regularly arranged rectangular cells ; appears early.	Usually absent. If present indistinct and appears late; Lenticels present in later stages.
Phloem fibres	Less compact, due to broader rays and wider soft phloem layers. Ray cells and sieve tubes bigger and sometimes also more in number.	More compact, due to thin rays and narrow soft phloem layers. Ray cells and sieve tubes smaller.
Number of fibre layers	More (10-24).	Less (8-19).
Number of fibre bundles, per cross section	More (2573).	Less (2181).
Area of fibre bundle	Smaller (2573 sq.μ).	Larger (2766 sq.μ).
Xylem	More developed in extent showing indistinct or incomplete zonation. Xylem elements larger, thin-walled, less lignified and irregularly arranged.	Less developed in extent showing distinct zonation into wide compact regions of thick-walled lignified elements and narrow, less compact regions of less lignified thin-walled cells.

	C. capsularis L.	*C. olitorius L.*
Pith	Persisting.	Collapsed (hollow).
Crystals	Frequently observed in the pith, rays and cortex.	Not very common.
Branching habit	Branched or unbranched ; axillary buds may or may not develop into branches.	Branched, but branches normally develop less vigorously.
Leaf	Glabrous, usually 5 to 13 cm. x 2.6 to 8.2 cm., ovate-oblong, acuminate, coarsely toothed; Lower-most pair of serrations enlarged and end in hairy appendages.	Glabrous, usually 7 to 18 cm. x 4 to 8 cm., oblong, acuminate; coarsely toothed lower most pair of serrations more enlarged than in *capsularis* and hairy appendages longer.
	Petiole, 4 to 8 cm., varies in colour from green to pink in different varieties.	Petiole, 4 to 9 cm., varies in colour from green to dark-red.
	Stipule, usually 0.5 to 2 cm. or more; foliaceous in some varieties; tip coloured except in the full green types; base coloured or green.	Stipule, usually 0.5 to 1.5 cm. or slightly more; tip coloured or green; base coloured except in the full green types.
Flower	Small, 0.3 to 0.5 cm. in length and 0.5 to 0.6 cm. in breadth, in leaf opposed cymes in groups of 2 to 5 or more ; sepals 5, coloured or green; petals 5, yellow or pale yellow ; stamens 20 to 30, anthers coloured yellow or pale yellow; Ovary rounded, 5-carpelled, syncarpous; ovules axile, usually 10 in each loculus in two rows giving 50 ovules in each ovary ; style 2 to 4 mm. ; stigma 2 to 3 fid, pubescent.	In leaf opposed cymes in groups of 2 to 5, about 1 cm. in length, about 2 to 2½ times the size of those of *capsularis* ; sepals 5 to 6, coloured or green ; tips prolonged in flower buds; petals 5 to 6, yellow, entire or split, stamens 30 to 60, anthers yellow; Ovary elongated, 5, rarely 6 carpelled, syncarpous; ovules axile, usually 40 in each loculus in 1 row giving 200 ovules in each ovary ; style 3 to 5 mm. ; stigma globular, entire, pubescent.
Anthesis	1 to 2 hours after sunrise.	An hour or less before sunrise.
Capsule	Rounded, 1 to 1.5 cm. in diameter, wrinkled, rarely smooth, muricate and 5-locular; Seeds 7 to 10 in two rows in each locule, without transverse partitions, 35 to 50 in each fruit.	Elongated, 6 to 10 cm. long 0.3 to 0.8 cm. in diameter, ridged lengthwise and 5 to 6 locular; Seeds 25 to 40 in single row in each loculus, with transverse partitions between each seed and 140 to 200 in each fruit.
Seed	Small, chocolate brown, 4 to 5 faced, weigh about 300 seeds per gram.	Smaller than those of *capsularis*, bluish green to steel-grey or even black in colour; Weigh about 500 seeds per gram.

The two species differ in the quality of fibre. Fibre of *olitorius* is usually finer, softer, stronger and more lustrous than that of *capsularis*. The fibre of *capsularis* is ordinarily whitish and therefore it is called "white jute" by the trade. *Olitorius* fibre has either yellowish, reddish or a greyish shade, depending upon the nature of the retting water.

Within each of these species there are a number of well defined varieties, based on various characters, such as pigmentation, pod shape and size, petal and anther colour, stipule character, seed-coat colour, taste of leaves, maturity, yield, quality of fibre, etc.

The races or forms of *capsularis* are more numerous than those of *olitorius*. After making a thorough study of the morphological and cultural characteristics of the plant R. S. Finlow, then Fibre Expert to the Government of Bengal, and his associate concluded (1907) that there were 33 distinct *capsularis* races and 5 *olitorius* races; three of these are grown as vegetables. Studies in the Jute Agricultural Research Institute indicate the existence of more than 70 races of *capsularis* and at least 12 of *olitorius* (excluding the wild types of both). Based on general morphological characters and yield, the races of *capsularis* and olitorius occurring in the major jute growing districts have also been described.

The colour of stem, petiole, leaf and pod varies in the different forms. It may be green, pink, red or purple, but this has no relation with the colour of fibre. The differences in the pattern of colour due to presence of anthocyanin pigments in the cultivated species of *Corchorus* form a striking feature of the jute crop. By this character alone many of the strains and cultures can be easily indentified.

Breeding Work

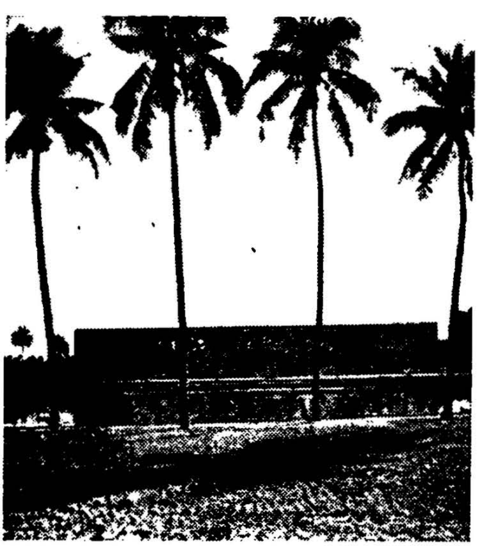
The necessity for genetic improvement of jute was felt by the Government of Bengal as early as 1900 when a Committee was set up to devise ways and means towards that end. On the recommendation of that Committee a fibre section was set up in the Department of Agriculture, Bengal in 1904 with Mr. R. S. Finlow as Fibre Expert. As a result of the researches carried out by Mr. Finlow and his associates for nearly 15 years, two high yielding strains, D 154 (*capsularis*) and C. G., or Chinsurah Green (*olitorius*) were evolved by pure-line selection and released for distribution about the year 1920. For many years they were the standard strains.

D 154 is a green-stemmed, branching type with a red tinge only on the upper surface of the petiole, at the tips of stipules and tips of basal serration of leaves. It is late maturing with fairly good quality of fibre. C. G. is a tall full green type, takes about three and a half months to mature and is suitable for highland areas.

Work on the improvement of jute fibre from the field to the factory was taken up by the Indian Central Jute Committee set up by the Government of India in 1936 on the recommendation of the Royal Commission on Agriculture. Agricultural research on jute was carried out by the Jute Agricultural Research in Laboratories established at Dacca, in 1939. After the partition of India in 1947, the Jute Agriculture Research Laboratories were completely disorganized and the Jute Agriculture Research Institute was at first set up as a nucleus in 1948 at Hooghly and permanently in 1953 at Barrackpore in West Bengal where the programme of work on the improvement of the jute crop started at Dacca was continued and expanded.

As jute is a fibre crop harvested long before the seeds mature, both fibre of good quality and seed cannot be obtained from the same plant. If it is harvested at the proper stage of fibre maturity, no seeds can be obtained. If on the other hand, harvest is delayed till seed maturity, the plant becomes dry, does not ret properly and fibre extraction is unsatisfactory. Since a selected plant has to be kept for seed and its fibre content cannot be determined directly it is necessary to base the criteria for selection of plants on morphological characters which influence the yield of fibre. To arrive at a sound criterion for proper selection work, a number of plant characters were evaluated at the Jute Agricultural Research Laboratories in 1939. Two such characters in jute are the height of the plant and its thickness at the base; the correlation coefficient of the two characters with the yield of fibre being +0.761 and +0.914 respectively. The greater the height and the greater the basal thickness, the larger is the out-turn of the fibre.

Two main considerations in the improvement of jute are the yield and quality of the fibre, both of which should progress simultaneously. Jute plants generally require a long vegetative period in order to attain a good height and stem thickness, hence late maturing types usually yield higher. While such late types are good yielders, they usually suffer in quality. Colour, lustre and softness are concomitant with good quality of fibre. Early maturing types like a strain called *Fanduk* give much superior fibre; plants of such early types with short vegetative period are usually thin-stemmed and not tall and consequently they yield low.



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With such divergent considerations as yield and quality, it appears that improvement in one direction means retrogression in the other. In order that advance in one may not mean undue sacrifice in the other, research work for the evolution of suitable strains has been conducted at the Jute Agricultural Research Institute and some promising strains, with high yield and superior quality of fibre, have been evolved; some of these are mentioned below.

Capsularis Strains

JRC-212, a full green high yielding type with very good quality of fibre and maturing about a week earlier than D154, suitable for high and medium lands; *JRC-13*, similar to *JRC-,212* but late maturing like D154; *JRC-412*, a type with narrow leaves and coppery red colour on the upper surface of the petiole and on the pod, admirably suited to those lowl and areas where jute is harvested by the third and fourth week of July; *JRC-312* an early type with coppery red stem, yielding high under low land conditions and giving fibre of very good quality; *JRC-1* a rather late, high yielding type producing medium quality fibre; *JRC-918* a very late non-branching type selected from a type introduced from Brazil; *JRC-919*, a very late, very high yielding branching strain selected from a type introduced from Brazil, *JRC-206*, another high yielding strain selected from a type introduced from

Brazil with quality of fibre better than that of *JRC-919*; *JRC-5854*, a non-branching strain with coppery red stem selected from multiple cross materials, yielding as good as D154 and performing very well under U. P. conditions in recent years.

Olitorius Strains

JRO-632, a full green, late maturing type, yielding much higher than C. G; its seed-coat colour is steel grey (in C. G; seed-coat colour is bluish green); *JRO-153*, a full green late maturing type similar to *JRO-632*; *JRO-620*; a type with light red stem, maturing earlier than *JRO-632*, but yielding slightly less than that strain.

Varietal Trials

With a view to testing the yield performance of the different strains evolved by the Jute Agricultural Research Institute, full scale varietal trials with different *capsularis* and *olitorius* strains were conducted at the Institute and also at the Government farms of different jute growing States from 1950 to 1955. In general the strains evolved by the Institute have given higher yields. To test the improved strains over a wide range of soil and climatic factors under cultivators' conditions simple varietal trials were conducted in West Bengal, Bihar, Assam, Orissa and Uttar Pradesh. The results of these trials carried out from 1952 to 1958 are given in the Table below.

Multiple Crossing

In an endeavour to synthesise high yielding, non-branching, early maturing and disease resistant strains, a multiple crossing scheme involving eight *capsularis* types having different characteristics, as branching, and non-branching, late and early maturing, high yielding with medium quality fibre, comparatively low yielding with very good quality fibre,

SIMPLE VARIETAL TRIALS (1952-58)

mds./acre

Capsularis	JRC-321	JRC-212	D-154	Lccal
West Bengal	19.27	19.11	19.22	17.57
Bihar	23.43	21.82	22.45	20.28
Assam	20.64	19.80	20.70	17.63
Orissa	17.51	19.28	19.53	18.47
U. P.	21.89	23.18	22.31	20.63

Olitorius	JRO-632	JRO-753	JRO-620	C. G.	Local
*West Bengal	22.02	21.29	19.72	18.33	17.66
Bihar	18.68	18.21	19.86	17.85	17.59
*Assam	20.39	20.05	193,5	18.29	16.65
Orissa	22.86	24.15	22.69	20.76	18.64
U. P	18.42	20.05	16.64	15.02	14.88

* Results of 1951-54 only.

comparatively disease resistant, etc. was taken up by the Jute Agricultural Research Laboratories in 1944 when the first crosses were effected.

In 1947 more than 2000 selections were made from the progenies of the third mating in the various groups of the multiple crossing materials but all were lost in Pakistan at the time of partition. Nevertheless, work was continued at the Institute with some of the available old materials of multiple crosses. On the basis of analysis of yield data from family block trials conducted for a number of years, progenies of a promising, non-branching selection have been bulked up for multiplication and further yield trials in a full scale varietal trials. Among the promising strains selected from derivatives of multiple crossing materials, *JRC-5854* has been found to be the best.

A planned programme of inter-varietal hybridization, including back-cross technique has already been taken up anew by the Institute for the selection of types with desired combination of characters. Crosses have been made covering various combinations and the materials are now in the early yield trial stage.

Studies on Irradiation with X-rays

It has been reported by some workers that treatment of jute seeds, both dry and soaked, with different doses of X-rays produces various structural aberrations in the plants of both the cultivated species and that variations in plants raised from soaked seeds are more than in those from dry seeds.

In 1947, a scheme of research work on X-irradiation of jute was taken up by the Bose Research Institute, Calcutta, under the auspices of the Indian Central Jute Committee. A tall mutant of *olitorius* with a height of 17 feet and basal diameter of 1.9" was obtained from X-irradiated seeds. In 1952, a small bulk trial was conducted at the Jute Agricultural Research Institute with the Tall Mutant obtained by the Bose Research Institute, C. G. and the improved strains evolved by the Jute Agricultural Research Institute. The results have shown that the improved strains, *JRO-632* and *JRO-753*, of the Jute Agricultural Research Institute are significantly superior to the Tall Mutant at 1 per cent level giving higher yields of 49 and 48 per cent respectively.

With a view to studying the effect of X-rays on jute and to produce desirable mutations, seeds of two high yielding strains of jute, viz., *JRC-212* (*capsularis*) and *JRO-632* (*olitorius*) were treated in the dry and soaked state with different doses of soft and hard X-rays during 1952 and 1953. The soft rays ranged from 500 to 30,000 r units and hard rays from 1,000 to 40,000 r units.

It was observed that in the different X-rayed generations numerous variations in almost all parts of the plant body were produced in both soaked and dry seeds, treated with various doses of hard and soft rays.

In yield trials conducted with the promising progenies of irradiated materials in successive generations, it was found that a number of *capsularis* and *olitorius* materials proved equal to or better than the controls in yield. Two high yielding *olitorius* strains *OX52-7460* and *OX52-7475* evolved by *X-ray* treatment and which proved better than C. G. in respect of yield were bulked up during 1954 season. Further selection from these two cultures has yielded *JROX-514* and *JROX-452*. Trials with other promising X-rayed materials are in progress at the Jute Agricultural Research Institute.

Both *JRO-632* and *JRC-212* were also treated with acute gamma rays from CO^{60} in 1960. While the morphological effects are similar to the X-ray induced variation, the number of variations induced at corresponding doses is fewer than in X-rays.

Genetics of Jute

Studies on the inheritance of different characters have been carried out for a number of years; the results are summarised below.

Anthocyanin Pigmentation

In the studies of variation in the colour of jute plant the following patterns have been recognized :

(1) Red stem, red petiole, red fruit, bright yellow flower;

(2) Green stem, rosy petiole, rosy fruit, red on the outside of the flower bud and bright yellow flower;

(3) Green stem, green petiole, green fruit, no red on the outside of the flower bud, with pale yellow flower.

Some of the patterns show intermediate shades of pigment and the constancy of these combinations suggests interesting Mendelian inheritance.

In the inheritance of pigment a single gene difference between red and green pigments was observed by some workers, red being dominant to green. Some other workers examined the same experimental data and found that more than one gene was involved in the production of red pigment.

The differences in the pattern of anthocyanin pigmentation in the cultivated varieties of *Corchorus* are found to be very helpful in the identification of many of the strains. Further work has shown that in *capsularis* the anthocyanin pigmentation, which ranges in intensity from pure green to dark red, is the result of the interaction of three different genes, viz.,

C—the chromogen gene fundamental for the production of pigmentation.

A—Pigment producing gene with no visible effect on the plant body except in the presence of dominant chromogen gene C. It is present in multiple allelomorphic series.

R—Pigment reducer gene, the effect of which is most marked on the stem.

The pigmentation patterns studied, fall under three groups: (1) the full-greens with combinations of different allelomorphs of A with R and r but with recessive chromogen gene, C, (2) green pigmented types with different allelomorphs of A with dominant C and R, and (3) the red group with the allelomorphs of A with dominant C and recessive r. All the five possible green-pigmented types and four of the red types, besides six of the ten possible full-green types have been isolated.

In *olitorius*, the anthocyanin pigmentation is controlled by a single gene in allelomorphic series *ADo—ARo—ao* (Deep red—red—green). Thus the green type in *olitorius* is the result of recessive anthocyanin allele where as in *capsularis* the green type is due to the recessive chromogen gene and the occurrence of any particular green type is dependent on the anthocyanin multiple allele and the reducer allele carried by it.

Pod-Shape

In crosses between the oval pod variety, *Deodhali*, and a round pod variety, *D154*, the pods of the F_1 were found to be intermediate in shape, the base of the pod being less elongated than in *Deodhali*. The F_2 families segregated in a simple monogenic ratio. The gene for pod-shape, *G*, was found to be linked with the chromogen gene, *C*, with 8 per cent cross-over.

Branching Habit

The branching habit in *capsularis* is found to be controlled by a single gene pair, Br-br (Branched-Non-branched). All Indian *capsularis* types are branched while the recessive gene, br, occurs only in some foreign *capsularis* types.

Stipule Character

In some foreign *capsularis* types like *Halmahera* and *Salimos* (from Formosa and Brazil) the stipule is foliaceous and is in marked contrast to the stipules observed in Indian *capsularis*. The stipule character is controlled by a single factor pair Sfl-sfl.

Bitter Taste

Monogenic inheritance of bitter taste in *capsularis*, Tb-tb (Bitter-Non-bitter), was established. The gene for bitterness was found to be linked with Br, the gene for branching, with a crossing-over percentage of 22.2, while there was no evidence of linkage with the allelomorphic series of the anthocyanin genes.

Undulate Leaf

In *capsularis*, the undulate leaf type when crossed with normal flat leaf type gave F_1 that was intermediate. The F_2 progeny segregated in a monogenic ratio (undulate =W, normal=w).

Corolla Colour

Corolla colour in *capsularis* is either yellow or pale yellow and is controlled by a single factor pair, Py-py (Yellow-Pale). In cultivated types of *olitorious* no pale yellow flowered types have been found but in a foreign variety, light yellow corolla and light-yellow anthers were noticed and the factor pair controlling their colour was designated as Pyo-pyo (Yellow—light yellow). The corolla colour gene is not linked with any of the anthocyanin genes.

Anther Colour

Monogenic inheritance was established for anther colour in *capsularis*. The light yellow anther is recessive to yellow anther and is completely linked with the pale yellow petal.

Seed-coat Colour

The seed-coat of some cultivated *olitorius* is leek-green, while in wild *olitorius* the seed coat is dull black. The inheritance of seed-coat colour is governed by a single factor Gr-gr (Dull—leek green).

Cytogenetics

The haploid chromosome number in *capsularis olitorius* and *acutangulus* was first reported in 1932 as seven, which was confirmed later by other workers in several types of *capsularis*. In 1953 some workers reported haploid chromosome number in *tridens*, *trilocularis* and *fascicularis* as seven and also found hypo-and hyperploidy in all the Indian species of *Corchorus*, *siliquosus* was found to be a natural polyploid having haploid chromosome number, n=14. Normal type of cytological behaviour in pollen development of both *capsularis* and *olitorius* was first reported in 1933 and later confirmed by another worker in 1939-41.

Meiotic lability was first reported in 1952, in both the cultivated species of jute and later in *fascicularis*. This behaviour was observed in other species of *Corchorus* and was considered to be a characteristic of the genus.

A trisomic mutant in *capsularis* which showed dimorphic gametes with seven and eight chromosomes was described in 1937. In 1944 some workers described the morphology of V2 and V3 mutants. V2 was found to be a gene mutant having 2n=14, and V3 an aberrant branch of a normal diploid, the branch being a trisome having 2n+1=15.

Secondary association in *capsularis* was reported by a worker in 1937, whose contention was challenged later by another worker. Further work on this aspect is in progress at the Jute Agricultural Research Institute.

There is much scope for improvement in the yield and quality of jute, if the characters of the two species of jute can be combined through hybridization. But unfortunately these two species do not cross. No difficulty is experienced in hybridizing races of *capsularis* amongst themsleves or races of *olitorius* amongst themselves, but inspite of numerous attempts viable seeds were never obtained from crosses between the two species. In some of the crosses, however, pods were formed and matured, but seeds failed to germinate. Over 1000 interspecific crosses were attempted both at diploid and tetraploid levels and their combinations at the Jute Agricultural Research Institute. A number of crosses made using the ordinary method of straight crosses resulted in failure. Other methods like application of stigma paste of the male parent on the stigma of the female parent, reducing the length of the style in *olitorius* mothers by cutting, and mixed pollen methods were tried without success. The results were no better even when the two species were crossed in the tetraploid state.

To overcome the incompatibility, seeds of both the species were treated with colchicine to raise tetraploid plants, which could be hybridized. Tetraploids in *capsularis* were obtained but not in *olitorius* by some workers. Some workers obtained tetraploids in both the species and made a large number of reciprocal crosses between the auto-tetraploid forms and they expected a few fertile amphidiploids among the tetraploid hybrids F_1. Tetraploidy in *capsularis* by treating seeds with a cheap fungicide *viz.* Benzene hexachloride, commonly known as Gamexane was also obtained. Since 1949, Colchicine induced polyploids of both the species of jute are under study at the Jute Agricultural Research Institute. The *olitorius* polyploids are shorter than the normal diploids but the base diameter is slightly greater. Yield of *olitorius* polyploids is significantly lower.

As the two species are incompatible, it has become necessary to see if incompatibility barrier resides in the stigma, style or ovule or if it is due to genic differences. Results of investigations have pointed out that incompatibility was not due to any retardation in the growth of the pollen tubes within the styler tissue in either case. Investigations have also indicated that failure of seed-setting in this cross is not due to the lack of fertilization, but that it is caused by the premature abortion of hybrid embryos. By using 300 p.p.m. 3-indole-acetic acid to smear the pedicel after pollination some workers obtained three hybrid plants. The workers at the Indian Agricultural Research Institute, New Delhi, have claimed to have hybridised successfully these two species.

The development of the embryo-sac in jute has been found to be normal and fertilization to be porogamous.

Anatomy of Jute Plant

The gross anatomy of the jute stem has been described by various authors. Based on developmental studies, the author of this article for the first time in 1942 described the origin and structure of the fibre. Jute fibre is developed from the outer portion of bark of the stem. The entire fibrous region is in wedge-shaped groups, each having alternate patches of scelrenchyma fibres and soft tissues. The outermost layer of fibres is developed from the protophloem and all the inner layers of fibres forming part of the secondary phloem are developed by the activity of the cambium. Each pyramidal wedge of the secondary phloem tapers outwards and has a broad basal region. At the basal region of the plant there are usually 8 to 24 layers of fibre bundles (10 to 24 in *capsularis* and 8 to 19 in *olitorius*) in radial depth, alternating with an equivalent number of soft tissues. The number and size of fibre bundles in the phloem wedge is the result of cambial activity and is dependent on the growth and vigour of the plant.

Secondary wood, developed by the cambium, forms a thick zone and occupies the greater part of the radial depth of the section. The number of vessels with wide lumen in the secondary xylem is very small compared to the number of smaller lignified elements, mainly fibres and wood parenchyma. The pith in *olitorius* collapses early so that the mature stem has a hollow region in the centre. In *capsularis*, however, the pith persists and consists of large thin-walled cells.

The wood of *capsularis* differs from that of *olitorius* in having less pronounced growth zones, cell walls of the different wood elements being comparatively less thickened; the vessels occur singly and are more diffused. In *olitorius*, however, the cell walls of wood elements are more thickened, vessels usually occurring in groups of two or three, rarely more, occasionally singly. The wood of *olitorius* becomes harder than that of *capsularis* on account of the presence of thicker wood elements. As a result more difficulty is experienced in harvesting *olitorius* crop.

The fibre bundles vary greatly in shape and size. They may be more or less square, rectangular or elongated radially. In *olitorius* the radially elongated fibre bundles occur more frequently and form a striking feature of this species. The number of ultimate fibre cells in the bundle is very variable in both the species though, in general, it is lower in *capsularis*.

The fibres that are commercially important are the secondary phloem or phloic fibres, that is, those developed by the activity of the cambium. The single layer of bundles of the outermost fibres is derived from the protophloem and usually dose not exceed 10 per cent by weight of the total fibre content of the plant.

In surface view, the fibre bundles, which form definite strands, are found to be arranged in the form of a network. In tangential longitudinal sections passing through the fibrous areas of the stem, gradually from outside to the interior, it is noticed that the outer fibre groups (bundles) form a loose network with intervening patches of wide oval ray tissue, and the inner ones form a closer network with much narrower ray tissues in the meshes. The degree of meshiness not only increases from the exterior to the interior but also from the top to the base and is more in *capsularis* than in *olitorius*. This depends on the activity of the cambium, formation of the secondary rays and the frequency of the division and reunion of the fibre bundles.

The cells which make up the fibre strands or patches are elongated in the direction of the stem axis with pointed or tapering ends and appear more or less polygonal in outline with well defined angles in a cross section. Each fibre cell is also known as ultimate fibre and can be easily separated by macerating the fibre bundles in different chemicals. They vary from 500 to 6500μ in length and from 10 to 30μ in diameter. The average length of the fibres of the outer group developed from the protophloem is 3.2 mm. and that of the fibres of the inner group is 1.5 mm. but there is very little difference in their diameter.

The ultimate fibres of jute are cemented together by an isotropic, non-cellulosic intercellular substance which forms a layer of middle lamella between the cells. The fibres are 18 to 20μ wide.

The walls are thick and lignified and except for occasional transverse cracks are relatively smooth and unmarked. The lumen or cell cavity is as wide as the cell walls, but shows characteristic constrictions at irregular intervals, and sometimes is even completely closed due to the uneven thickening of the cell wall.

The anatomy of branching and non-branching plants has shown that the bud meristems, which are present invariably in every axil of the leaf of the branching plants, are absent in the non-branching plants due to early vacoulation. In the non-branching types some branches develop sporadically but their rate of growth is slower than that in the normal.

Physiology of Jute Plant

Photoperiodic Effects

Both species of jute are typical short day plants. The transition from vegetative to reproductive phase in jute is influenced mainly by the available daily light period. The prevailing long photo-period prolongs the vegetative period of jute plants which flower with the approach of short-day of late August and early September, irrespective of the sowing period.

Effects of Date of Sowing

It is observed from pot-culture experiments that the vegetative growth and development as well as yield of fibre are greatly influenced by the time of flowering. In *capsularis*, satisfactory yields have been obtained with sowing between 16th March and 1st May. In *olitorius*, sowing between 15th April and 16th May have given significantly higher yields than other sowings. In both, sowing during third to fourth week of April gave the best yields. Yield of fibre in *capsularis* sown after 16th May and in *otilorius* sown after 15th June, progressively decreases. Plants of both the species sown in September and after, showed slow growth and those sown in November, December and January have very poor growth. Both the species grown at the Jute Agricultural Research Institute attained a height of 8 to 12 inches and developed very few capsules; but the capsules were fully developed and showed normal dimensions and the number of seeds per capsule was also normal. Plants raised from such seeds in the normal jute season showed normal performance with regard to height and base diameter, but they flowered earlier.

Vernalization

Response to pre-sowing cold treatments of seeds is manifested by delayed germination and production of more green pigments in the leaves and more vigorous growth in the early stages; there is no significant effect on the date of flowering. Some workers have reported that there was some earliness of flowering and fruiting due to vernalization. The differences in the vegetative growth with reference to the total heights reached, daily increase in height and mean length of each internode due to vernalization were not statistically significant.

Water Relation in Jute

Both species require plenty of water and humid conditions for their normal growth and the growth of plants is adversely affected under waterlogged conditions. It has, however, been found that the water requirements and moisture economy in the two species of jute are different. Drought resistance investigations carried out at the Jute Agricultural Research Institute have shown that in the early stages of growth, *capsularis* can withstand natural drought better than *olitorius*. Resistance to drought can also be induced by alternate soaking and drying of seeds before sowing. The response to this kind of treatment also varies in the two species, *capsularis* showing greater resistance to drought than *olitorius*.

Mineral Nutrition of Jute

It has been found by agronomic trials carried out at the Jute Agricultural Research Institute that nitrogen from inorganic or organic sources increases the yield of jute. Higher yields are obtained by application of nitrogen from inorganic sources than from organic sources. There is a differential response to different combinations of N, P and K in *capsularis*. It has been observed that ammonia is a better source of nitrogen than nitrate. The omission of K,P and Ca in nutrient solution produced stunted growth and various visual symptoms such as drying up of tips, chlorosis, smaller size and bluish-green colour of leaves.

Growth Variation in Jute

Growth in height and basal diameter of the stem, and development of bark, wood and fibre during the life cycle of the plant show characteristic differences in the two species, *capsularis* and *olitorius*. Within the species, varietal differences are also noted. High positive correlations in the variations of the different components during the different stages of growth of the plant have been noticed in both the species. The ratio of fibre formation to that of wood formation varies with the progressive age of the plant from the vegetative to the flowering and pod stage. More fibre is produced in the early stages than in the later stages of growth when more wood is formed. The calculated values of fibre formation on the total dry matter show more wood formation in *olitorius* than in *capsularis*.

Salt Tolerance

It has been reported that the coarser varieties of jute could be grown in the salt impregnated soil of the Sunderbans in Bengal. It is also reported that jute can be successfully grown on high lands, about 4 feet above the flood level, containing 0.20 to 0.25 per cent of sodium chloride. Jute failed to grow on soils containing more salt.

Seeds of both *capsularis* and *olitorius* cannot tolerate a concentration higher than one per cent of sodium chloride and even at this strength there is a perceptible delay in germination. Seeds of *capsularis* are more tolerant than those of *olitorius* under similar conditions. *Capsularis* seeds when previously soaked in 0.5 to 2.0 per cent solutions of sodium chloride for different periods showed delayed germination with the increase of concentration up to 1.5 per cent. Almost all the seeds treated with 2 per cent solution failed to germinate. In the experiments conducted at the Jute Agricultural Research Institute, artificially raising the sodium chloride concentration of soil by adding common salt, it was observed that in soil containing 1.5 per cent sodium chloride, the plants were stunted in growth, the leaves were pale yellow in colour showing less chlorophyll development, and very few flowers and pods were formed. When common salt was added to the soil, at different ages 27 days, 74 days and 89 days of the plant, to make the concentration approximately 3 to 4 per cent it was observed that the effect of salt was deleterious and plants of any of these ages did not survive.

Germination at Different Stages

In order to determine the exact stage at which jute plants should be harvested to obtain seeds of the best quality, experiments were conducted at the Dacca Farm by the Department of Agriculture, Bengal, in 1927. Plants of both *capsularis* and *olitorius* were harvested when (1) stem and pods were both green but pods were nearing maturity, (2) stem green but pods ripe, and (3) stem and pods both dead ripe.

The germination percentage was tested periodically. The results indicated that in the case of *capsularis*, the plants can be harvested even when the stem and pods are not dead ripe.

In the case of *olitorius*, the best stage of harvest for obtaining seed of good quality is when the stem and pods are both dead ripe, but at this stage the pods tend to dehisce and shed the seeds to some extent; as a result, there is loss of seed. It is, therefore, necessary that particular care should be taken to collect seeds at the proper stage.

Experiments were conducted at the Jute Agricultural Research Institute to find out the possibility of obtaining both fibre and seed of good quality from the same plant. Plants were harvested when the pods were (1) green, (2) half-matured and (3) fully matured and the top portions were cut out for seed collection after drying and the stems were retted for fibre. To estimate the loss of fibre yield when tops are removed for seed, whole plants were also retted. It was observed that by removal of the top portion for seed, the yield of fibre was not appreciably affected, the reduction being 40-80 lb. per acre. The germination capacity of seeds collected at different stages showed that in *capsularis*, normal germination was obtained from the second and third stages of harvest. In *olitorius*, germination percentage was highest in the third stage although seeds of fairly good germination were obtained in the second stage of harvest also. The yield of seed was, however, highest in the last stage.

Soil

Jute can be grown on all types of soils, generally of alluvial origin, varying in texture from clay to sandy loam. It does not grow well on very sandy lands without the addition of large quantities of organic manures.

It thrives very well on the *Chur* or *Khadar* lands, that is, inundated lands along the river banks. These lands are sandy loam in nature and are usually renovated by deposits of silt left on the subsidence of annual floods. Laterite and gravelly soils are not favourable to the growth of jute. A good crop can be raised on nearly all types of lands which are neither very sandy nor very clayey provided the soil is deep enough and the rainfall well distributed over the months of March, April and May.

Climatic Conditions

Jute is grown during the rainy season. Humid heat is most favourable for growth of the crop. In areas where jute is grown, the maximum temperature does not usually exceed 100°F or fall below 60°F during the crop season, but in many parts of West Bengal, Orissa and U.P., the maximum temperature during the growing period may occasionally be as high as 110°F or sometimes more. Humidity varies from 65 to 95 per cent.

The sowing of seeds starts by the middle of February and is continued till the middle of June in some areas. The monsoon in most of the jute areas except Assam sets in towards the middle of June and the crop that is sown during mid-February to May has to depend entirely on sub-soil moisture and pre-monsoon 'norwester' showers. In many of the jute growing areas, cultivators mostly depend on pre-monsoon showers for sowing.

In Eastern and Northern Bengal pre-monsoon rains start early and amount to more than 15 inches.

These rains start usually by second week of April in West Bengal and amount to about 9 inches. Pre-monsoon rains are about 3 to 8 inches in Bihar and about 6 inches in Orissa. In Assam, however, the rains start much earlier. The total amount of rainfall ranges from 50 to 70 inches in West Bengal, about 60 inches in Orissa, 45 to 70 inches in Bihar, 90 to 120 inches in Assam and 70 to 90 inches in Eastern Pakistan. The minimum rainfall required for cultivation of jute has not yet been determined. Jute has, however,, been successfully grown in such areas in Uttar Pradesh where the rainfall is between 35 and 40 inches.

Alternate periods of sunshine and rainfall are beneficial for a good crop of jute. Young jute plants are very sensitive to water logging which usually checks their growth. When nearly fully grown, *capsularis* jute plants are tolerant to water which does not actually submerge them. It is, therefore necessary to adjust the sowing time of jute in such a way that the crop may attain a height of 3 to 4 feet before heavy monsoon starts. *Capsularis* jute will thrive well in inundated lands if the floods do not come before the crop has reached a height of 3 to 4 feet; but in such cases, the lower portion of the fibre tends to become very coarse due to the formation of adventious roots.

The most suitable conditions of soil and climate for the jute cultivation are: (*a*) A total rainfall of about 60 inches per year of which about 10 inches should precipitate during the months of March, April and May. Besides the total rainfall, the distribution of rainfall is a very important factor for a successful crop of jute; and (b) A deep loamy soil, not subjected to in undation.

Cultivation

Preparatory Tillage

Preparatory tillage starts just after the first shower of rain during the latter part of February or beginning of March. As the roots of jute plants reach more than a foot in depth, deep ploughing is necessary to remove the stubbles of the previous crop. Jute seeds being very small the soil should be thoroughly pulverised and a seed bed with fine tilth obtained before sowing.

Manuring

Manuring of jute lands is done differently in the different jute growing areas. Cowdung, ashes and composted house sweepings are usually used. Cowdung is applied at the rate of 400 to 800 lb. per acre and ploughed in during the course of land preparation. In many areas, where it is available, water hyacinth, either composted or in the form of ash is applied. The ash of water hyacinth contains about 20 per cent of potassium chloride and is highly suitable as a manure for jute crop. Mustard and castor cake, are also used but the practice is not very widespread. Silt from tanks, ponds and ditches is also used wherever available.

Till recently chemical fertilizers were rarely used for jute. As a result of the dissemination of the results of research among the cultivators and the fertilizers now made available in remote villages by the State Agricultural Departments, the use of chemical fertilizers, particularly of ammonium sulphate, has increased.

Experiments conducted at the Jute Agricultural Research Institute and elsewhere have shown that nitrogenous manures and fertilizers have the greatest influence on the vegetative growth of the plant. Among the various inorganic and organic sources, ammonium sulphate and town compost respectively have been found to be the best. Best results were obtained by the application of town compost at the rate of 40-80 maunds per acre at the time of preparatory tillage, followed by 100-200 lb. of ammonium sulphate applied as top dressing when the crop is about a month old. Such mixtures provide about 30 to 60 lb. of available nitrogen per acre.

Potash singly was not usually found to have any direct effect on the yield of jute fibre. Slight increases in yield by the addition of 25 to 50 lb. of potash as muriate of potash were noticed when applied alone or in combination with lower levels of nitrogen; but these increases were, in many cases, not significant. Addition of potash, has, however, been found to check diseases.

No positive responses were obtained by application of phosphate so far as yield of fibre was concerned but this may prove useful in phosphate deficient areas as indicated by preliminary trials carried out by the Jute Agricultural Research Institute. The author of this article observed that application of phosphate prevents lodging. It may, therefore, be tried in light soils.

Addition of calcium as lime is beneficial to the normal growth of the plant in acidic soils. Due to the application of lime at 240 to 480 lb. per acre, either alone or in combination with nitrogen, increased fibre yields were obtained in some of the district trials. In non-acidic soils, however, the role of calcium, like that of potash, is mainly in protecting the plants against diseases.

From preliminary experiments carried out by the author of this article at the Jute Agricultural Reserve Institute it was found that in the case of jute, the soil nitrogen, which is exhausted during the growth of the plant, is replenished by normal leaf-fall that occurs during the growth of the plant. It has been observed that the phosphate content of surface soils increases when jute is grown for a number of years.

Sowing

Seeds are usually sown broadcast at the rate of 10 lb. per acre for *capsularis* and 6 lb. per acre for *olitorius*. As the seeds are very small, they are often mixed with loose earth for the convenience of handling at the time of sowing. Sowing is carried out crosswise, that is in one direction first and then at right angles to this, thus ensuring a fairly even distribution of the seed. After sowing, the land is harrowed and then laddered so that the seed is covered and comes in close contact with the moist soil, which helps germination. In order to ensure uniform germination the seed should remain 1 to 1-1/2 inches below the surface of the soil.

Intercultural Operations

If seeds with a germination percentage of about 80 are sown, there are about 1,089,000 potential plants per acre whereas the final population harvested in an acre usually ranges from 100,000 to 200,000. The seed-rate of jute, therefore, is very high. Although it is possible to raise a good crop of jute with much lower seed-rates under favourable conditions, this high seed-rate is considered necessary for the following reasons :

(*i*) The germinating seedling is very delicate and often cannot singly break through the soil crust that may form when there is rain soon after sowing and therefore requires the help of other seedlings for emergence. (*ii*) Till the regular monsoon sets in sometime in June, the young crop is often subjected to long periods of drought as the 'norwester' showers, on which it depends, are irregular and in the event of mortality of seedlings during drought adequate population is ensured. (*iii*) The thick stand in the initial stages also helps to check the growth of weeds.

During the first two months of

crop growth a large number of plants have to be thinned out gradually. When the plants are about 3 to 9 inches high, they are thinned out by a hand rake (*bida* or *anchra*) drawn over the land. This operation may be repeated twice.

Weeding is an important step in jute cultivation. Jute fields should be kept free from weeds. After the initial thinning with a rake, the crop is weeded with a hand-weeder (*khurpi*) two or three times; weeding is also accompanied by thinning. The plants should be thinned so as to leave a space of about 4 inches between them. With more spacing the height and thickness of the plants increases; with too much spacing, however, the plants tend to branch, which is not desirable.

Growing as a Row Crop

Jute responds very favourably to interculturing which should be carried out in time. If this is neglected, the crop will not grow properly, the outturn of fibre will be much less and the crop may even fail. Interculture alone accounts for 40 to 50 per cent of the total cost of production of fibre. Weeding and thinning have to be carried out very expeditiously within short periods. During this period, the supply of labour is inadequate, and for this reason interculture is not often done satisfactorily. Sowing jute in rows and interculturing by hand-hoe have given very satisfactory results. By this method seed rate is reduced by about 50 per cent; more uniformity in the growth of crop is ensured and the cost of weeding and thinning is cut down by about 60 per cent. In line-sown crop, the yield of fibre in *capsularis* is increased by about 18 per cent and in *olitorius* by 16 per cent over the broadcast crops.

Young jute crop being hand-hoed.

Hand-pushed seed-drill in operation.

In trials carried out from 1948 to 1951 at the J. A. R. I. seeds were hand-dibbled in lines and interculture was given by hand-hoes. By 1952, however, a continuous sowing hand-pushed jute seed-drill to suit the growers with small holdings was evolved by the Jute Agricultural Research Institute in collaboration with a local engineering firm and tried out. As the sowing by this drill was continuous, the different spacings used within the line were adjusted at the time of thinning. Among the different spacings tried, a spacing of 12 inches between the lines and 2 to 3 inches between plants in the lines gave comparatively higher yields though the various spacings, 1", 2", 3" and 4" between plants within the lines were not statistically different.

Rotational Cropping

Jute, planted for fibre production, occupies the land only for about four months and it is possible to raise a second or sometimes even a third crop other than jute in the same year. Such a programme of double or triple cropping is possible in low and midlands where rains start early or where irrigation facilities exist. In such areas, *capsularis* jute is sown early and after the harvest of jute, a crop of transplanted paddy often followed by a third crop of pulses can be raised. In high lands where sowings are late, the land is usually cropped with late varieties of jute, generally *olitorius*, which is followed by a crop of potato or pulses. Being a bast fibre crop which can be harvested at any stage without complete loss of yield, jute offers an advantage over grain crops which can be harvested only after the maturity of grain. Hence in a programme of cropping paddy lands with jute as an early crop, the transplantation of paddy, the time for which is fixed for each area, need not be delayed for the maturity of the jute crop.

Harvesting

Jute crop may be harvested at any time before it is dead ripe, but harvesting is not usually done before the flowering stage. In areas subjected to flooding, the crop may have to be harvested sometimes even before the appearance of flower buds for fear of its complete destruction by early flood. Since the plants are immature at this stage, the yield of fibre is low.

The ideal stage of harvest is when the plants are in small pods. In most places, except in the flooded areas, jute is harvested at this stage, when both yield and quality are found to be good. If harvested earlier, the yield is lower and if harvested when the pods are fully mature, the yield of fibre is slightly higher, but the quality suffers.

The plants are cut close to the ground with a sickle. In flooded areas, particularly in many parts of Assam and Eastern Pakistan where the flood water rises very high, the workers have to dive under water and cut each time six to eight plants. In many low-lying areas where the crop remains two to four feet in water at the time of harvest, plants are pulled out and the root portions are usually cut out before steeping.

In high lands, the harvested plants are left in groups at different places of the farm for two to four days, when most of the leaves get dried. After this period the plants are tied into bundles of about six to nine inches in diameter. At the time of bundling, the plants are shaken when most of the leaves fall off. In many places the harvested plants are immediately made into bundles and are laid on the ground in long narrow lines so that the leafy tops of one set of bundles cover the bare lower portions of the stems of another set. After two to four days the leaves fall and the bundles are steeped in water. During the period of two to four days the tissues shrink and the cells rupture. This facilitates the entry of micro-organisms into the stems, when steeped in water. In low lands where jute plants may be standing in water, steeping is carried out immediately after cutting.

Retting and Extraction of Fibre

The tied bundles of jute stems are taken to the nearest pool or ditch for retting. The bundles are laid flat in water at least two to three feet in depth and arranged side by side so as to form a regular platform. The layer of bundles sinks partly by its own weight. If the water is deep enough it may be possible to have a second layer or even a third layer of bundles over the first and at right angles to it. The top layer is covered with weeds or other refuse and it is

Jute being harvested.

Stripping and washing of retted jute.

submerged by weighting it down with logs, banana stems or clods of earth. When nothing else is available cultivators use only clods of earth, which discolour the fibre and thus lower the quality.

Retting is a process by which the fibres in the bark get loosened and separated from the woody stalk due to the removal of pectins, gums and other mucilaginous substances. This is usually effected by the combined action of water and micro-organisms. Use of different substances for stimulating the growth of micro-organisms responsible for retting has shown encouraging results.

In retting, when the top portions are retted, the thick lower portions still remain unretted. If the lower portions are allowed to ret properly, the top portions become over-retted. To ensure uniform retting of the whole plant, bundles of stems should be placed upright in about two feet of water initially for two to three days before they are completely steeped in water. The retting process completes itself in 8 to 30 days. The time required for retting depends upon several factors, like the maturity of the plants, temperature and other conditions of the water in which they are steeped, etc. In the earlier part of the retting season, about the end of July when the temperature of the water is about 85°F, the process may take only 8 to 10 days but as the season advances and the water becomes comparatively colder, a longer period is required, which may be three to five weeks after the end of September. When the period of retting is prolonged, the fibre becomes dazed and weak.

The correct stage when retting is complete can only be judged by experience. Considerable care and close watching are necessary to determine this stage. When retting is complete, fibre must be extracted as quickly as possible.

The methods of stripping as followed in India and Pakistan are as follows: The worker stands two to three feet deep in water and takes up in one hand a handful (six to ten) of the retted stems and beats the bark round the base of the stems gently with a wooden or bamboo mallet in the other hand. The fibres at the bottom are thereby loosened. He then breaks the woody core about one to two feet from the base. With slight jerks the piece of broken stems from the base are taken out and thrown on dry ground. The loosened fibre is grasped in hand and the remaining portions of the retted stem are jerked, backward and forward in water, thereby separating the fibre from the woody portion,. Taking a bundle of the steeped fibre, the labourer lashes it on the surface of the water and again pulls it towards himself by a few sharp jerking motions which rid the fibre of the adhering bits of wooden pieces. Finally he spreads out the clean fibre on the surface of water and picks up any bits, if still adhering, by hand. Water is then wrung out of the fibres. The clean fibres are dried in the sun over a bamboo frame (dry rack) for two or three days and then tied into bundles for the market. During drying, the fibre is also bleached by the sun. A labourer can strip 40 lb. of dry fibre per day working for about six to seven hours. A highly skilled labourer can, however, strip up to 80 lb. of dry fibre during the same period.

In many districts of East Bengal (Eastern Pakistan) and Assam (India) retted stems are stripped singly. Fibre obtained by this practice is usually better than that obtained by bundle-method of extraction.

Fibre Yield

The yield of jute fibre depends upon a number of factors like fertility of the soil, the variety, care of the crop and the stage of harvest. Besides. the season and incidence of diseases and pests also affect the yield of fibre.

The fibre content of the plant is an important factor influencing the yield. It generally ranges between 4.5 and 7.5 per cent of the green weight with an average of about 5.5 per cent.

There is a common saying among Bengali cultivators that the yield of a crop is at the rate of one maund (1 md.=82.29 lb.) per *bigha* (one-third of an acre) per *hat* (1-1/2 feet) of the crop. This is a rough estimate for small crops and is equivalent to saying that the yield in maunds per acre is equal to twice the height of the crop in feet. Although this approximation is more or less true, higher yields may be obtained when the average height of the crop exceeds 8 feet. On well cultivated and manured land an out-turn per acre of 30 maunds of fibre or more may be expected. Normal average yield per acre is estimated to be about 13 to 14 maunds in India and about 16 maunds in Pakistan. In India, the yield is about 14 maunds per acre in Assam and 14.5 maunds in West Bengal, while in Bihar, Orissa and Uttar Pradesh it is about 10 maunds.

Diseases

Jute crop suffers from various diseases affecting the yield and quality of fibre. Fungi causing important diseases are *Macrophomina phaseoli* (Maubl.) Ashby, *Pellicularia rolfsii* (Sacc.) West and *Diplodia corchori* Syd. Besides these, a number of other fungi attack jute plants at various stages of growth and cause minor damage to the crop. *Macrophomina phaseoli* attacks the jute plant at all stages of growth and is the cause of the most serious and widely prevalent disease of the crop. According to the part of the plant attacked and the nature of attack, terms like seedling-blight, stem-rot, collar-rot are used to denote the diseases. When the seedlings are attacked, necrotic lesions are formed on the hypocotyl, on the collar or on the cotyledonary leaves. Under wet conditions such seedlings damp off and the condition is known as seedling-blight. Attack at collar regions is termed collar-rot and plants suffering from collar-rot often die. The tap-root of the plant is also affected directly by the fungus remaining in the soil and the disease is then called root-rot. Plants affected by root-rot wilt and gradually die. Capsules are also sometimes attacked resulting in discoloration. The infected capsule may split open, in which case the fungus enters inside and infects the seeds. Diseased seeds are lighter and paler in colour; dormant mycelia of the fungus or sclerotia remain within the seed or the seed-coat. The pathogen is seed-borne as well as soil-borne. The over-wintering phase is mainly sclerotial. Sclerotia are found almost on all the diseased parts, namely stubbles, stems, pods and seeds. Pycnidia are formed usually on leaves and sometimes on the stems and form the source of heavy secondary infection.

Soft-rot is caused by the fungus *Pellicularia rolfsii* (Sacc.) West (*Sclerotium rolfsii*) which is mainly soil-borne. Usually it starts growth on decaying jute leaves on the ground in the months of July and August. Infection starts in the stem at ground level. The stem turns brown and is often covered with white mycelia. At later stages, brown mustard like sclerotia are formed on the affected portions, from where the fibre layers shred and as a result the plants lodge. In all cases of attack, the plants are ultimately killed. The only practical remedial measure is to remove the old decaying leaves from which the infection starts. Cases of attack through air-borne basidiospores are also known

Black-band disease is caused by *Diplodia corchori* (Syd.) and is usually prevalent during the middle of July. Attacked plants wilt and are completely defoliated. Pycnidia develop all over the stem, which appears black due to the development of sooty spore masses in abundance. It has been observed that it usually attacks weak plants or plants weakened or damaged by other agencies.

Recently it has been found that a species of *Colletotrichum* attacks jute causing *Anthracnose* disease. *capsularis* is more susceptible than *olitorius*, while several types of the former species are fairly resistant. The disease starts in the hot humid days of late July and is most widespread during late August. Initially, small brownish black spots appear on the stem which in course of time coalesce together forming cankerous tissues. The stem usually breaks when such tissues yield to the weight of the crown or strong wind.

Other minor diseases are, mildew, caused by *Oidium* spp. and leaf spots, caused by *Cercospora* spp. *Phyllosticta* spp. and *Phomopsis* spp. also cause oval necrotic lesions on the stem without seriously affecting the fibre layer.

Chlorosis in Jute : Finlow first observed the yellow and light-yellow patches on the leaf surface leading to variegated appearance and applied the term *chlorosis* to describe the phenomenon. Investigations were started in 1917 and continued for a number of years. In 1918 it was reported that only two cultures were immune to *chlorosis*. In 1939, Finlow while reviewing the work on jute referred to *chlorosis* as a 'morphological imperfection' and suggested that serious attention should be given to the study of this phenomenon. Work on this aspect has been started at the Jute Agricultural Research

Institute. It has been found that plants may be chlorotic from the very early stages or may become chlorotic later at any time during the vegetative period of the plant. In mild form the imperfection is not directly harmful, but in severe cases the leaves become crinkled and brittle and growth is checked. It has been observed that *olitorius* is less affected by *chlorosis*.

The problem appears to be highly complicated and work on this phenomenon is being carried out in two directions to investigate its nature, i.e. (a) whether it is a virus disease transmitted through pollen or seed and/or (b) if it is a genetical phenomenon. Some workers have reported that *chlorosis* may be caused by a virus. True breeding chlorotic cultures have also been established and crosses have been made between chlorotic and non-chlorotic plants in both the directions. The seed germination in crosses was good and all the F_1 progenies were chlorotic. Back-crosses involving both the chlorotic and the non-chlorotic parents have been obtained. A small proportion of the F_2 progenies of the crosses are normal in the early stages but with the approach of maturity, these also turn chlorotic.

Diseases caused by Nematodes

Corchorus olitorius has been mentioned as a host for the root-rot nematode, *Heterodera merioni* (Corusi) Goodey, in the list of hosts compiled by the Imperial Bureau of Agricultural Parasitology, 1931. The author of this article was the first to describe nematode attack in both the cultivated species of jute in 1946. He observed that numerous root-galls are found in the infected plants. Comparatively less damage is done to the crop when the population of nematodes in the soil is low. In extreme cases of attack, the plants remain stunted, the development of leaves is poor; leaves may also get etiolated and all the plants may even die before flowering. Brinjal is an important alternate host. Repeated cultivation of jute in the affected field increases the extent of attack. Infection by nematodes appears to be on the increase in recent years.

Pests

During all the stages of growth, right from the seedling stage, jute crop is liable to suffer damage and loss by various insect and mite pests. All parts of the plant are subject to attack and yield as well as quality are affected. Of the pests causing heavy damage the following may be mentioned:

Anomis sabulifera (jute semi-looper) is very widely spread. The caterpillar of the pest causes damage to the crop. It has a green body with yellow head and a semi-looping mode of locomotion. It attacks the crop when it is about three feet high and ravages it for two months. DDT and BHC are effectively used for control.

Diacrisia oblique (hairy caterpillar) also occurs abundantly. The full-grown caterpillar is very hairy and has an orange coloured body with both the ends black. The young caterpillar eats the softer leaf tissues leaving only the upper epidermis and skeleton of the leaf, while the old ones devour the entire leaf. Though they usually cause damage to the older leaf, in severe attacks the plants may be entirely defoliated. DDT and BHC are also effectively used for control.

Jute mites are minute leaf sucking organisms and are of two types: (*i*) white mite (*Hemitarsonemus latus*) and (*ii*) red mite (*Tetranychus bioculatus*). White mites are more widespread in the early part of the season and occur in the mid and high land areas while red mites are less common and are met with in the later part of the season, mainly in the low lying areas. Mites damage the crop by sucking the sap from the leaves which get discoloured and drop off prematurely. The growth is stunted and as a result yield is affected. Two dustings of lime-sulphur in the ratio of 3:1 at an interval of 24 hours, effectively control the pest.

Apion corchori (jute apion) is also a very common pest widely distributed throughout the jute growing areas. It causes damage to the crop at all the stages of growth. The insects puncture the apical parts of the stem at the base of the petiole and lay eggs singly in the holes. It is the grub of the insect which causes damage. The attached plant can be recognized by the withered and drooping tops and leaves. DDT and BHC are often used to prevent egg laying by the pest.

Laphygma exigua (indigo caterpillar) is an important pest of seedling jute. Caterpillars of the pest cause damage to the young leaves. They are gregarious during the early part of their life and at this stage are more destructive to the seedling jute. BHC and DDT are effective for control.

Nupserha bicolor spp. *postbrunnea* is an important pest of *olitorius* jute, while all the *capsularis* varieties have been found to be completely resistant. Egg laying female has been found to be responsible for damaging the crop. It cuts the stem about 16 cm. below the apex in two parallel rings 1.5 to 2.0 cm. apart, and lays the eggs inside the inter space. The portion above the upper cut soon dries up and dies. Plants with height ranging from 100 cm. to 200 cm. seem to suffer more from damage than others. Yield is much decreased as a result of such attack. DDT has been found to be a useful preventive.

Quality of Jute

The quality of jute is usually judged by its suitability for the production of various types of yarns and its behaviour in the manufacturing process. The fibre which spins into the finest yarn is considered to be of the best quality. Indian jute mills have been the biggest consumers of the jute produced in India and they have always exercised a very great influence over the raw jute trade. These mills, on the basis of their requirements of jute for the production of either hessian cloth or sacking bags, have fixed certain standards about the quality of raw jute.

In judging the quality of fibre the following characters are usually assessed: (i) length, (ii) strength, (iii) colour, (iv) lusture, (v) percentage and quality of cutting, (vi) proportion of faults, such as, roots, specks, knots, runners, hard crop, etc. and (vii) such general qualities as, fineness, stiffness and hardness. Of the above characters colour, lustre and strength are usually considered very important by the mills. A fibre having good length and strength, high colour and lustre, free of any fault and with smallest percentage of 'cutting' is regarded good quality fibre. The length of the fibre depends on the growing conditions. If climatic conditions are favourable and the fields are properly manured, a good length of fibre can be expected. It may, however, be said that it is difficult to get fibre of ideal quality except in certain areas where proper natural conditions for jute production exist.

Of the various characters used for evaluating the quality of jute fibre, the strength of the fibre is the most important and it is estimated as the breaking load in 1 lb. of unit length of fibre. The quality ratio (Q. R.) is the strength of the yarn in lb. multiplied by 100 and divided by its grist (weight in lb. of 14,000 yds. of yarn). Other characters which are usefully employed in determining fibre quality are the uniformity and the slipperiness of the yarn. The differences in the quality of fibre are generally associated with difference in the average length of the filament during the processing and with the increase in the mean length of the filament, mass of unit length of the filament increases. Work at the Technological Research Laboratories of the Indian Central Jute Committee has shown that fibre that feels heavier in the hand tends to have a higher spinning quality. Though this apparent density of fibre cannot normally be expected to be very closely correlated with the spinning quality when considered alone, it is found to be a very useful criterion when used in conjunction with other fibre characters like fineness, strength, etc. *Olitorius*, in general, has a higher apparent density than *capsularis*. The higher oil absorbancy of *capsularis* fibre when immersed in light mineral oils suggests that it has bigger pore spaces or bigger surface areas or both as compared to the fibre of *olitorius*.

The most important factor on which quality mainly depends, is 'retting'. In such areas where good and abundant retting water is available, fibre quality is expected to be better. Apart from the quality and quantity of retting water, the retting technique that is followed also influences the quality. It has been found that suitable selection of covering material, size of jute bundles, volume of water in the retting tank or ditch, depth of the 'jaks' (layers of jute bundles) below the surface of water, all play their role in determining the quality of fibre.

The fibre from tall and thick plants is generally inferior to that from short and thin plants. This is due to the fact that in thick and tall plants, by the time the thicker end of the stem has retted completely, the thinner end becomes over-retted and consequently the fibre from the upper portion of the stem becomes weak and dazed. Generally thick and tall plants are obtained from late maturing varieties. By the time the late varieties mature, there may be shortage of retting water and steeping ditches may have been over-worked. This adds to the contrast in the colour of the fibre, the fibre of early varieties being usually free from discoloration.

Besides retting, other factors like variety, cultivation practices, diseases and pests, climatic conditions etc., have influence on the quality of jute. Such 'mechanical' conditions as the presence of excess of dirt, moisture and other faults also determine the quality. Factors responsible for improved quality of jute fibre fall mainly under two heads, (*a*) non-controllable factors like environmental conditions, particularly soil and climate, and amount and quality of retting water available, and (b) controllable factors like variety, improved methods of cultivation, stage of harvest and methods of retting and extraction.

Of all the textile fibres jute exhibits the largest variation in colour. The colour of *capsularis* fibre varies from pale cream to dull grey to brown and dull grey black. A good colour is often regarded as a criterion for good quality. It is known that from areas where retting is done in clearer and slow-running water (the river Brahmaputra and its tributaries being the source) comes fibre of better colour than that from areas where retting water is muddy (source being the river Ganges and its tributaries). The stems and leaves of jute plants contain a certain amount of tannin. When the plants are retted in muddy water usually containing iron, the tannin from jute plants in combination with the iron of the retting water forms the dark colour of jute. Dull grey black or 'shyamla' colour of *olitorius* jute is considered to be due to the greater tannin content of the plants. Although dark coloured fibre is considered as of low quality, technological tests have, however, proved that these fibres, if properly retted and extracted have a good spinning quality.

Increased Production in India

At the time of partition of India in 1947 Indian Union produced only 16.58 lakh bales of raw jute. This quantity was quite insufficient to meet the requirements of Indian jute mills which was about 60 lakh bales. The shortage was, however, met by imports from Pakistan. With the idea of being self-sufficient in raw jute a programme of gradual increased production of jute was taken up by the Government of India during the Five-Year Plan periods. The production has gradually increased to 62.69 lakh bales in 1961-62. It is now estimated that by the end of the Fourth Five-Year Plan period our requirement of raw jute will rise to 100 lakh bales. It is possible to achieve this target of 100 lakh bales without further increase in acreage by adopting intensive methods of cultivation, by the use of improved seeds, growing jute as a row crop, by judicious application of manures and fertilizers and by adopting proper plant protection measures.

In spite of the increase in the area and output of jute since the partition of India the production of good quality jute has been, however, confined to limited areas. An Expert Committee was set up by the Government in 1953 to make recommendations on the improvement of quality of Indian jute. The Committee suggested, amongst others, the use of seeds of improved strains, improved methods of cultivation, improved retting technique and proper plant protection measures. The Committee was also of the opinion that more attention should be paid to increase the per acre production in areas where good quality jute is produced, without going in for an increase in the acreage in such areas where the quality is definitely poor. This procedure has been followed in the jute development programme of the Government of India.

Jute in other Countries

Almost all the world's jute is grown in the Indian sub-continent where the main jute producing tracts are in north-east India and East Bengal; the latter is now a part of Pakistan. Outside India and Pakistan jute is under cultivation in Nepal, Formosa, China and Japan for a long time. Continued attempts have been made for developing jute cultivation in other countries also, particularly in Nigeria, Gambia, Uganda, Nyasaland (now called Malawi), Sudan, U.A.R. Turkey, Iran, Thailand, Indonesia, Paraguay, *Brazil, Argentina, Mexico and the* U.S.S.R. Of all the countries the cultivation in Brazil has been the most successful.

The acreage, production and yield per acre of jute in different jute growing States in India are given in Table I and the figures for the whole world in Table II.

TABLE I

ACREAGE, PRODUCTION AND YIELD OF JUTE PER ACRE IN INDIAN UNION.

State	Acreage in '000 acres						
	1947-48	1951-52	1952-53	1953-54	1954-55	1955-56	1961-62
West Bengal ...	266	876	836	535	551	616	1,144
Assam ...	209	334	317	257	282	371	363
Bihar ...	144	487	460	303	270	279	565
Orissa ...	22	161	117	59	87	105	114
U. P. ...	—	68	80	27	34	34	38
Tripura ...	11	25	24	15	19	20	35
Total (India) ...	652	1,951	1,834	1,196	1,243	1,425	2,259
	Production in lac bales (bale=400 lb).						
West Bengal ...	6.49	23.31	24.13	14.98	14.96	19.58	33.52
Assam ...	5.36	8.40	9.25	8.07	7.50	12.12	11.31
Bihar ...	4.03	9.56	8.79	6.01	3.74	5.88	12.63
Orissa ...	0.44	3.87	2.56	1.29	1.92	2.45	3.04
U. P. ...	—	1.03	1.64	0.56	0.70	0.86	1.14
Tripura ...	0.26	0.61	0.58	0.38	0.46	0.48	1.05
Total (India) ...	16.58	46.78	46.95	31.29	29.28	41.37	62.69
	Yield per acre in maunds (1 md. = 82 lb. app.)						
West Bengal ...	11.90	12.97	14.10	13.66	13.22	15.51	
Assam ...	12.49	12.24	14.24	15.32	12.97	15.95	
Bihar ...	13.66	9.56	9.32	9.66	6.78	10.29	
Orissa ...	9.76	11.71	10.68	10.68	10.78	11.36	
U. P. ...	—	7.37	10.00	10.10	10.05	12.34	
Tripura ...	11.51	11.90	11.80	12.34	11.80	11.71	

TABLE II

WORLD ACREAGE, PRODUCTION AND YIELD OF JUTE PER ACRE.

Countries	1934 to 1938	% on Total	1947 to 1948	% on Total	1953	% on Total	1954	% on Total
	Area in thousand acres							
India ...	862.38	28.72	652.00	23.67	1,196.00	53.60	1,243.00	48.37
Pakistan ...	2,115.18	70.45	2,059.00	74.74	966.16	43.30	1,242.91	48.36
Formosa ...	14.83	0.50	7.00	0.25	17.30	0.78	27.18	1.06
Brazil ...	—	—	12.00	0.43	49.42	2.21	54.36	2.12
Others* ...	9.88	0.33	25.00	0.91	2.47	0.11	2.47	0.09
Total (World) ...	3,002.27	100.00	2,755.00	100.00	2,231.35	100·00	2,569.92	100.00
	Production in lac bales (bale=400 lb.)							
India ...	19.01	22.62	16.58	19.25	31.29	45.00	29.28	37.25
Pakistan ...	63.59	75.67	68.37	79.38	36.09	51.89	46.62	59.36
Formosa ...	0.61	0.72	0.11	0.13	0.28	0.40	0.72	0.92
Brazil ...	—	—	0.34	0.39	1.16	1.67	1.27	1.62
Others* ...	0.83	0.99	0.73	0.85	0.72	1.04	0.67	0.85
Total (World) ...	84.04	100.00	86.13	100.00	69.54	100.00	78.56	100.00
	Yield per acre in maunds							
India ...	10.7		12.4		12.8		11.4	
Pakistan ...	14.7		16.2		18.2		18.3	
Formosa ...	19.9		7.7		7.8		12.9	
Brazil ...	—		13.8		11.4		11.4	
Others* ...	—		14.24		—		—	

*Include Nepal, Japan, Iran and Thailand.