AN UPDATED OVERVIEW ON CYTOLOGICAL AND CYTOGENETICAL ASPECTS OF *CORCHORUS* SP. (TILIACEAE)

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Abstract: *Corchorus* (Family: Tiliaceae) possessing more than 170 species are fibrous annual plants distributed in warm regions throughout the world. *Corchorus capsularis* L. (white jute) and *C. olitorius* L. (tossa jute) yields fibre of commerce (phloem fibre) from bark of the stem (commonly known as pat); while, few wild species found and grown in India are important genetic resources (*C. trilocularis* – abiotic stress tolerance, tolerant genotype to water inundation; *C. pseudoolitorius* and *C. pseudocapsularis* – fungal disease resistance; *C. tridens*, *C. trilocularis* and *C. aestuans* – fine fibre quality). India is an important producer of commercial jute and socio-economic significance is associated with the crop plant. With a view to fibre yielding importance of the cultivated species of *Corchorus* as well as considering the potentiality of wild members an updated overview is conducted only on cytological and cytogenetical (including plant type mutation) aspects to provide adequate necessary information to researchers interested in the field of conventional cytogenetics so that the methodology may be explored for effective utilization in crop improvement and human benefit.

Keywords: *Corchorus*, Overview, Cytology, Cytogenetics, Plant type mutation

INTRODUCTION

Corchorus (Family: Tiliaceae) are annual fibrous plants distributed in warm regions throughout the world (Kundu 1951, Purseglove 1968). The genus comprises of more than 170 species as per 'Index Kewensis' (Mahapatra and Saha 2008) and based on species concentration East and South Africa were considered to be the centre of diversity and place of origin (Edmonds 1990). Mahapatra *et al.* (1998) reported 10 species (2 cultivated and 8 wild) from India of which *C. capsularis* L. (white jute) and *C. olitorius* L. (tossa jute) yield fibre of commerce (common name 'pat'; Wallace 1909) from bark of the stem (phloem fibre); while, wild members are important genetic resources (*C. trilocularis* – abiotic stress tolerance, tolerant genotype to water inundation; *C. pseudoolitorius* and *C. pseudocapsularis* – fungal disease resistance; *C. tridens, C. trilocularis* and *C. aestuans* – fine fibre quality). India contributes about 40% of the world production of jute fibre earning annually about 1200 cores rupees as foreign exchange by exporting different jute products apart from possessing high socio-economic (about 2.5 lakhs people are employed in the jute industry and 25 lakhs are engaged in jute based ancillary sector) significance (Karmakar *et al.* 2008). Present communication is an updated overview on cytological and cytogenetical aspects including plant type mutation in *Corchorus* spp. (key components; knowledge of which is essential for efficient breeding among jute species) with an objective to provide repository of references to researchers for generating interest in conventional cytogenetics as well as effective utilization of the cytogenetical approach in efficient breeding and crop improvement.

CYTOLOGICAL STUDIES

Karyotype Analysis

Chromosome ($2n$=14) size in *C. capsularis* (Paria and Basak 1973) and *C. olitorius* (Sharma and Roy 1958) was documented as 1.7 to 3.7 µm and 1.3 to 2.7 µm respectively. Datta *et al.* (1975) suggested morphological types of 2 (A-B) in *C. urticaefolius*, 3 (A-C) in *C. capsularis* and *C. olitorius*, and 4 (A-D) in *C. aestuans* with absolute chromosome length varying from 1.00 to 3.30 µm and the cultivated members were considered primitive than the wild species. Karyotype analysis suggested that evolution was divaricated. Akhter *et al.* (1991) studied karyotype analysis in diploid and colchicine induced tetraploids of 2 cultivated species and suggested that in few pairs of chromosomes there exist intra-pair chromosomal heteromorphocity. Samad *et al.* (1992) performed HCl-Giemsa banding technique and reported that unlike *C. capsularis* all the pairs of chromosomes in *C. olitorius* were homomorphic. Banding patterns also revealed 3 common pairs between *C. olitorius* and *C. capsularis* and it was evinced from karyotype studies on F_1 hybrid. Alam and Rahman (2000) constructed fluorescent banded somatic karyotypes of *C. capsularis, C. olitorius* and *C. trilocularis* and reported 14 equal sized median chromosomes with a pair of satellites. The 2-satellited chromosomes of 3 species had 2 DAPI (4',6-diamidino-2-phenylindole) negative bands at the satellited regions. One interstitial DAPI-positive band was also found in *C. capsularis*. Maity and Datta (2009a) used Image Analyzing System (enzyme digestion technique) to karyotype 9 species (photoplates were documented) of *Corchorus* (2*n*=14) to get accurate numerical data and revealed 3 (*C. fascicularis*), 2 (*C. capsularis, C. olitorius C. aestuans, C. pseudocapsularis,* and *C. pseudoolitorius*) and 1 (*C. tridens, C. trilocularis* and *C. urticaefolius*) morphologically distinct chromosome types in the genus with prevalence of median chromosomes, mostly graded and symmetric. *C. fascicularis* also showed 2*n*=28 (11.54%) chromosomes. Absolute chromosome length among the species varied from 1.37 µm to 3.50 µm. Haploid chromatin length (11.97 µm – 17.72 µm) ranged significantly ($p<0.001$) among the species. The authors proposed an identification key of the studied species on the basis of karyomorphological data. Clustering of the species by UPGMA using cytological data revealed close interrelationship between *C. olitorius* and *C. aestuans* and among *C. pseudoolitorius, C. trilocularis* and *C. urticaefolius*. From karyotype analysis it was inferred that evolution in the genus was complicated and *C. capsularis* and *C. olitorius* may not be closely related from cytological point of view for efficient breeding.

Meiotic Studies

PMC squash preparations showed 7II formation at diplotene and metaphase I (MI) mostly in *Corchorus* (*C. capsularis, C. olitorius, C. aestuans, C. fascicularis, C. pseudocapsularis, C. pseudoolitorius, C. tridens, C. trilocularis* and *C. Urticaefolius*) species; however, *C. aestuans, C. fascicularis, C. pseudocapsularis, C. pseudoolitorius,* and *C. tridens* showed variation in chromosome numbers (n=1, 2, 3, 4, 5, 6, 9, 10 and 14) in addition to normal n=7, and such numerical variations in chromosome number was attributed due to cytomixis (Maity and Datta 2009a). Meiotic lability was also reported earlier (Rao and Datta 1953, Sharma and Datta 1953) in *C. olitorius* (4 to 12 even up to 14), *C. capsularis* (6 to 12), *C. fascicularis* (14 bivalents), *C. tridens* (5 to 9 bivalents) and *C. trilocularis* (5 to 9 bivalents).

Nandi (1937) suggested the formation of secondary association of bivalents in *C. capsularis*, which was however challenged by Ganguli (1945). Occasional presence of 2 bivalents in attachment with the nucleolus was observed both in *C. capsularis* and *C. olitorius* (Datta 1952). Kumar *et al.* (1981) reported preponderance of ring bivalents in cultivated jute species; while, Maity and Datta (2009a) reported more of rod than ring bivalents (excepting *C. capsularis*) in *Corchorus* spp. at diplotene and they were non-randomly distributed among the genotypes. Rao and Datta (1953) were of opinion that *C. fascicularis* appear to be a structural hybrid because a quadrivalent appears frequently, and PMCs with 14 bivalents along with normal 7 were noted which was attributed due to irregularities in the pre meiotic division.

Mandal and Datta (unpublished) studied meiotic configurations in 2 cultivated (*C. capsularis* and *C. olitorius*) and 6 wild (*C. aestuans, C. fascicularis, C. pseudocapsularis, C. pseudoolitorius, C. tridens* and *C. trilocularis*) species of jute and reported 2*n*=14 chromosomes at diplotene (prevalence of rod bivalents), MI and anaphase I mostly as well as secondary polyploid (*x*=4) nature of the species with frequent occurrence of cytomixis in *C. fascicularis*, *C. trilocularis* and *C. aestuans* with numerical variation in chromosome numbers (Figs. 1-12).

CYTOGENETICAL STUDIES

Interspecific Hybridization

Islam and Rashid (1960) reported that 365 seeds obtained from 15 fruits in 115 crosses between *C. olitorius* (female) × *C. capsularis* (male), only 7 seeds germinated but 3 F_1 plants reached the adult stage. No hybrids were secured from the reciprocal. In some characters of F_1 plants *C. olitorius* was dominant, in others *C. capsularis* was dominant, while in a number of characters the hybrids were intermediate. The hybrids formed 7II regularly and good seeds were obtained by selfing. Swaminathan and Iyer (1961) studied chromosome associations during microsporogenesis in F_1 hybrids of *C. olitorius* (female) × *C. capsularis* (male) and found 5II + IV or 1III + 5II +1I in several meiocytes of diakinesis and MI and one of the bivalents was heteromorphic. The F_2 progenies of the hybrids contained more than 40.0% of non-viable seedlings and about 11.0% population had various types of chlorophyll deficiency, abnormalities in leaf shape and poor vigour. Datta and Sen (1961) performed crossings between *C. sidoides* (female) × *C. siliquosus* (male) and obtained 19.1% pod setting in comparison to 8.7% in reciprocal crossings but in either case crossed pods had non-viable seeds. The authors were of opinion that the species were phyllogenetically unrelated and therefore the possibilities of getting viable hybrids were rather impossible.

Interspecific hybridization between *C. aestuans* and *C. capsularis* (Islam and Sattar 1961), *C. trilocularis* and *C. capsularis* (Faruqui, 1962; Arangzeb and Khatun, 1980), *C. aestuans* and *C. capsularis* (Haque and Islam 1970) and *C. trilocularis* and *C. capsularis* and *C. olitorius* (Arangzeb, 1994) were attempted with the objective to incorporate fine fibre trait from wild species (donor) to cultivated members of jute. Of practical importance, it was found that *C. trilocularis* donated fine fibre trait to *C. capsularis* in the elite strain 'Tri Cap' an interspecific hybrid from Bangladesh (Khatun, 2007).

Maity and Datta (2008) reported that F_1's (*C. capsularis* – male parent × *C. trilocularis* – female parent) were intermediate to parents for few traits (stem color, bud shape and flower color); while, for other characters (pod color and shape) they resembled the female parent. Average chromosome association per cell at diplotene and MI of F_1 plants was 0.007 VI + 0.007 IV + 6.74 II + 0.70 I (parents: *C. capsularis* – 6.98 II + 0.03 I/cell, *C. trilocularis* – 7II/cell) and it varied from 0.05 VI + 4.00 II + 2.00 I to 8.86 II + 0.00 I among the lines of hybrid plants. F_1 plants formed bivalents (4.00 to 8.86/cell, frequency – 0 to 14/cell) and univalents (0.00 to 2.00/cell, frequency – 0 to 24/cell) mostly (7II formation in 70.2% cells) and very rarely quadrivalents (0.07/cell) and hexavalent (0.05/cell) in ring configurations. The hybrid plants formed PMCs with aneuploid (hypoploids and hyperploids) and polyploid (n=1, 2, 3, 4, 5, 6, 8, 10, 12 and 14) chromosome numbers at diplotene and MI only which was attributed to the consequences of cytomixis (the phenomenon was also evident in female parent). Pollen fertility in F_1 plants was high (79.7% to 95.6%). Maity and Datta (2010) studied selfed progenies of F_1 hybrid (*C. capsularis* – male parent × *C. trilocularis* – female parent) were studied at F_2 and F_3 for different qualitative and quantitative traits as well as for meiotic configurations and it was found that F_2 and F_3 plants were similar to one another and did not vary significantly from F_1 plants..

F_1 hybrids were raised from 201 accessions belonging to 7 different species of *Corchorus* and it was observed that some cross combinations like *C. trilocularis* (WCIJ 109) × *C. olitorius* (JRO 524), *C. trilocularis* (WCIJ 65) × *C. olitorius* (JRO 524), *C. trilocularis* (WCIJ 72) × *C. olitorius* (JRO 524) were resistant to *Macrophomina* and meiotic analysis of hybrid plants revealed $2n$=14 (parents $2n$=14 uniformly) along with abnormalities like sticky bridges, univalent chromosome formation, clumped metaphase, presence of extra chromosome and elimination of chromosomes ($2n$=12) etc. (Anonymous 2009-10).

Hassan *et al.* (2010) employed 2 types of short natural fibres namely jute and betul nut fibres for the formation of short fibre reinforced polypropylene composites in different ratios (fibre content: 3, 5, 10 and 20%) by hot press moulding technique. Different jute-betul nut reinforced polypropylene hybrid composite were prepared in the ratio of 10:5, 10:10 and 10:15 wt% fibre content with 85%, 80% and 75% PP respectively for assessment of mechanical properties like tensile, bending and impact strength and it was found to show improve performance with respect to other composites.

Datta and Banerji (1960) reported on the cause of seed failure or seed setting in 4n cultivated *C. olitorius* × 2n cultivated *C. olitorius* and 4n cultivated *C. capsularis* × 2n cultivated *C. capsularis* and their reciprocal through cytogenetical studies. The causes documented were failure of pod set, lack of fertilization and degeneration of ovules. Datta and Choudhury (1966) also reported seed failure following hybridization between 4n *C. capsularis* (strain D. 154) and 3n *C. olitorius* (strain C.G) and its reciprocal due to pod shed and ovule degeneration.

Amphidiploids

Islam *et al.* (1973) isolated a spontaneous amphidiploids in the F_3 progeny of the cross, *C. olitorius* × *C. depressus*. Islam *et al.* (1981) failed to develop any plantlet in an attempt to produce polyploids through anther culture from a spontaneous amphidiploids of the hybrid *C. olitorius* × *C. depressus*. Maity and Datta (2010) induced an amphidiploids of F_1 (*C. capsularis* – male parent ×

C. trilocularis – female parent) following colchicines (0.50%, 6hrs treatment for 2 consecutive days) treatment and the marked plant showed similer qualitative traits as F_2 and F_3; however, it evinced reduced growth and low seed viability. The amphidiploids formed bivalents (12.95/cell) and univalents (2.10/cell) only. The amphidiploids produced 32 seeds and one plant could only be raised in the following generation which dried up at the prolonged vegetative stage after 68 days from sowing which open up the question about the potential genetic mechanism by which natural crossing and doubling of chromosome number give rise to new species.

Desynapsis

Paria *et al*. (1978) reported genetically (monogenic recessive) controlled desynaptic mutants for M_2 population (seeds of JRO 632 treated with 0.5% EMS followed by 20 kR X-ray irradiation) and the mutants were highly sterile, very late maturing plants with very small pods. Maity and Datta (2009b) screened a spontaneous desynaptic mutant (mutant trait monogenic recessive to normal) of *C. fascicularis* (1 out of 27 plants scored cytogenetically) from the natural population showing distinctive morphological variations than normal. Compared to normal plants, the mutant (medium strong type) demonstrated enhanced univalent frequency per cell (4.05, normal – 0.31), reduced number of chiasma (6.67, normal – 7.28) and bivalent (5.12, normal – 6.99).

Polyploids

Bhaduri and Chakravarti (1948) obtained tetraploids in both *C. capsularis* and *C. olitorius* following seed and seedling treatments with colchicines and the polyploids showed giganticism of several morphological characters but the number of ultimate fibres did not increase, though the total volume of fibre as compared to the diameter of the stem increased. Rao and Kundu (1949) and Nakajima (1949) obtained autotetraploids in *C. capsularis* following seed treatments with gammexane and colchicines respectively. Kundu and Sharma (1956) suggested that crosses between 4n *C. capsularis* and 4n *C. olitorius* in both the directions were unsuccessful. Basak and Biswas (1968) studied pairing behaviour of chromosomes in autotetraploid *C. olitorius* and reported that maximum number of quadrivalents per PMC varied from 3 to 5, 4 been the modal number and quadrivalent realization coefficient was 0.57. Quadrivalent configurations noted were ring, chain, spoon and figure of eight and their coorientation was linear, convergent, parallel and indifferent types. Chiasmata per chromosomes in 4n and 2n were found to be 0.89 and 0.93 respectively. Hossain and Sen (1978) reported that colchicine treatment (0.05% for 12 hrs.) to 15 days old seedling in the first generation after X-ray or gamma-ray exposure was lethal in contrast the same treatment to 15 days old seedling in the 2nd generation was effective in inducing polyploids. Several other workers (Panda and Datta 1962, Datta 1966) attempted to induce autotetraploid in cultivated jute species but in all cases yield of fibre in tetraploid families was significantly lower than that of the diploids.

Datta (1965) performed cytogenetical studies on autotriploid (2n × 4n) *olitorius* jute (strain chinsurah green) and found 2.48 I + 4.64 II + 0.58 III (Y shaped common) + 1.80 IV (ring and chain) + 0.064 VI + 0.064 fragments per cell. Other common (sticky bridge, laggards etc.) chromosomal abnormalities were also recorded including the formation of monads to octads with or without micronuclei. Pollen fertility and size and morpho-physiological parameters were studied in 3n in comparison to 2n and 4n. Haploidy in *C. olitorius* was also reported (Jacob and Sen 1961).

Trisomics

A trisomic in *C. capsularis* which showed dimorphic gametes with seven and eight chromosomes was described by Nandi (1937). Das and Iyer (1972) screen red pigmented trisomic (F_2 population) as well as green trisomic (F_3) from hybrid population of *C. olitorius* × *C. capsularis*, and on meiotic analysis it was found that green trisomics were with higher trivalent frequencies per PMC in contrast to red possessing enhanced univalent frequencies per meiocytes. No significant difference in chiasma formation was observed between red and green trisomics or between trisomics and their parental species. The authors were of opinion that segmental homology in the parental chromosomes probably resulted in varying degree of preferential pairing in the trisomic hybrid. Das (1972) also studied cytological behaviours of trisomic hybrids from F_3 and F_4 progenies of the cross between *C. olitorius* × *C. capsularis*. Paria and Basak (1979) identified all seven possible primary trisomics in jute (*C. capsularis*) chromosomally and morphologically and designated genes controlling anthocyanin pigment, crumpled leaf and palmate leaf shape on chromosome number 2, 3 and 4 respectively. Jute trisomic analysis was also made by several other workers (Swaminathan and Iyer (1961), Iyer (1968), Thakare *et al.* (1974), Basak and Paria (1980).

PLANT TYPE MUTATION

C. olitorius

Mutants namely, *crumpled leaf* (40 kR X-ray, tolerance to drought and non-shattering pod; Singh *et al.* 1973), *tobacco leaf* (50 kR X-ray, increased number of internodes; Singh *et al.* 1973), *narrow leaf* (60 kR X-ray + 1.0% EMS, small narrow deep green leaf; Chattopadhayay *et al.*, 1999), KOM 62 (gamma-ray induced, Chowdhury *et al.*, 2004) and *viridis* and thick stem (gamma-rays + EMS; Maity and Datta 2009c) amongst others were reported.

C. capsularis

Mutants like *stem fasciation* (Basak *et al.* 1971), *blue seed coat* and *snow white fibre* (Ahmed *et al.* 1983), *patchy albino leaf* (30 kR X-ray, rectangular fibre wedge; Singh *et al.* 1973), *ribbon leaf* (male sterile – Rakshit 1967), *leafy stipule* and *green seed coat* (Basak 1993), *cordate leaf* and *dwarf stem* (Basak 1993), *soft stem* (absence of lignified fibres, Chattopadhayay *et al.* 1999), *unfolded lamina* (50 kR X-ray, no lignifications in secondary phloem; Chattopadhayay *et al.* 1999), *short petiole* (efficient solar radiation utilize; Sinhamahapatra 2005), JRC 7447 (X-ray induced; Chowdhury *et al.* 2004), KC1 and Bidhan pat I (gamma-ray induced; Chowdhury *et al.* 2004) amongst others.

Inheritance of qualitative traits

Most of the qualitative traits in jute mutants were monogenic recessive excepting for *leaf surface, rolled leaf, fuzzy-seed coat* in *C. olitorius* and narrow leaf in *C. capsularis* which showed digenic mode of inheritance (Hazra and Karmakar 2008). Hazra and Karmakar (2008) were of opinion that genetics of anthocyanin pigmentation in jute was rather complex and about 56 and 44 qualitative genes in *C. olitorius* and *C. capsularis* respectively were involved.

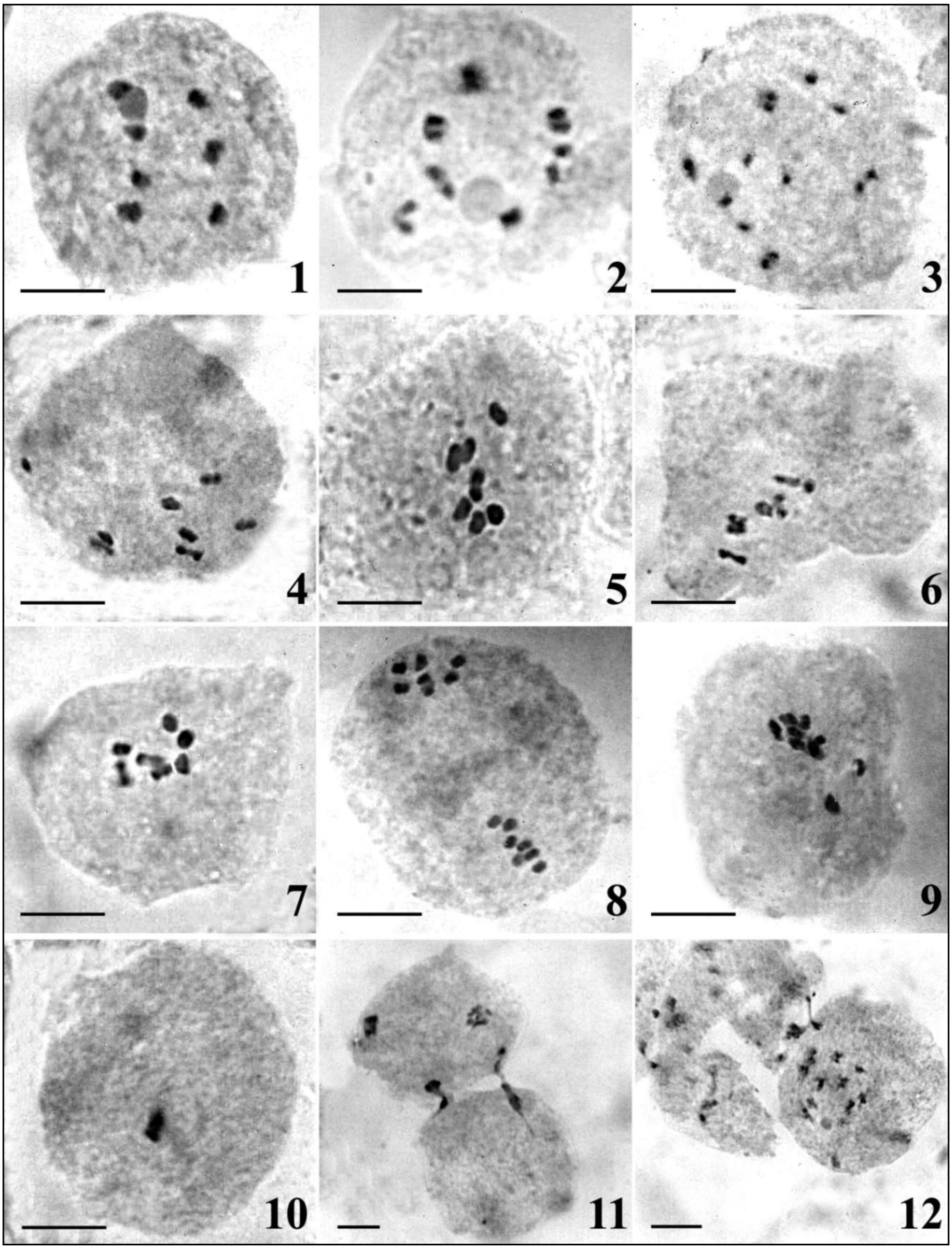

Figure Legends

Figure plate I (1-12) showing meiotic configurations **(Figs. 1-8: 2*n*=14)** in *Corchorus* spp. **(1-2)** 7II at diplotene; **(3)** 4II + 6I at diplotene; **(4)** 6II + 2I at MI; **(5-6)** 7II in 2II(3) + 1II(1): 4 group classes at MI; **(7)** 7II in 3II(1) + 2II(2) in 3 group classes at MI; **(8)** 7:7 separation at AI; **(9)** 9II at MI; **(10)** 1II at MI; **(11-12)** chromosome/chromatin migration between/among meiocytes – cytomixis. Scale bar = 10 µm.

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REFERENCES

Ahmed, S.; Ahmed, Q.A. and Islam, A.S. (1983). Inheritance study of fibre colour, disease resistance and water logging tolerance in *Corchorus capsularis* L. for breeding a variety with snow white fibre. *Bangladesh Journal of Botany*, **12:** 207-215.

Akhter, R.; Haque, M.I.; Sarkar, R.H.; Alam, S.K.S. and Haque, M.M. (1991). Karyotype analysis in diploid and colchicine induced tetraploids of *Corchorus olitorius* and *C. capsularis*. *Bangladesh Journal of Scientific Researches*, **21:** 183-188.

Alam, S.S. and Rahman, A.N.M.R.B. (2000). Karyotype analysis of three *Corchorus* species. *Cytologia*, **65:** 443-6.

Anonymous. (2009-10). Annual report 2009-10, CRIJAF, Barrackpore, Kolkata. P. 16.

Arangzeb, S. (1994). Cross compatibility of eight wild species of jute with cultivars and among themselves. Ph.D. Thesis, University of Dhaka, Dhaka, Bangladesh.

Arangzeb, S. and Khatun, A. (1980). A short note on inter-specific hybridization between *C. trilocularis* and *C.capsularis*. *Bangladesh Journal of Jute & Fibre Research*, **5:** 85-89.

Basak, S.L. (1993). Review on the genetics and breeding of jute. International Jute Organization. Dakha. Bangladesh. Pp. 1-167.

Basak, S.L. and Biswas, P.K. (1968). Pairing behaviour of chromosome in autotetraploid of jute (*C. olitorius* L.). *Cytologia*, **33:** 50-53.

Basak, S.L.; Jana, M.K. and Paria, P. (1971). Inheritance of some characters in jute. *Indian Journal of Genetics and Plant Breeding*, **31:** 248-255.

Basak, S.L. and Paria, P. (1980). Desynapsis and spontaneous trisomy in jute (*Corchorus olitorius* L.). *Theoretical and Applied Genetics*, **56:** 253-256.

Bhaduri, P.N. and Chakravarti, A.K. (1948). Colchicine induced autotetraploid in jute *Corchorus capsularis* and *Corchorus olitorius* and the problem of raising improved varieties. *Science and Culture*, **14:** 212-213.

Chattopadhyay, S.; Chaudhury, S.K.; Gupta, D.; Hazra, S.K.; Kumar,D.; Mahapatra, A.K.; Mandal, N. and Saha, A. (1999). Crop improvement. *In:* “Fifty years of research”. CRIJAF, Barrackpore. Pp. 40-63.

Chowdhury, S.K.; Kumar, D. and Saha, A. (2004). Varietal development and improved varieties of jute. CRIJAF publication, *Technical Bulletin Series*, **1:** 1-12.

Das, P.K. (1972). Trisomic analysis in jute cytological behavior of trisomic hybrids from F_3 and F_4 progenies of the cross between *Corchorus olitorius* and *Corchorus capsularis*. *Nucleus*, **15:** 163-7.

Das, P.K. and Iyer, R.D. (1972). Studies on trisomics in a jute hybrid. *Genetica*, **43:** 473-88.

Datta, R.M. (1952). Meiosis in *C. capsularis*. *Science and Culture*, **18:** 385-386.

Datta, R.M. (1965). Cytogenetical studies on autotriploid (2n × 4n) *olitorius* jute (*Corchorus olitorius* Linn. strain chinsurah green). *Theoretical and Applied Genetics*, **34:** 335-340.

Datta, R.M. (1966). Investigation on the autotetraploids of the cultivated and the wild types of jute **(***Corchorus olitorius* Linn.and *C. capsularis* Linn.**)**. *Theoretical and Applied Genetics*, **33:** 17-33.

Datta, R.M. and Banerji, S.N. (1960). On the cause of seed failure or seed setting in 4n cultivated *Corchorus capsularis* L. X 2n cultivated *C. capsularis* and 4n cultivated *C. olitorius* L. X 2n cultivated *C. olitorius* and their reciprocals through cyto-genetical studies. *Genetica*, **31:** 385-409.

Datta, R.M. and Choudhury, M.R. (1966). Seed failure following hybridization between 4n *Corchorus capsularis* L. (strain D. 154) and 3n *C. olltorius* L. (strain C. G.) and its reciprocal and some cytonetical observations. *Biology Bulletin of the Academy of Sciences Bohemoslov,* **8:** 288-91.

Datta, R.M. and Sen, S.K. (1961). Interspecific hybridization between *Corchorus sidoides* F. Muell. and *C. siliquosus* L., a natural polyploidy. *Euphytica,* **10:** 113-119.

Datta, R.M.; Mukhopadhaya, D.; Panda, B.S. and Sasmal, P.K. (1975). Cytotaxonomic studies of different *Corchorus* (jute) species. *Cytologia,* **40:** 685-692.

Edmonds, J.M. (1990). Herbarium survey of African *Corchorus* species: Systematic and eco-geographic studies in crop gene pools. International Board of Plant Genetic Resources. Rome, Italy. Pp. 2-3.

Faruqui, S. (1962). Interspecific hybridization between *C. olitorius* and *C. walcotti* F.V.M. and *C. trilocularis* × *C. capsularis*. M.Sc. Thesis, Sind University, Pakistan. P. 105.

Ganguli, J.K. (1945). A note on the secondary association of chromosomes and the basic number in *Corchorus capsularis. Science and Culture,* **11:** 272.

Hassain, M.M.; Wagner, M.H.; Zaman, H.U. and Khan, M.A. (2000). Study on the performance of hybrid jute/betel nut fiber reinforced polypropylene composites. *Journal of Adhesion Science and Technology,* **25:** 615-626.

Haque, M. and Islam, A.S. (1970). Some promising material among F_4 and back-cross derivatives of the natural hybrid *C. aestuans* × *C. olitorius*. *Sindh University Research Journal (Science Series),* **4:** 97-107.

Hazra, S.K. and Karmakar, P.G. (2008). Cytogenetics, mutagenesis and genetics of qualitative characters of jute and allied fibres. *In:* Jute and Allied Fibres Updates: Production and Technology. Karmakar, P.G., Hazra, S.K., Ramasubramanian, T. Sinha, M.K. and Sen, H.S. (Eds.). Pp. 46-56.

Hossain, M. and Sen, S. (1978). Radiation induced high fibre yielding chlorophyll mutant in jute. *Indian Journal of Genetics and Plant Breeding,* **38:** 179-181.

Islam, A.S.; Jahan, B. And Chowdhury, M.K.U. (1981). Attempt to produce polyploids from a spontaneous amphidiploid of the jute hybrid, *C. olitorius* × *C. depressus. Bangladesh Journal of Botany,* **10:** 63-68.

Islam A.S. and Rashid, A. (1960). First successful hybridization between the two jute yielding species, *Corchorus olitorius* (Tossa) × *C. capsularis* (White). *Nature,* **185:** 258-259.

Islam, A.S. and Sattar, M.A. (1961). Interspecific hybridization in the genus *Corchorus*: *C. aestuans* × *C. capsularis,* (pp. 6-7) Proceeding XIII Pakistan Science Conference, Dacca, Pakistan, 11 January 1961. Dacca.

Islam, A.S.; Shah, N. and Haque, M. (1973). Origin of spontaneous amphidiploid in the F_3 progeny of the cross, *C. olitorius* × *C. depressus. Bangladesh Journal of Botany,* **2:** 41-50.

Iyer, R.D. (1968). Towards evolving a trisomic series in jute. *Current Science,* **37:** 181–183.

Jacob, K.T. and Sen, S. (1961). Haploidy in jute (*Corchorus olitorius* L.). *Nature,* **192:** 288-289.

Karmakar, P.G.; Hazra, S.K.; Ramasubramanian, T.; Mandal, R.K.; Sinha, M.K. and Sen, H.S. (2008). Jute and Allied Fibre Updates: Production and Technology. CRIJAF, Brrackpore, India. 327p.

Khatun, A. (2007). Recent agricultural developments in jute, kenaf and mesta through traditional and biotechnological approaches. pp. 1-13. A seminar on jute and kenaf held in Myanmar organized by the Ministry of Agriculture and Irrigation, Myanmar Jute Industries and the International Jute Study Group (IJSG). Myanmar. 7 February 2007.

Kumar, D.; Paria, P. And Basak, S.L. (1981). Genotypic control of chromosome behaviour in *Corchorus olitorius* L. *Cytologia*, **46:** 643-647.

Kundu, B.C. (1951). Jute — world's foremost bast fibre, II. Technology, marketing, production and utilization. *Economic Botany*, **10:** 203-240.

Kundu, B.C. and Sharma, M.S. (1956). Studies on colchicine induced tetraploids of *Corchorus olitorius* Linn. (Jute). *Journal* of the *Indian Botanical Society,* **33:** 11-26.

Mahapatra, A.K. and Saha, A. (2008). Genetic resources of jute and allied fibers crops. Jute and allied fibers updates: production and technology. Barrackpore, Kolkata. P. 327.

Mahapatra, A.K.; Saha, A. and Basak, S.L. (1998). Origin, taxonomy and distribution of *Corchorus* species in India. *Green Journal,* **1:** 64-82.

Maity, S. and Datta, A.K. (2008). Cytomorphological studies in F_1 hybrids (*Corchorus capsularis* L. × *Corchorus trilocularis* L.) of jute (Tiliaceae). *Comparative Cytogenetics*, **2:** 143-149.

Maity, S. and Datta, A.K. (2009a). Meiosis in nine species of jute (*Corchorus*). *Indian Journal of Science and Technology,* **2:** 27-29.

Maity, S. and Datta, A.K. (2009b). Spontaneous desynapsis in *Corchorus fascicularis*. *Indian Journal of Science and Technology,* **2:** 34-36.

Maity, S. and Datta, A.K. (2009c) Induced viable macromutants in *Corchorus capsularis* L. *Journal of Phytological Research,* **22:** 43-46.

Maity, S. and Datta A.K. (2010). Cytomorphological studies in F_2, F_3 and induced amphidiploid of jute (*Corchorus trilocularis* L. X *Corchorus capsularis* L.). *Nucleus,* **53:** 85–87.

Nakajima, G. (1949). Tetraploid plants of jute and China jute raised by colchicine method. *Japanese Journal of Genetics,* **2:** 121-131.

Nandi, H.K. (1937). Trisomic mutation in jute. *Nature*, **140:** 973-974.

Panda, B.S. and Datta, R.M. (1962). Meiotic chromosome pairing in the population of 2n × 4n *Corchorus olitorius* strain C.G. *Indian agriculturist,* **6:** 31-34.

Paria, P. and Basak, S.L. (1973). Genotypic control of chromosome behavior in *Corchorus capsularis*. *Nucleus,* 16: 210-5.

Paria, P. and Basak, S.L. (1979). Identification of seven primary trisomic of jute. *Indian Journal of Genetics and Plant Breeding,* **39:** 178-187.

Paria, P.; Basu, M.S.; Chattopadhyay, S. and Basak, S.L. (1978). Genetic control of artificially induced desynapsis in jute (*Corchorus olitorius* L.). *Current Science*, **47:** 916-917.

Purseglove J.W. (1968). Tropical Crops. Dicotyledons 2. Longhman, London, 613–618.

Rakshit, S.C. (1967). Induced male-sterility in jute (*Corchorus capsularis*). *Japanese Journal of Genetics,* **42:** 139-142.

Rao, N.S. and Datta, R.M. (1953). Chromosomes of the genus *Corchorus*. *Nature,* **13:** 754.

Rao, N.S. and Kundu, B.C. (1949). Effect of gammexane on the root-tips of *Corchorus capsularis* Linn. *Science and Culture,* **14:** 484.

Samad, M.A.; Kabir, G. and Islam, A.S. (1992). Chromosome banding in two species of *Corchorus* and their F1 hybrid. *Bangladesh Journal of Botany,* **9:** 113-117.

Sharma, M.S. and Datta, R.M. (1953). Complex chromosome mosaic and variable microsporocytes in *C. capsularis* L. *Science and Culture,* **10**: 202-203.

Sharma, A.K. and Roy, M. (1958). Cytological studies on jute and its allies. I Agron. Lusitana 20, 5-15.

Singh, D.P.; Sharma, B.K. and Banerjee, S.C. (1973). X-ray induced mutations in jute (*Corchorus capsularis* and *Corchorus olitorius*). *Genetica Agraria*, **27:** 115-147.

Sinhamahapatra, S.P. (2005). Development of desirable strain in jute *C. capsularis* L. using mutants in cross breeding. *Journal* of *Nuclear Agriculture and Biology*. **34:** 111-114.

Swaminathan, M.S. and Iyer, R.D. (1961). Skewed recombination in a rare interspecific hybrid. *Nature,* **192:** 893-894.

Thakare, R.G.; Joshua, D.C. and Rao, N.S. (1974). Radiation induced trisomics in jute. *Indian Journal of Genetics and Plant Breeding,* **34:** 337–345.

Wallace, D.R. (1909). Romance of jute 1909 cited in *Jute in India* by B.C. Kundu, K.C. Basak and P.B. Sarkar. Indian Central Jute Committee. Calcutta. P. 4.