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Genetic diversity in jute (*Corchorus* spp) and its utilization: a review

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ABSTRACT

Natural fibres of commercial importance are obtained from the bark of two jute species (*Corchorus capsularis* L. and *C. olitorius* L.), and they are cultivated in different south-east Asian countries including India and Bangladesh. High-yielding varieties of both species evolved around a very narrow genetic base, supported by pedigree relationship, morphological analysis including distinctness, uniformity and stability (DUS) testing and molecular marker analysis. A number of microsatellite markers developed recently has shown sufficient transferability between these two species and effectiveness in elucidating polymorphism. Molecular analysis of germplasm and released elite varieties using different marker systems indicated more narrowness of *C. capsularis* as compared to *C. olitorius*. The differentiation and separation of both species in the evolutionary pathway may not be recent, although cultivation for fibre use has a short history. Intra-specific hybridization utilizing diverse genotypes and inter-specific hybridization between *C. capsularis*/ *C. olitorius* and wild species having quality fibre characteristics and resistance to biotic and abiotic stresses should be emphasized to widen the narrow genetic base of both species.

Key words: *Corchorus,* Diversity, Germplasm, Hybridization, Inter-specific, Jute, Microsatellite, Molecular marker

Jute comprises two cultivated species of the genus *Corchorus,* viz *C. capsularis* L. and *C. olitorius* L. Roxburg during the last part of 18th century, identified jute (*Corchorus* spp; 2*n* = 2*x* = 14) as an alternative to European hemp (*Cannabis sativa* L.) (Ghosh 1983). The cultivation of jute dated back about 200 years ago in the tropics having high rainfall and availability of retting water. As jute was domesticated recently, many mutants have not yet been accumulated in endemic *Corchorus* population resulting from little human selection pressure in course of evolutionary history. Both cultivated species are distinguished by growth habitat, branching habit and leaf, flower, fruit, seed, bast fibre characteristics and photosensitivity. However, they are characterized by narrow genetic variability for adaptability to not only various agronomic environments, but also fibre yield, quality and susceptibility to diseases and pests.

In Indian subcontinent, jute is the second most important natural fibre crop after cotton (*Gossypium hirsutum* L. and *G. arboreum* L.). For manufacturing diversified value-added industrial products and packaging materials, jute has a great potential. It is largely a self-pollinated crop, however, its natural genetic variability is very narrow making it difficult for the plant breeders to develop new varieties through conventional breeding. In this context, it is to be noted that plant breeding essentially leads to qualitative rather than quantitative shifts in registered cultivars. Besides, germplasm collections are required to be optimized for maximal redundancy with regard to genotypes, gene complexes or possibly even genes.

In view of above considerations, jute breeders have become more aware of the needs of maintaining genetic diversity among varieties and improving the management of genetic resources through the conservation of traditional land races and germplasm. These populations exist with high genetic variability and fitness to the natural and anthropological environments where they have been originated and domesticated (Brandolini 1969). They represent not only a valuable source of potentially useful traits, such as resistance or tolerance to biotic and abiotic stresses, but also an irreplaceable repository of highly co-adapted genotypes. However, this crop demands the immediate attention of plant breeders. The available elite cultivars are essentially derived either through pure line selection or hybridization, followed by selection from a few common accessions. Earlier reports indicated that limited success was obtained in crossing between two cultivated jute species, possibly because of the presence of a strong sexual incompatibility barrier (Patel and

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Datta 1960, Swaminathan *et al.* 1961). Therefore, valuable genetic variability from diverse germplasm sources either at intra- or inter-specific levels should be utilized.

GENETIC DIVERSITY ANALYSIS IN JUTE

Germplasm status

The Indian Council of Agricultural Research, New Delhi has been maintaining more than 1 450 *C. olitorius* and about 830 *C. capsularis* accessions of the International Jute Organization (IJO) since 1993 (Palit *et al*. 1996). In Bangladesh, the largest gene bank of jute and allied fibres (JAFs) is being maintained at Bangladesh Jute Research Institute (BJRI), with 5 936 accessions comprising 15 species of *Corchorus,* 22 species of *Hibiscus* and 15 of allied genera, yet to be characterized (Haque 2007). In India, during 1999–2004, 655 accessions including land races and wild relatives were collected from different agro-ecological regions. Presently, CRIJAF is maintaining 939 accessions of *C. capsularis*, 1 647 accessions of *C. olitorius* and 313 wild species covering eight species (Mahapatra and Saha 2008).

Morphological analysis

A broad approach using phenotypic and molecular markers is required to analyze diversity and to support conservation, management and development of plant genetic resources (Hammer *et al*. 1999). Phenotypic markers are of great value in studies of crop evolution (Gepts P 1993), germplasm evaluation (eg Bretting and Wildrlechner 1995) and in revealing differences between varieties (Gilliland *et al.* 2000). Estimation of genetic diversity and genetic advance of 192 *C. olitorius* and 216 *C. capsularis* accessions of IJO, inclusive of certain induced mutants of Indian cultivars has been reported (Palit *et al*. 1996). This estimation was based on 4 morpho-physiological attributes, such as plant height, harvest index, cambial activity and fibre strength that are related to yield characters. Because estimations of genetic variability based on morphological traits have the disadvantages of being influenced by both environmental and genetic factors, morphological analysis may not provide proper estimation of genetic diversity.

Varietal development in India

Efforts for varietal development in jute were initiated in the early part of twentieth century. *C. olitorius* cv 'Chinsurah Green' and *C. capsularis* cv 'Dhaka 154' (D 154) were released during 1915 and 1919, respectively, through pure line selection (Patel and Ghosh 1940). Till date 27 improved jute varieties (14 in *C. olitorius* and 13 in *C. capsularis*) have been developed in India. The details of these varieties are given in Tables 1, 2. Plant height and base diameter were identified as the two major criteria for selection as these traits are highly correlated with fibre yield (Kundu *et al*. 1959). Development of *C. capsularis* (white jute) cvs 'JRC 321' and 'JRC 212' and *C. olitorius* (tossa jute) cv 'JRO 632' increased the fibre yield from 1.0 to 1.25 tonnes/ha during the sixties (Saha and Hazra 2008). White jute varieties occupied more than 80% of the jute growing areas till early seventies because they were found suitable for mid-March to mid-April sowing and thus fit for the rice-based multiple cropping sequences. Tossa jute cv 'JRO 632', despite being higher yielder, suffered from pre-matured flowering when sown earlier. Subsequently, tossa jute cvs 'JRO 878', 'JRO 7835' and 'JRO 524' resistant to pre-mature flowering were released in 1967, 1971 and 1977, respectively after successfully transferring the early flowering resistance gene from an exotic germplasm 'Sudan Green' to Indian elite cvs 'JRO 620' and 'JRO 632'. This resulted in a paradigm shift in jute agriculture as the entire jute growing area of the country was taken over by the tossa jute. These *olitorius* varieties, particularly 'JRO 524', enabled jute to be fitted in the multiple cropping sequences with transplanted *Aman* paddy mainly because of their shorter duration (120 days) and suitability for mid-March sowing (Das and Maiti 1998). Now a series of new *olitorius* varieties, like 'JRO 66', 'JRO 8432', 'JRO 128', 'S 19' and *capsularis* varieties, viz 'JRC 698', 'JRC 80' are available for cultivation. These varieties have wider adaptability to varied agro-climatic situations and were responsible for the quantum jump realized in average fibre yield (2.3 tonnes/ha) at national level. Besides *olitorius* varieties 'JBO 2003-H', 'JRO 204' and 'AUOJ-1' with higher yield and better fibre quality were released for cultivation in the tossa jute belts. The characteristic features of improved jute varieties are well-documented (Kundu *et al*. 1959, Ghosh 1983, Basak 1993, Chaudhury *et al*. 2004, Karmakar *et al*. 2008).

The genetic base of elite jute varieties is quite narrow. The 14 *olitorius* and 13 *capsularis* varieties released till date have been developed from 14 and 24 parental accessions, respectively, which make the varieties susceptible to various biotic and abiotic stresses. However, CRIJAF has a collection of 2 899 germplasm accessions belonging to jute only. Many of the germplasm possess desirable traits of tolerance to biotic and abiotic stresses as well as improved fibre quality like fineness, strength, etc. The germplasm available in CRIJAF Gene Bank are in the process of rigorous multi-location field screening, and are being used in the breeding programme to develop suitable jute varieties with desirable agronomic traits.

Pedigree relationship among released varieties

Pedigree relationship of 14 *olitorius* varieties released so far in India shows narrow genetic base utilized in developing these varieties. One variety was developed by pureline selection ('JRO 632'), 12 by hybridization, followed by selection and one by mutation breeding (Fig 1). The two exotic introductions, 'Sudan Green' and 'Tanganyika 1' were one of the parents for developing 5 varieties each including

Table 1 Details of released varieties of tossa jute (*Corchorus olitorius* L.) in India

Variety	Developing institute	Year of release	Parentage	Stem and foliage colour	Pod shattering and seed coat colour	Salient features	Days to 50% flower (days)	Seed to seed maturity (days)	Optimum sowing time	Fibre yield (tonnes /ha)
'JRO 632' ('Baisakhi Tossa')	CRIJAF, Barrackpore, West Bengal	1954	Selection from indigenous type	Full green	Dehiscent on maturity, brownish-grey	Susceptible to premature flowering if sown before mid-April, suitable for late sowing	130–140	220–240	Mid April to end April	3.0–3.2
'JRO 878' ('Chaitali Tossa')	CRIJAF, Barrackpore, West Bengal	1967	'JRO 620' ×'Sudan Green'	Red	Non-dehiscent on maturity, blackish-grey	Resistant to premature flowering on mid-March sowing, better fibre fineness	180–200	260–280	Mid March to end April	3.0–3.2
'JRO 7835' ('Basudev')	CRIJAF, Barrackpore, West Bengal	1971	'JRO 632' ×'Sudan Green'	Full green	Non-dehiscent on maturity, blackish-grey	Resistant to premature sowing, flowering on mid-March waterlogging tolerance at late growth stage	180–200	260–280	End April Mid March to end April	3.2–3.4
'JRO 524' ('Navin')	CRIJAF, Barrackpore, West Bengal	1977	'Sudan Green' × 'JRO 632'	Full green	Non-dehiscent on maturity, blackish grey	Resistant to premature flowering on mid-March sowing, resistant to root rot and yellow mite, better retting and easy fibre extraction	180–200	260–280	Mid March to end April	3.4–3.6
'TJ 40' ('Mahadev')	BARC, Trombay, Maharashtra	1983	Selection from inter-mutant from cross	Full green	Dehiscent on maturity, brownish-grey	Susceptible to premature flowering if sown before mid-April, better fibre quality	140–150	220–240	Mid April to end April	3.0–3.5
'JRO 3690' ('Savitri')	CRIJAF, Barrackpore, West Bengal	1985	Tobacco leaf Long inter-node	Full green	Dehiscent on maturity, steel-grey	Susceptible to premature flowering if sown before mid-April, better fibre quality, suitable for late sowing	130–140	220–240 ×	Mid April to end April	3.0–33
'KOM 62' ('Rebati')	Jute Research Station, Kendrapara, Orissa	1992	Gamma-ray derivative of 'JRO 878'	Full green	Blackish grey, non-dehiscent on maturity	Susceptible to premature flowering if sown before mid-April, suitable for early sowing	135–145	240–250	Mid March to late April	3.0–3.5
'JRO 66' ('Golden Jubilee Tossa')	CRIJAF, Barrackpore, West Bengal	1998	Multiple crosses involving six parents	Full green	Steel-grey, non-dehiscent on maturity	Susceptible to premature flowering if sown before mid-April, fibre quality TD2 grade	145–155	240–250	Mid April	3.5–4.0

(*Continued*)

(*Table 1 concluded...*)

Variety	Developing institute	Year of release	Parentage	Stem and foliage colour	Pod shattering and seed coat colour	Salient features	Days to 50% flower (days)	Seed to seed maturity (days)	Optimum sowing time	Fibre yield (tonnes /ha)
'JRO 8432' ('Shakti')	CRIJAF, Barrackpore, West Bengal	1999	'IC 15901' × 'Tanganyika I'	Full green	Steel-grey, non-dehiscent on maturity	Resistant to premature flowering on mid-March sowing	170–180	260–270	Mid March to late April	3.5–4.0
'JRO 128' ('Surya')	CRIJAF, Barrackpore, West Bengal	2002	'TJ 6' × 'Tanganyika I'	Full green	Steel-grey, non-dehiscent on maturity	Resistant to premature flowering on mid-March sowing, good fibre quality	170–180	260–270	Mid March to end April	3.5–4.0
'S 19' ('Subala')	CRIJAF, Barrackpore, West Bengal	2005	('JRO620' × 'Sudan Green') × 'Tanganyika 1'	Light red	Steel-grey, non-dehiscent on maturity	Resistant to premature less flowering on mid-March sowing, finer fibre quality with lignin content	170–180	260–270	Mid March to end April	3.5–4.0
'JRO 204'	CRIJAF, Barrackpore, West Bengal	2007	Pure line selection between 'IDN/SU/053' × 'KEN/DS/060'	Full green	Non-shattering pod	Resistant to premature flowering, non-lodging tall cylindrical stem	120	240–250	1st week of March to end April	3.6–3.8
'AAU OJ 1' ('Tarun')	AAU, Jhorhat, Assam	2007	Pure line selection between 'Tanganyika 1'× 'JRO 640'	Full green	Non-shattering pod	Resistant to premature flowering, better biotic resistance to stem rot, root rot, anthracnose yellow mite	120	230–250	Mid March to early May	3.6
'JBO 2003 H' ('Ira')	CRIJAF, Barrackpore, West Bengal	2008	('JRO 632' × 'Sudan Green') × 'Tanganyika 1'	Full green	Non-shattering pod	Resistant to premature flowering, better biotic resistance to stem rot, root rot, anthracnose yellow mite	120	230–250	Last week of March to end April	3.6

Table 2 Details of released varieties of white jute (*Corchorus capsularis* L.) in India

Variety	Developing institute	Year of release	Parentage	Stem and leaf colour	Seed coat	Pod shattering habit	Flowering behaviour	Days to 50% flower (days)	Seed to seed maturity (days)	Fibre yield (tonnes /ha)
'JRC 321' ('Sonali')	CRIJAF, Barrackpore, West Bengal	1954	Selection from indigenous type 'Hewti'	Stem and upper surface of leaf petiole coppery red.	Shining chocolate	Non-dehiscent	Late February sowing does not induce premature flowering	120–130	200–210	20–25
'JRC 212' ('Sabuj Sona')	CRIJAF, Barrackpore, West Bengal	1954	Selection from indigenous type	Full green	Shining chocolate	Non-dehiscent	Mid March sowing does not induce premature flowering	150–160	220–230	25–28
'JRC 7447' ('Shyamali')	CRIJAF, Barrackpore, West Bengal	1971	X-ray derivative of 'JRC 212'	Full green	Shining chocolate	Non-dehiscent	Mid March sowing does not induce premature flowering	150–160	225–235	28–30
'JRC 4444' ('Baldev')	CRIJAF, Barrackpore, West Bengal	1980	'JRC 212'× 'D 154'	Full green	Shining chocolate	Non-dehiscent	Early-March sowing does not induce premature flowering	150–160	210–225	30–32
'UPC 94' ('Reshma')	Jute Research Station Bahraich, Uttar Pradesh	1983	'JRC 321'× 'JRC 212'	Stem and upper surface of leave foliage coppery red	Shining chocolate	Non-dehiscent	Late-February sowing does not induce premature flowering	130–140	210–220	25–27
'Padma'	CRIJAF, Barrackpore, West Bengal	1983	'JRC 6165'× 'JRC 412'	Stem and upper surface of leave foliage coppery red.	Shining chocolate	Non-dehiscent	Late-February sowing does not induce premature flowering	140–150	210–220	25–28
'KC I' ('Jaydev')	Jute Research Station, Kendrapara, Orissa	1992	Gamma-ray derivative of 'JRC 4444'	Full green	Shining chocolate	Non-dehiscent	Early-March sowing does not induce premature flowering	140–150	210–220	26–33
'JRC 698' ('Shrabanti')	CRIJAF, Barrackpore, West Bengal	1999	Multiple crosses involving13 parents	Full green	Shining chocolate	Non-dehiscent	Early-March sowing does not induce premature flowering	120—130	210–220	30–35
'Bidhan Pat 3'	B C KV V, Kalyani, West Bengal	2000	'D 154'× 'D 18'(mutant)	FuII green	Chocolate	Non-dehiscent	Photo-period insensitive	110–115	180–190	25–27
'Bidhan Pat l'	B C KV V, Kalyani, West Bengal	2001	Gamma-ray derivatives of 'D 154'	Full green	Chocolate	Non-dehiscent	Photo-period insensitive	65–70	140–150	13–14
'Bidhan Pat 2'	B C K V V, Kalyani, West Bengal	2001	'D 154'× 'D 18' (mutant)	Full green	Chocolate	Non-dehiscent	Photo-period insensitive	90–95	170–180	20–23
'JRC 80' ('Metali White')	CRIJAF, Barrackpore, West Bengal	2005	'CIN 114'× 'JRC 321'	Full green	Chocolate	Non-dehiscent	Early-March sowing does days not induce premature flowering	110–120	200–210	30–35

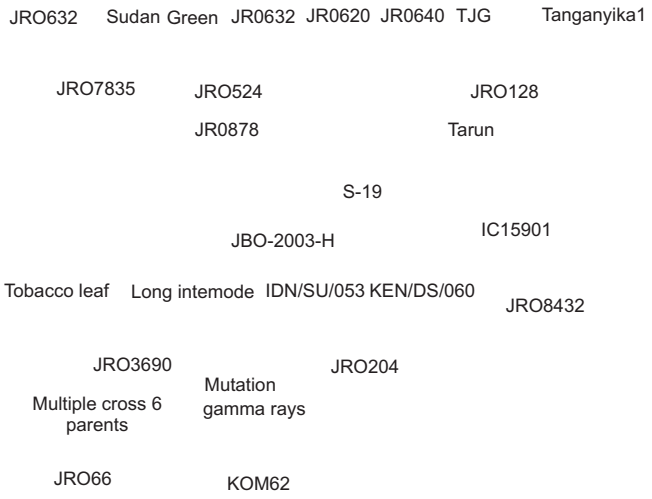

Fig 1 Relationship among different released varieties of *C. olitorius* in India. Direction of arrow indicates the female parent used in crossing for developing recombinant lines

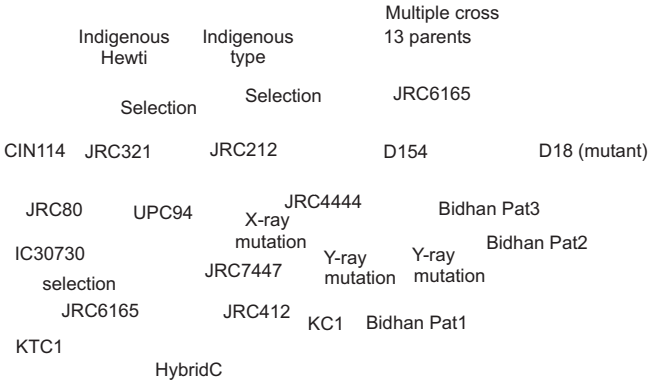

Fig 2 Pedigree relationship among released varieties of white jute (*C. capsularis*)

two varieties, viz 'S 19' and 'JBO 2003-D' where both were used as parents for transferring pre-mature flowering-resistance in adapted lines. The other four varieties originated from diverse genotypes, indicating that the genetic base of released *olitorius* varieties is indeed narrow.

Similarly, the nature of genetic diversity among 13 *capsularis* varieties released till date also represented narrow genetic base considering the pedigree relationship among those varieties. 'D 154' was one of the contributing parents involved either directly or indirectly in developing five varieties, whereas 'JRC 212' served as a parent for four varieties inclusive of two varieties where both 'D 154' and 'JRC 212' contributed genes for wide adaptability.'JRC 321', a fine fibre genotype, was one of the parents of two varieties 'JRC 80' and 'UPC 94'. This pedigree relationship could correctly explain the high genetic similarity among the released *capsularis* varieties (Fig. 2).

Qualitative and quantitative traits in jute: *an insight through DUS testing*

All the *olitorius* varieties (12 notified and six common knowledge) and seven *capsularis* varieties ('D 154', 'UPC 94', 'JRC 4444', 'KTC 1', 'Bidhan Pat 3', 'JRC 7447' and 'JRC 698') were distinguished for DUS testing (Table 3). Kumar *et al*. (2006) could distinguish only few varieties using 16 morphological traits based on Draft National Test Guidelines of Jute (Kumar and Mahapatra 2004). They advocated exploring a combination of morphological characters with biochemical and molecular markers for

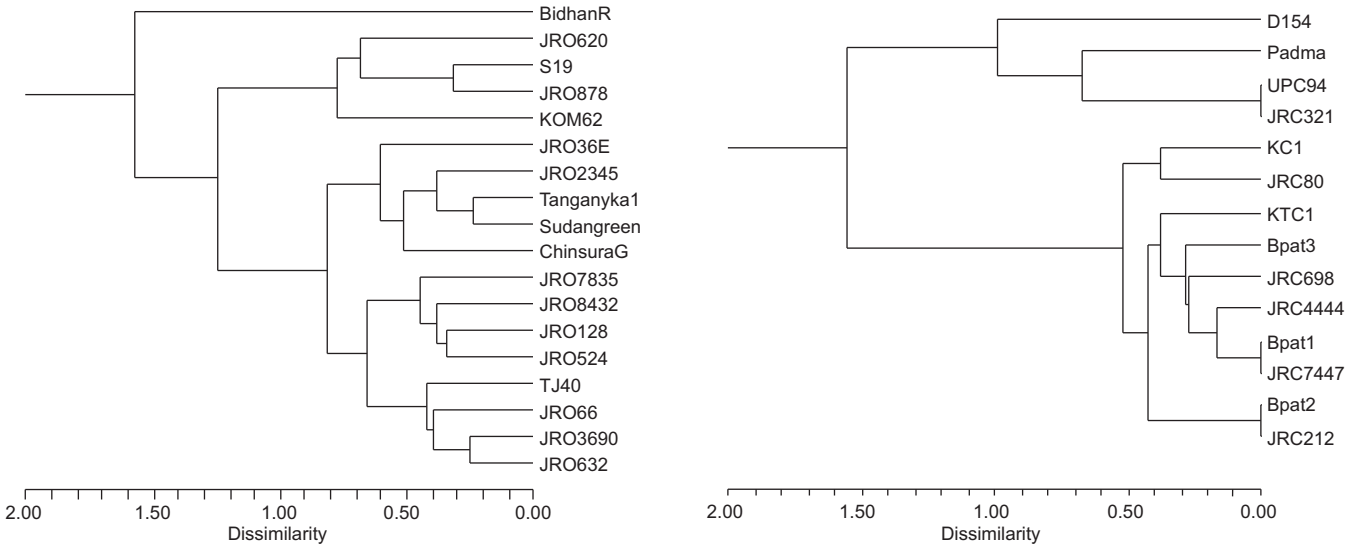

Fig 3 Dendograms showing the relationship among released/ notified and common knowledge varieties of both (a) *C. olitorius* and (b) *C. capsularis* based on 17 morphological (qualitative and quantitative) characteristics as revealed by cluster analysis. Clustering was based on Euclidian distance with Un-weighted Pair Group Method of Arithmetic averages (UPGMA)

Table 3 Morphological characteristics used in DUS testing in jute

Morphism	Morphological traits	
	C. capsularis	*C. olitorius*
Monomorphic	(i) Premature flowering resistance (ii) leaf lamina colour (iii) stipule colour (iv) leaf shape (v) basal stem root primordial (vi) pod dehiscence (vii) seed colour	(i) Premature flowering resistance (ii) leaf lamina colour (iii) leaf shape (iv) time of 50% flowering (v) pigmentation of calyx (vi) basal stem root primordial (vii) seed size (viii) pod dehiscence
Dimorphic	(i) Leaf petiole colour (ii) stem colour (iii) plant height (iv) pigmentation of calyx (v) time of 50% flowering (vi) pod pigmentation (vii) seed size	(i) Leaf petiole colour (ii) leaf vein colour (iii) stem colour (iv) plant height (v) stipule colour (vi) pod pigmentation (vii) seed colour (viii) fibre fineness (ix) fibre strength

discriminating *capsularis* varieties. Attempts have recently been made for precise characterization of jute varieties of both species for obtaining protection under Protection of Plant Varieties and Farmers Right Act in India. Kumar *et al*. (2008) characterized 25 released or notified varieties and seven common knowledge varieties of both species using 17 morphological characters for DUS testing. Out of 17 morphological traits, eight were monomorphic, seven dimorphic and two polymorphic in *C. capsularis*. In contrast *C. olitorius* was represented by eight dimorphic and nine polymorphic traits. The revised DUS test guidelines of jute (PPV and FRA 2008) were formulated keeping cvs 'Bidhan Rupali' (*C. olitorius*) and 'D 154' (*C. capsularis*) as dummy candidate varieties.

Although, qualitative morphological characters in jute are mostly monomorphic with few belonging to dimorphic and polymorphic types, certain distinguishing features are being utilized in seed certification programme of released/ notified jute varieties (Kumar *et al*. 2005). But classifying quantitative morphological traits into categorical morphs could be misleading. Therefore, when quantitative morphological traits were treated as interval variables along with qualitative variables (consisting of nominal and ordinal categories), the clustering pattern in both species is emerged as shown in Figs 3a, b.

Application of molecular markers

Molecular markers provide a direct measure of genetic diversity and go beyond indirect diversity measures based on morphological traits or geographical origin. They have been successfully employed to characterize genetic diversity and for the identification of closely related genotypes (Me´tais *et al.* 2002). Use of molecular techniques could be of help in devising strategies to improve the jute crop. However, there appears to be very little molecular information about jute or its related species as available at the gene bank, and very few efforts have been made in the past to develop molecular markers to study its genetic variability (Hossain *et al*. 2002, 2003, Roy *et al*. 2006, Basu *et al.* 2004, Haque *et al.* 2007, Mir *et al.* 2008). Different authors had determined the genetic variability of various jute varieties and accessions collected from diverse locations, using RAPD (Qi *et al*. 2003, Haque *et al*. 2007), ISSR (Qi *et al*. 2003b), RAPD and AFLP (Hossain *et al*. 2002, 2003), AFLP and SSR (Basu *et al*. 2004), STMS, ISSR and RAPD (Roy *et al*. 2006) and SSR (Mir *et al*. 2008) markers (Table 4).

Hossain *et al*. (2002) investigated nine different varieties and 12 accessions of jute cultivars belonging to both species using RAPDs. Out of 29 primers used, seven and six primers gave polymorphism within the varieties and accessions, respectively. Distinct clustering of the cultivated jute species was obtained and species-specific RAPDs had been generated to distinguish between *C. olitorius* and *C. capsularis*. Existing genetic classification was in agreement with molecular marker data.

Qi *et al.* (2003a) generated fingerprints of 10 species including 27 accessions of the genus *Corchorus* using 25 RAPD primers. The presence of abundant genetic diversities was reported among 15 wild species and 12 cultivated *Corchorus* spp, with genetic similarity co-efficients ranging from 0.49 to 0.98, and clustering corroborated the

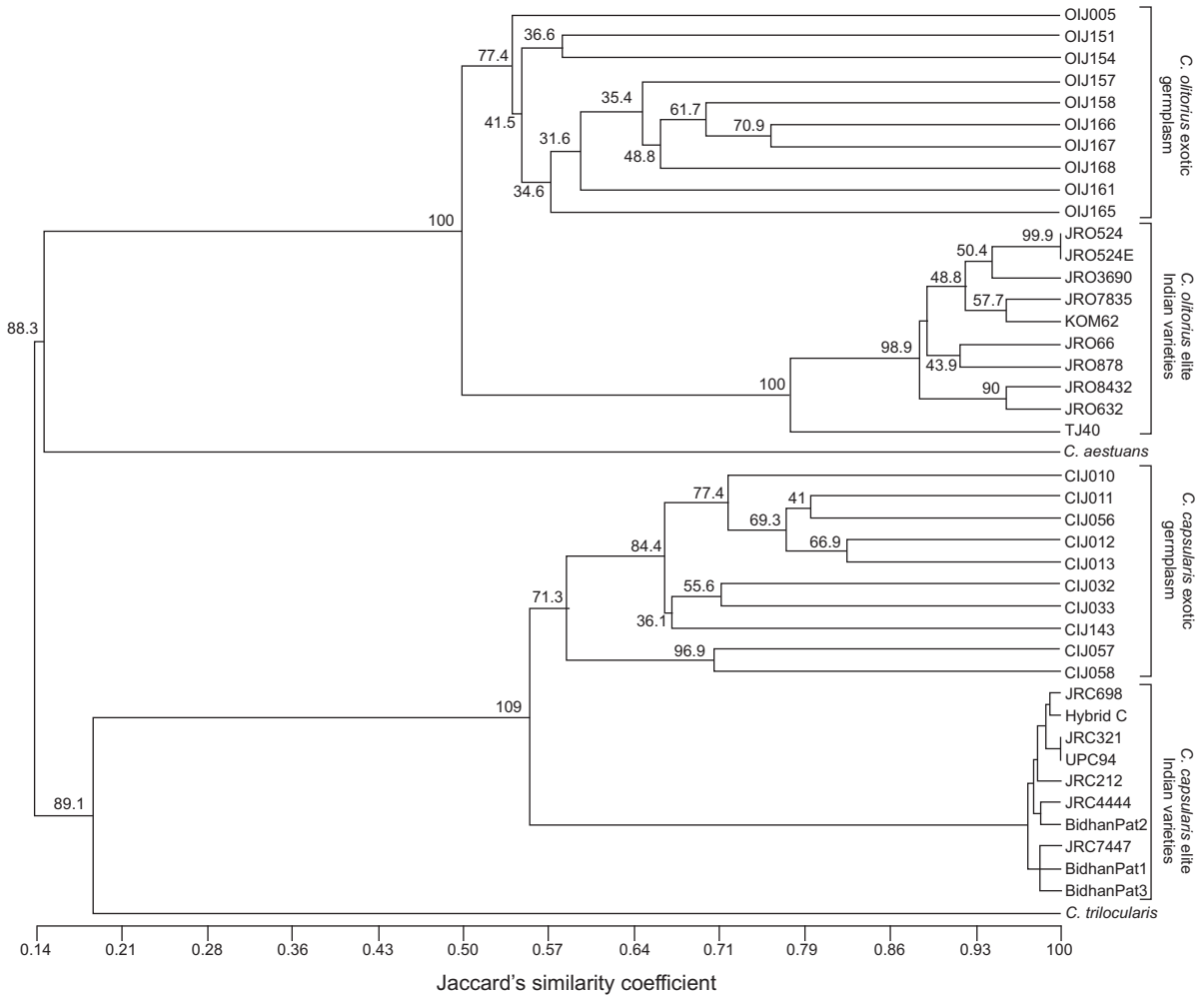

Fig 4 Dendrogram showing relationship and diversity of elite Indian varieties and exotic germplasm of both *C. capsularis* and *C. olitorius* along with wild species *C. trilocularis* and *C. aestuans* using STMS markers (adapted from Roy *et al*. 2006)

morphological classification; close wild species of cultivated varieties were genetically different from wild species. *C. capsularis* had a close relationship with *C. olitorius*, and further relationship with *C. uriticifolius*, *C. uritifolius* and *C. aestuans* could distinguish them as primary wild species of jute. The round-fruit cultivars were found to be genetically more similar than long-fruit cultivated species. Qi *et al*. (2003b) applied ISSR technique on the same set of 27 accessions to reveal higher intra-specific genetic resemblance and abundant inter-specific genetic diversity. Based on morphology and DNA classification, it was found that *C. urticifolius* could be one of the original wild species and *C.trilocularis* was a variation of *C.trilocularis.*

Basu *et al.* (2004) evaluated 49 genotypes collected from Bangladesh, India, Thailand, Nepal, China, Pakistan, Sudan, Tanzania, Kenya and America, for their genetic diversity using SSR and AFLP markers. On the basis of cluster analysis and pair-wise genetic distances, the two jute species were widely separated, but differences in geographical locations did not affect genetic diversity. The results suggested that the two species are allopatric sharing certain common alleles. Such distinction provides support to the earlier hypothesis that the two species originated from two different geographical locations: C. *capsularis* from the Indo-Burma region including south China and *C. olitorius* from Africa (Kundu 1951).

DNA fingerprinting of 20 exotic germplasm lines and 20 commercial varieties of the two cultivated species (*C. olitorius* and *C. capsularis*) and two wild relatives of jute (*C. aestuans* and *C. trilocularis*) have been done using RAPD, ISSR and SSR techniques (Roy *et al*. 2006). Six STMS markers developed from the genomic sequence of *C. olitorius* was not fully transferable to *C. capsularis,* and revealed a very low level of intra-specific polymorphism. The four ISSR and 22 RAPD primers employed in the study revealed 98.44% and 100% inter-specific polymorphism, respectively, while intra-specific polymorphism was significantly low. Released varieties of *C. capsularis* had extremely narrow genetic bases requiring immediate diversification programme. Higher levels of genetic diversity

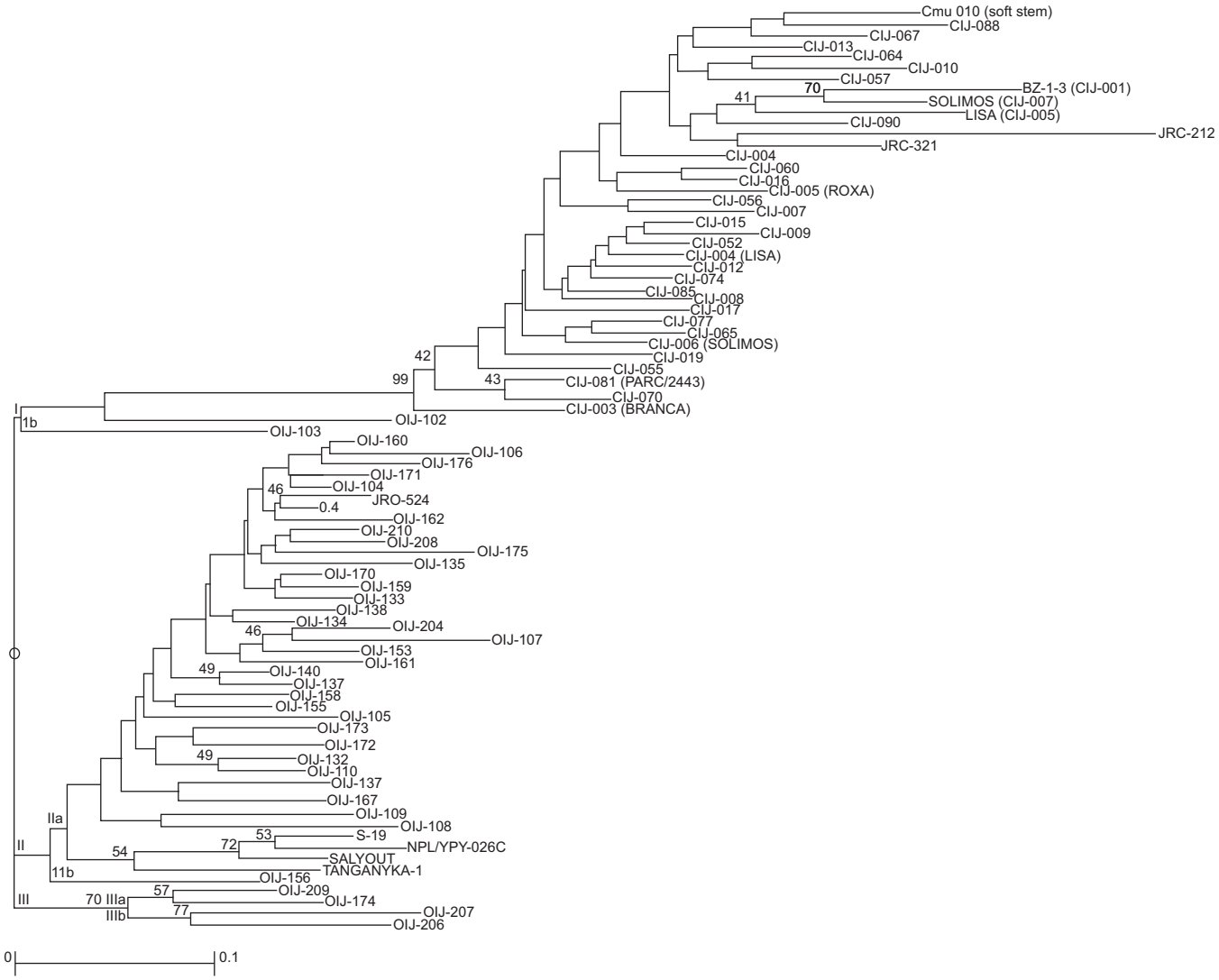

Fig 5 Clustering pattern of 81 jute genotypes based on genetic distances estimated from SSR polymorphism. IJO, International Jute Organization; OIJ, *C. olitorius* IJO collection; OIN, *C. olitorius* indigenous collection (adapted from Mir R R *et al*. 2008a)

observed with germplasm of both the cultivated species advocated their use in broadening the genetic base in jute. Polyphyletic origin of the two cultivated species was apparent from the co-existence of *C. olitorius* with the wild species *C. aestuans* and of *C. capsularis* with *C. trilocularis* with distinct clusters.

Haque *et al*. (2007) determined genetic diversity and species relationship among 18 jute genotypes of both *C. capsularis* (6 varieties and 5 land races) and *C. olitorius* (4 varieties and 3 land races) using 40 RAPD primers. However, only 12 primers were able to generate intra-and inter-specific polymorphism among the jute genotypes. This study revealed that the two jute species are distantly related, with a high level of similarity within the species.

Genomic SSRs were first developed by Mir R R *et al*. (2008a) in *C. olitorius* cv O4. Out of 67 genomic SSRs, 60 were found to be simple, and the remaining 7 were compound. In both species, using a subset of 45 genomic SSRs derived from *C. olitorius*, genetic diversity and DNA polymorphism analyses showed that SSRs of *C. olitorius* have high transferability (70.43%) to *C. capsularis*; and this can further be improved by the use of EST-SSR. EST-SSRs represent the transcribed region of genome compared to low-copy sequences. Higher level of genetic as well as allelic diversities were found in *olitorius* genotypes than in *capsularis* genotypes using cpSSRs and genomic SSRs, ISSR and RAPD markers, which could be attributed to higher level of natural out-crossing in *C. olitorius* (8–12%) than in *C. capsularis* (3–4%). Mir *et al*. (2008a) advocated that divergent genotypes of both species should be used in intra-specific crosses for developing improved cultivars of white and tossa jute. It was also shown that many SSRs examined were redundant because 15 polymorphic SSRs resulted in the same level of polymorphism as realized with 41

polymorphic SSRs.

Mir *et al.* (2008b) carried out DNA fingerprinting of 16 selected jute accessions, 8 each from *C. olitorius* and *C. capsularis*, using SSR and RAPD markers to develop mapping populations on fibre fineness. High level of polymorphism was detected between fine and coarse fibre-yielding jute accessions differentiating two main clusters between *C. olitorius* and *C. capsularis* and each main cluster into two clusters containing fine and coarse fibre jute accessions. RAPD and SSR marker data were highly correlated (r = 0.97). Grouping of jute accessions based on morphological and molecular data was also highly correlated.

STEPS FOR WIDENING GENETIC BASE

Intra-specific hybridization

Varietal development of cultivated *Corchorus* is confined to intra-specific hybridization. There is limited scope for further improvement of cultivated varieties of jute in the absence of requisite variability and genetic diversity due to narrow genetic base. Therefore, additional genetic variability is required to provide new phenotypes in breeding populations. Jute breeders should utilize vast array of germplasm, specially from African continent in varietal breeding programmes of both species.

Inter-specific hybridization

Inter-specific crosses may help in combining desirable attributes from the two jute species, as it has been successfully attempted and utilized in the past (Islam and Rasid 1960, Swaminathan *et al*. 1961, Islam 1964, Sinha *et al*. 2004). However, strong sexual incompatibility barrier exists between the two cultivated jute species, which do not cross-fertilize (Patel and Datta 1960, Swaminathan *et al.* 1961). But Choudhuri and Mitra (1962) have succeeded in producing inter-specific jute hybrids. However, those putative hybrids exhibited dominance of the female parent in F_1 and F_2 generations, making it impossible to release varieties. Rout and Naik (1983) followed the hybrid progenies up to F_3 generations, but there was no report on exploitation of those hybrids in later generations. This is probably because of the fact that the later generation of the entire population resembled the female parents. Bhaduri and Bairagi (1968) succeeded in obtaining successful inter-specific hybrids between the two cultivated species. However, all these attempts did not lead to the development of elite cultivars through recombination breeding.

Recently, Sinha *et al*. (2004) obtained successful inter-specific hybrids using mutant *C. capsularis* female parent ('CMU 001') with *C. olitorius* cv 'JRO 524'. The resulting hybrid exhibited better fibre fineness and cellulose content, but low-lignin content and reduced fibre strength. They advocated selection of progenies with quality fibre in advance generations for utilizing and blending in textile industries. A successful inter-specific hybrid between wild species *C. pseudo-olitorius* ('WCIJ 34') × *C. capsularis* ('Tripura') was obtained to introgress resistance to diseases like stem rot, black band, soft rot and anthracnose (Palve *et al.* 2005). This inter-specific hybrid exhibited partial to full male sterility due to non-homology between parents. The resultant semi-fertile hybrids, which are now in F_4 generation, are expected to have considerable values with respect to breeding for disease resistance and fibre quality.

Utilization of wild species of Corchorus

Most of the wild species of *Corchorus* are poor yielder, but potent sources of biotic and abiotic stress tolerance coupled with finest quality of fibre (Palve *et al.* 2004; Mahapatra and Saha 2008). *Corchorus depressus, C. asplenifolius, C. cinerascens, C. erinoceus* and *C. erodiodes* exhibited a higher degree of drought tolerance and *C. trilocularis* and *C. tridens* (WCIJ 046) showed a significant level of tolerance to water stagnation. *Corchorus hirtus, C. sulcatus* and *C. siliquosus* have the ability to colonize on extremely shallow soil. *Corchorus pseudo-olitorius* showed immune reaction to fungal diseases like stem rot, root rot, black band, soft rot and anthracnose. Similarly, *C. urticifolius* and *C. pseudo-capsularis* exhibited resistant reactions to all diseases except soft rot and anthracnose, respectively. Besides these, *C. junodii, C. pinnatipertitus, C. saxatilis* and *C. gillettii* are also potent sources of biotic stress tolerance. *C. urticifolius, C. pseudo-capsularis* and *C. pseudo-olitorius* were found to be moderately resistant to root knot nematode, *Meloidogyne incognita* (Cofoid & Chitwood) Chitwood. Nematode galls were observed only in the lateral roots, but the main root was free of galls. The number of egg masses and galls/plant were 7 and 12 in *C. pseudo-capsularis* as against 310 and 403 in *C. capsularis* cv 'JRC 212' (S K Laha, personal communication). *C. pseudo-capsularis* produces finest fibre (0.20 tex), followed by *C. urticifolius* (0.30 tex), *C. aestuans* (0.51 tex), *C. trilocularis* (0.77 tex), and *C. pseudo-olitorius* (0.95 tex). *Corchorus angolensis* and *C. merxmuelleri* were found to be high fibre yielder with superior quality. So, introgression of desirable genes from wild germplasm into cultivated *Corchorus* species is utmost important. Being divergent from the cultivated species, wild species should be used as source of variability and parents for initiating inter-specific hybridization programme through traditional and advanced tools of biotechnological approaches to increase the productivity and quality of jute fibre.

Corchorus species are characterized by a high degree of inter-specific variability, but a low level of intra-specific variability. Due to modern method of cultivation, the genetic base of the cultivated varieties has become very narrow, where *C. olitorius* cultivars are dominating in cultivation as compared to *C. capsularis* varieties. Most of the adapted areas of the jute growing region are represented by only a few *olitorius* varieties, particularly 'JRO 524'. Narrow genetic

Table 4 Application of molecular markers in genetic diversity analysis in *Corchorus* species

Plant material studied	Molecular marker used*	Country	Reference
27 accessions of 10 species (*C. aestuans*, *C. tridens*, *C. fascicularis*, *C. pseudo-olitorius*, *C. pseudo-capsularis*, *C. trilocularis*, Tian Jute [untitled], *C. capsularis*, *C. olitorius* and *C. uriticifolius*) in Genus *Corchorus*	RAPD and ISSR	China	Qi *et al.* 2003a, 2003b
9 different varieties and 12 accessions of both *C. olitorius* and *C. capsularis*	RAPD	Bangladesh	Hossain *et al.* 2002
2 varieties and 4 accessions of *C. olitorious*	RAPD(30) and AFLP(25)	Bangladesh	Hossain *et al.* 2002
C. capsularis (1 variety and 21 wild accessions), *C. olitorious* (2 varieties and 25 wild accessions)	SSR & AFLP	India	Basu *et al.* 2004
C. capsularis , *C. olitorius* varieties and germplasm (10 each), *C. aestuans*, *C. trilocularis*	RAPD (22) ISSR(4) STMS (6)	India	Roy *et al.* 2006
C. capsularis (6 varieties and 5 accessions), *C. olitorious* (4 varieties and 3 accessions)	RAPD(40)	Bangladesh	Haque *et al*. 2007
C. capsularis (45) and *C. olitorius*(36)	SSR(45)	India	Mir R R *et al*. 2008a
16 selected jute accessions, eight each of *C. olitorius* and *C. capsularis*	SSR and RAPD	India	Mir J I *et al*. 2008b

*Figures in parentheses denote the number of primer used.

base in *C. capsularis* is a matter of great concern in varietal development. Although a number of molecular markers have been employed, refinement in enrichment and development of more microsatellite markers and their utilization will be essential for jute genomic research. The identification of diverse lines with these molecular markers will assist jute breeders in achieving a greater success for both intra-and inter-specific hybridization. Validation of marker diversity should not be contradicted with morphological, biochemical and physiological diversity. Although both kinds of markers have their advantages and disadvantages, their combined utilization would increase the resolving power of genetic diversity analysis.

REFERENCES

Basak S L. 1993. Review on the genetics and breeding of jute, International Jute Organization, Dhaka, Bangladesh.

Basu A, Ghosh M, Mayer R, Powell W, Basak S L, and Sen S K. 2004. Analysis of genetic diversity in cultivated jute determined by means of SSR markers and AFLP profiling. *Crop Science* **44**: 678–85.

Bhaduri P N and Bairagi P. 1963. Inter-specific hybridization in jute(*Corchorus capsularis* and *C. olitorius*) *Science and Culture* **34**: 355–7.

Brandolini A.1969. European races of maize. *Annual Corn Sorghum Research Conference Proceedings* **24**: 36–48.

Bretting P K, Wildrlechner M P.1995. Genetic markers and plant genetic resource management. (*in) Plant Breeding Reviews*, pp 11–71 Janick J (Ed) Vol 13. Wiley, New York.

Chaudhuri S D and Mia A J. 1962. Species crosses in the genus *Corchorus* (jute plants). *Euphytica* **11**: 61–4.

Chaudhury S K, Kumar D and Saha A. 2004. Varietal development and improved varieties of jute. *Technical Bulletin Series No1/ 2004*, p 1–11, CRIJAF, Batrrackpore, Kolkata.

Das, B B and Maiti S N. 1998. Jute (*Corchorus* species) and allied fibres research in India. *Indian Journal of Agricultural Research* **68**(8): 484–93.

Gepts P. 1993. The use of molecular and biochemical markers in crop evolution studies. *Evolutionary Biology* **27**: 51–94.

Ghosh T. 1983. *Plant Production and Protection. Paper No.51*. 219pp FAO, Rome.

Gilliland T J, Coll R, Calsyn E, de Loose M, van Eijk MJT, Roldan-Ruiz I. 2000. Estimating genetic conformity between related ryegrass (*Lolium*) varieties. I. Morphology and biochemical characterization. *Molecular Breeding* **6**: 569–80.

Haque S, Begum S, Sarker R H and Haseena Khan. 2007. Determining genetic diversity of some jute varieties and accessions using RAPD markers, *Plant Tissue Culture and Biotechnology* **17**(2): 183–91.

Hossain M B, Awal A, Rahman M A, Haque S and Khan H. 2003. Distinction between cold sensitive and cold tolerant jute by DNA polymorphisms. *Journal of Biochemistry and Molecular Biology* **36**: 427–32.

Hossain M B, Haque S and Khan H. 2002. DNA fingerprinting of jute germplasm by RAPD. *Journal of Biochemistry and Molecular Biology* **35**: 414–9.

Islam A S 1964. A rare hybrid combination through application of hormone and embryo culture. *Nature* **210**: 320.

Islam A S and Rashid A.1960 First successful hybridization between the two jute yielding species. *Nature* **185**: 258–9.

Islam A S and Rashid A.1961. A new jute hybrid. *Journal of Heredity* **52**: 287–91.

Karmakar P G, Hazra S K, Sinha M K and Chaudhury S K. 2008. Breeding for quantitative traits and varietal developments in Jute and allied fibre crops. (*in) Jute and Allied Fibre Updates: Production and Technology,* pp57–75. Karmakar P G, Hazra S K, Ramasubramanian T, Mandal R K, Sinha M K and Sen H S

(Eds) CRIJAF, Barrackpore, Kolkata.

Kumar D, Begum T, Kotal B and Shil S. 2008. Descriptors of Jute Varieties. *Technical Bulletin No. 2/2008*, CRIJAF, Barrackpore, Kolkata.

Kumar D and Mahapatra A K. 2004. *Draft National Guidelines for the Conduct of Tests for Distinctness, Uniformity and Stability in Jute*, pp 1–14,CRIJAF, Barrackpore.

Kumar D, Das A, Mahato P, Lakshman S S and Mandi S. 2005. Identification key for notified varieties and varieties of common knowledge of jute (*Corchorus olitorius* L. and *C. capsularis* L.) *Indian Journal of Genetics and Plant Breeding* **65**: 236–8.

Kumar D, Mahato P, Lakshman S S and Mandi S. 2006. Morphological characterization of jute varieties (*Corchorus olitorious* L. and *C. capsularis* L.) and their application in DUS testing. *Indian Journal of Genetics and Plant Breeding* **66**: 319–23.

Kundu B C. 1951. Origin of jute. *Indian Journal of Genetics and Plant Breeding* **11**: 95–9.

Kundu B C, Basak K C and Sarkar P B. 1959. *Jute in India-A. monograph*. 395 pp. Indian Central Jute Committee.

Mahapatra A K and Saha A. 2008. Genetics resources of jute and allied fibre crops. (*in*) *Jute and Allied Fibre Updates: Production and Technology*, pp18–37, Karmakar P G, Hazra S K, Ramasubramanian T, Mandal R K, Sinha M K and Sen H S (Eds) CRIJAF, Barrackpore, Kolkata.

Me´tais I, Hamon B, Jalouzot R, Peltier D. 2002. Structure and level of genetic diversity in various bean types evidenced with microsatellite markers isolated from a genomic enriched library. *Theoretical and Applied Genetics* **104**: 1346–52.

Mir R R, Rustgi S, Sharma S, Singh R, Goyal A, Kumar I, Gaur A, Tyagi A K, Khan H, Sinha M K, Balyan H S, and Gupta P K. 2008a. A preliminary genetic analysis of fibre traits and the use of new genomic SSRs for genetic dliversity in jute. *Euphytica* **161**: 413–27.

Mir J I, Karmakar P G,Chattopadhyay S, Chaudhury S K, Ghosh S K, Roy A. 2008b. SSR and RAPD profile based grouping of selected jute germplasm with respect to fibre fineness trait. *Journal of Plant Biochemistry and Biotechnology* **17**: 29–35.

Palit P, Sasmal B C, Bhattacharryya A C.1996. Germplasm diversity and estimate of genetic advance of four morpho-physiological traits in a world collection of jute. *Euphytica* **90**: 89–110.

Palve S M, Sinha M K, Chattopahdyay S. 2004. Genetic variability for fiber strength and fineness in wild relatives of genus *Corchorus*. (*in*) *Proceedings National Seminar on Diversified Uses of Jute and Allied Fiber Crops*, pp 99–103, held during 8th–9th Jan-uary, Barrackpore, Kolkata.

Palve S M and Sinha M K. 2005. Morphological studies in inter-specific hybrid between *Corchorus pseudo-olitorious* Islam and Zaid and *Corchorus capsularis* Linn. *Science and Culture* **71** (1–2): 35–7

Patel J S and Ghosh R L M. 1940. A review of agricultural investigations on jute in India. *Agriculture Research Bulletin* No. 1.

Patel G I and Datta R M. 1960. Inter-specific hybridization between *Corchorus olitorius* and *C. capsularis* and the cytogenetical basis of incompatibility between them. *Euphytica* **9**: 89–110.

PPV and FRA. 2008. Specific DUS test guidelines for six notified species of cotton and jute. *Plant Variety Journal of India.* **2**(1&2): 75–86.

Qi J, Zhou D, Wu W, Lin L, Wu J, and Fang P.2003a. Application of ISSR technology in genetic diversity detection of jute. *Ying Yong Sheng Tai Xue Bao* **14**: 1473–7.

Qi J, Zhou D, Wu W, Lin L, Fang P, and Wu J. 2003b. The application of RAPD technology in genetic diversity detection of Jute. *Ying Yong Sheng Tai Xue Bao* **30**: 926–32.

Raut R N and Naik G.1983. Inter-specific hybridization in cultivated jute. *Proceedings of FAO Expert Consultation on Jute and Kenaf improvement*, pp 1–11. held during 5–9 September, Calcutta.

Roy A, Bandyopadhyay A, Mahapatra A K, Ghosh S K, Singh N K, Bansal K E, Koundal K R, and Mohapatra T. 2006. Evaluation of genetic diversity in jute *(Corchorus* species) using STMS, ISSR and RAPD markers, *Plant Breeding* **125**: 292–7.

Saha A and Hazra S K. 2008. Jute – the Heritage of India. *(in) Jute and Allied Fibre Updates: Production and Technology*, pp1–17. Karmakar P G, Hazra S K, Ramasubramanian T, Mandal R K, Sinha M K and Sen H S(Eds) CRIJAF, Barrackpore, Kolkata.

Sinha M K, Mitra S, Nandy S, Sengupta D , Dutta P, Das F and Chakrabarty S C. 2004. Inter-specific hybrid between two jute (*Corchorus*) species for textile quality fibre. *Indian Journal of Genetics and Plant Breeding* **64**(4): 310–4.

Swaminathan M S, Iyer R D and Sulbha K.1961. Morphology, cytology and breeding behaviour of hybrids between *Corchorus olitorius* and *C. capsularis*. *Current Science* **30**: 67–8.