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Researches on Jute and Allied Fibre Plants

Zakaria Ahmed, Firoza Akhter, M. Ashraf Hussain, Md. Shamsul Haque,
M.M. Alamgir Sayeed and M.A. Quashem
Bangladesh Jute Research Institute, Manikmia Avenue, Dhaka-1207, Bangladesh

Abstract: A pectinolytic fungus identified as *Aspergillus niger* was isolated from jute softening bin of a jute mill. Enzyme treated low-grade jute could be blended in higher amounts with superior quality jute without any adverse effect on the blended product. Polyester resin forms an intimate bond with jute fibres up to a maximum fibre : resin ratio (v/v) of 60:40. Significant improvement in mechanical properties of jute fibre composites was observed by incorporation of polyesteramide polyol. Hybrid laminates (10-ply) containing 8 inner plies of untreated/silane/titanate/TDI treated jute fibre sandwiched between two outer plies of glass fibre (weight content of jute : 25-27%) are made. Although there exists a good potential of jute-glass hybrid composites. Whereas, for resin with jute, the ratio maintained is 3.5-4:1. The preferred natural fibre is jute in the form of needled jute felt. An acidic xylan from 4% alkali soluble fraction of unretted jute bark (a hybrid derivative from intervarietal cross of *Corchorus capsularis* and *capsularis* blue seeded). Dioxane acidolysis lignin of jute stick was isolated. Jute seed cake, was low in protein and high in lysine, isoleucine and fibre content. Qualitative improvement of low grade jute and jute cuttings using a crude enzyme preparation from *A. niger*. Induced changes in the genetic architecture of some macro mutants of jute.

Key words: Jute, research, allied fibre, pectinolytic fungus, *Aspergillus niger*

Enzyme application on jute: Jute is a strong, and stiff natural fiber. Low-grade jute fibres are mainly used for sacking weft batches. In processing technology these fibres draw least attention of the millers. When jute is blended with cotton, it makes a sturdy but prickly fabric due to protruding surface jute fibers. Samples of jute-cotton blended fabric were treated with commercial cellulases, xylanases and pectinases individually and in combination at various concentrations in order to smooth and soften the fabric. Sheikh *et al.* (1998) used enzymes to improve the softening of hard fibres for further processing. The enzymes were extracted by fermenting indigenous wheat bran as substrate with the fungi, *Aspergillus* spp. The carding effect was improved by introducing higher pin density at the sacking finisher card. By pretreatment with *A. terreus* enzyme, 36.37% jute cutting was used in hessian weft batch which reduced the batch cost without impairing yarn quality and production efficiency. Researchers carried out an enzyme treatment at 50°C in the presence of 0.1M phosphate buffer (pH 7.0) for 3h where addition of commercial cellulases alone extensively removed protruding jute and cotton fibers from the fabric, whereas addition of commercial pectinases or xylanases mainly loosened the protruding long jute fiber bundle. Combined treatment of pectinases and xylanases with reduced amounts of cellulases was equally effective as high levels of cellulases in the removal of surface protruding fibers. The amount of reducing sugar released correlated with removal of fibers from the fabric surface. Thus, the fabric surface was smoother in enzyme-treated samples compared to untreated control and treated with mixtures of enzymes were more effective than cellulase alone. Sarker *et al.* (1996) studied the heterogeneity in protein banding profiles among wild and cultivated species of jute by polyacrylamide gel electrophoresis (PAGE). Such electrophoretic patterns for each plant material has been found to be different in respect of their number, mobility and intensity of bands. Isozyme analysis with peroxidase, esterase and acid phosphatase activity also produced unique band patterns regarding their profiles, intensities and number in different *Corchorus* species. Thus electrophoretic and isozyme techniques can successfully be used to characterize different wild and cultivated *Corchorus* species. In 1998, Singh and Bisaria studied nitrate reductase activity (NRA), growth and yield in terms of fibre and wood weight in 8 cultivars of two species of Jute (*C. capsularis* and *C. olitorius*) under different subdued light. It was observed that NRA, growth and fibre yield decreased significantly with the reduction in light intensity. However, different cultivars responded differently to subdued light. Among the cultivars examined, maximum fibre yield and NRA was recorded in JRO 632 while the lowest in chlorina -1 under normal and light stress conditions. Positive correlation was obtained between NRA, fibre yield and growth under normal as well as low light treatment. NRA was also measured in the leaves of different bast fibres yielding plants and established optimum conditions for the assay of enzyme activity. Maximum NRA was obtained at pH 7.4 in Jute (*C. capsularis* and *C. olitorius*) and in Sunnhemp (*Crotalaria juncea*). On the other hand in Kenaf (*Hibiscus cannabinus* and *H. sabdariffa*), the highest activity of NR was found at pH 6.4. Study with electron donors revealed the presence of different forms of enzyme (NADH-NR and NAD(P)H-NR) in different test crops. Optimum NRA was observed at 35°C in both species of Jute and kenaf and at 40°C in Sunnhemp. At higher incubation temperature NRA decreased in all species. Two species, *C. capsularis* and *H. cannabinus* were found to be more heat tolerant. Both species of Jute and kenaf require higher nitrate content for maximum production of nitrite than in Sunnhemp. This study revealed as little as 0.05g of leaf tissue is sufficient for NR determination. Gokhale *et al.* (1998) studied the use of yeast cellulase-free xylanase for treatment of different agricultural waste residues including corn cob powder, raw jute fibers and sugarcane bagasse pulp where it was found that the high degree of hydrolysis (19.4 %) was achieved by using 22IU ml/l yeast xylanase in the case of treated bagasse pulp. Corn cob powder and raw jute fiber showed a slower rate of hydrolysis under the same conditions. The enzymatic hydrolysis was carried out using citrate buffer (50mM, pH 4.5) at 52-53°C for different time intervals. The hydrolysis products were analyzed by HPLC, and xylose was found to be the major end product with traces of xylobiose and xylotriose at the beginning hydrolysis (Gokhale *et al.*, 1998). Nitrate reductase activity (NRA) in the leaves of 19 different cultivars of jute (*C. capsularis* and *C. olitorius*) seedlings were studied in relation to yield characters where NRAs showed positive correlation with the yield characters. It was found that fibers and wood weight per plant and yield potential in term of fibre weight could possibly be related with nitrate reductase activity at seedling stage.

It is demonstrated that the stability of cellulolytic and hemicellulolytic enzymes from *Macrophomina phaseolina* improved on immobilization and was 1.5 to 2-fold more active against pre-treated wheat bran, rice bran or jute powder. The hydrolysis efficiency of the catalyst increased with a decrease in its particle size. About 80% (w/v) of the sugar obtained from wheat bran was assimilated by *Saccharomyces* sp., whereas the corresponding values for rice bran and jute powder were about 70 and 50% (w/v), respectively. Alam *et al.* (1994) isolated *Thermomyces lanuginosus* and *Thermoascus aurantiacus* from self-heated jute fiber stalk and were studied for xylanase production using various lignocelluloses under solid-state fermentation where *T. lanuginosus* produced cellulase-free xylanase, whereas *T. aurantiacus* produced a small amount of cellulase in addition in unsupplemented wheat bran at 55°C. Both xylanases displayed remarkable pH (5.0 to 11.0) and thermal stabilities by retaining most of their activities even after having been subjected to temperatures much higher than their optimal. Furthermore, they remained active under prolonged storage, having no loss of activity after 1 month of storage at 4°C and retaining up to about 90% after 10 days at 55°C. Xylanase from *T. lanuginosus* was found better and produced a softer and mechanically stronger final product than that from *T. aurantiacus* when both were applied to low-quality jute fiber. *Thermomyces lanuginosus*, was isolated from self-heated jute stacks in Bangladesh and studied for production of high level of cellulase-free thermostable xylanase at 50°C using xylan where the enzyme was almost stable over a broad range of pH 3-9 at 20°C, with an optimum stability at pH 6.5. After 51h heating at 50°C the enzyme retained 60, 100 and 90% activity at pH 5.0, 6.5 and 8.0, respectively. The crude enzyme could hydrolyze xylan effectively and in only 6h 67.3, 54.0 and 49.2% saccharifications were achieved for 2, 5 and 10% substrate levels, respectively and the principal product of hydrolysis was xylobiose together with smaller amounts of xylooligosaccharides (degree of polymerization 3-7) and xylose. A pectinolytic fungus identified as *Aspergillus niger* was isolated from jute softening bin of a jute mill. It produced 2.26, 2.12 and 0.42 IU/ml polygalactouronase, xylanase and carboxymethyl cellulase, respectively, in solid state fermentation on wheat bran. The enzymes were extracted from fermented bran by adding five volumes of water containing 1% (w/v) sodium chloride and preserved at room temperature with 0.1% (w/v) sodium azide. Addition of enzyme solution reduced the softening time by 50% over conventional chemical treatment. Enzyme pre-treated fibre showed appreciable improvements in physico-mechanical properties in terms of fibre fineness and quality ratio, but had unaltered bundle strength. Enzyme treated low-grade jute could be blended in higher amounts with superior quality jute without any adverse effect on the blended product. The addition of 3mg/l of nordihydroguaiaretic acid (NDGA) to BAP and tyrosine fortified MS medium was essential to obtain organogenic callus from the hypocotyl segments of two varieties (D-154 and CVL-1) of *C. capsularis*, one of the two jute species. When the organogenic callus, which is rich in large starch granules, was transferred to MS basal medium, it differentiated into single or multiple shoots usually in the first subculture and sometimes in the second. The activity of glyoxalase-I of the organogenic callus was found to be significantly lower than that observed in the non-organogenic callus initiated on MS medium supplemented with 2,4-D, tyrosine, BAP or just BAP and tyrosine. This suggests an inverse relationship between differentiation and the level of glyoxalase-I activity in the two varieties of *C. capsularis* jute. Protoplasts were isolated from cotyledon, hypocotyl and mesophyll cells of *C. capsularis*, a major fibre crop, by one step enzyme digestion method (Saha and Sen, 1992). They were further cultured successfully on modified KM-8p medium to form microcalli. The required cultural conditions could be used to achieve 34 to 78% plating efficiency, depending upon the source of protoplasts. Hypocotyl protoplasts gave the highest plating efficiency. On transfer to regeneration medium, somatic embryos developed at high frequency. This success is a significant step forward in the development of meaningful plant cell culture methods for application in jute.

Saccharification of agricultural cellulosic wastes using enzymes from *Aspergillus terreus* was studied by Ali *et al.* (1991). When jute stick was used as substrate, 54% saccharification was achieved by using 5% alkali treated substrate at pH 4.0 and at 50°C after a period of 24h hydrolysis. Glucose and xylose were the main products of jute stick hydrolysis, no cellobiose was detected in hydrolysate. Among the cellulosic substrates tested, sugar cane bagasse showed the highest degree of saccharification. Commercial enzyme preparations, viz. Pectinex ultra Sp-L and Flaxzyme consisting predominantly of pectinolytic enzymes were found to ret green jute ribbons within 48h, producing fairly good quality jute fibres. The commercial enzyme Celluclast, consisting mainly of cellulase, hemicellulase and a relatively low proportion of pectinase was, on the other hand, ineffective in bringing about similar retting. A 50-fold dilution of both Pectinex ultra Sp-L and Flaxzyme was able to ret ribbons of jute plants of 105-115 days old, producing fibres having a fineness in the range of 1.6-1.7 tex and a tenacity of bundles in the range of 23-25 g/tex. The fibres produced were totally free of barky root ends. Metal complexing agents such as citrate phosphate buffer and EDTA were found to stimulate enzymatic retting thereby helping to reduce effective enzyme concentration. The ret-liquor containing the retting end products were partially analyzed. Amongst the monosaccharides, galacturonic acid was most predominant followed by glucose, arabinose, galactose and xylose and amongst the gummy polysaccharides, pectin was most conspicuous (Majumdar *et al.*, 1991).

Genetic investigation: Reproductive effort (RE) of a day-length neutral mutant TCJ-5, its parent, and two other cultivars of jute (*C. capsularis*) was estimated as reproductive biomass/aerial biomass. Plant height at flowering and aerial biomass were significantly higher in the mutant, while the reproductive biomass at 55 days after flowering was statistically equal. Therefore, the estimated RE was significantly lower in the mutant compared to the parent and other cultivars. The lower RE of the mutant was due to delayed initiation of flowering and additional vegetative growth in this period. The results showed alteration of RE by a recessive mutation. Previous study reported on the improvement jute productivity, and on the locating of sources of suitable quantitative-trait genes in the jute collection where 216 accessions of *C. capsularis* and 192 accessions of *C. olitorius* were evaluated for four yield and quality linked morpho-physiological traits. He estimated the germplasm diversity, phenotypic (PCV) and genetic (GCV) coefficients of variation, broad sense heritability (h-2) and genetic advance (GA) with respect to origins and traits. Irrespective of origins all the traits showed more than 60-80% diversity in both species. Trait means of diversity were significant but not the origin means. Generally, only slightly higher PCV values than GCV were obtained for all the traits in both the species. High h-2 values ranging from 50% to more than 98% were also found. All the traits can be simultaneously utilized for genetic gain. Most of the *C. olitorius* accessions with two times higher GA estimates than those of the *C. capsularis* are likely to be more successful for that matter. Maximum genetic gain is expected from mutants of China, Brazil, India, Thailand, Nepal and Burma in *C. capsularis* than the mutants from Thailand, Tanzania and Kenya. Other countries in *C. olitorius*. *C. capsularis* mutants with high heterogeneity for most of the traits should be useful for finding many rare alleles. Inheritance studies on fibre yield, plant height, base diameter and node number of a nine parent diallel cross of *C. olitorius* were done where they elucidated that these characters are mainly controlled by additive genetic variances and such genetic variances were more stable over the years than those of dominance variances. A 12 times 12 half-diallel cross of *C. olitorius* showed the predominant role of additive type of gene action in the inheritance of fibre strength. To find out low temperature tolerant genetic resources, 1000 accessions of *C. olitorius* were studied through their seed germination at 16°C and other related growth parameters by Begum *et al.* (1998). Out of 1000 accessions 13 were identified with low temperature tolerance. Base temperature of four selected accessions 1540, 1805, 1852 and 2015 and two cultivars, 0-4 and 0-9897 were determined as 16.0, 15.5, 17.5, 16.5, 22.5 and 21.5°C respectively. The growth parameters of the accessions grown in pots in a growth chamber at 16°C were recorded. Only the selected accessions emerged on the sixth day after sowing (DAS) where, the cultivars failed to germinate at that low temperature. The primary root length of 2015 was found to be higher than those of other three accessions at all the stages of growth. Maximum shoot length was obtained in 1805 at 35 DAS and highest dry weight/plant was also recorded in 1805 (Begum *et al.*, 1998). From the studies of the nature of induced changes in the genetic architecture of five established macro mutants from a nine-parent diallel cross in *C. olitorius* jute for fibre yield, days to flower and average leaf area, it was found that the combining ability analysis revealed that each of the five mutants, although originated from the same mother cultivar, JRO-632, had different induced genetic background. Since these induced changes were not unidirectional, it may be concluded that these induce macro mutants can provide a wide array, a new genetic variability for breeding in a self-pollinated crop like jute.

Parameters for correlated inheritance of 12 quantitative characters in jute were studied with 54 varieties by means of genetic design of one factor (genotype). Heritabilities in broad, narrow and practical senses of each character and the correlated heritability between the characters were analyzed and compared. The relative efficiency of indirect selection on dry bark yield through other characters was also estimated. In addition, analysis for principal components and calculation for genetic correlation information (GCI) and genetic correlation contribution (GCC) were also performed. It is revealed that the three main quantitative characters, i.e., branch height, fresh stem weight and days to harvest, are the most important ones in the composition and for the selection of dry bark yield. Genetic studies on pigmentation of stem was carried out by Ahmad (1997) in kenaf where the crosses, green times red and green times green-pigmented stem yielded two different kinds of ratio i.e., 3:1 and 9:3:4 indicating the complex nature of inheritance. For elucidating the genetic control of the embryo weight and general role of the endosperm in seedling vigor and crop establishment, two sets of diallel crosses (5 times 5 and 6 times 6) including reciprocals were analyzed by Gupta *et al.* (1996). In view of predominant maternal and reciprocal effects the expressions of genetic components such as additive and dominance were found inconsistent. Predominance of maternal and reciprocal effects on endosperm was observed. The influence of pollination and maternal effects were observed as important in either decreasing or increasing the weight of the embryo and the endosperm (Gupta *et al.*, 1996). It is studied that the induced mutant characters of jute (*C. olitorius*) such as, chlorina, virescent, yellow, patchy albino leaf colour, waxy leaf surface, ribbon, cordate, trifid leaf forms; distant and extreme leaf serration, dwarf, stiff, lazy stem, drooping top, bushy stem, white stem; foliaceous stipule; white flower and round pod and all monogenic recessive in nature. They stated that the F2 generation of their crosses with the genotypes having wild type characters segregated into 3:1 ratio for each mutant characters detecting no linkage amongst these mutants. Chakraborty *et al.* (1996) observed the genetic variability among nine *C. olitorius* jute strains at 7 growth stages starting from 30th to 120th day. A few strains showed slow initial growth but had high growth rate later, while other strains showed opposite trend in respect of plant height, basal diameter, bark weight, and dry fibre weight. Tanganika was the best among the strains studied. The growth at one stage was significantly different from that in subsequent stages. Bark weight showed positive correlation with plant height, basal diameter, and dry fibre weight. While, Kumar and Palve (1995) stated that diallel cross involving eleven genotypes of white jute (*C. capsularis*) revealed predominant role of additive gene action in the inheritance of all the characters, except basal diameter. In the study of genetic variability and association of component characters for seed yield in olitorius jute, Dastidar *et al.* (1994) indicated that pod length, seeds per pod, seed weight per pod, 100 seeds weight and days to 50% flowering were likely to be operated by non-additive gene action in *Olitorius* jute. Correlation study indicated that the seeds of late flowering genotypes have higher volume than the early flowering genotypes. It is also suggested that good pod length is required for more number of seeds per pod as well as high seed weight per pod. From the path-coefficient analysis it is suggested that a medium flowering genotype with high 100-seeds weight, followed by seeds per pod and pod length is the most suitable for better seed production in olitorius jute. Chaudhury and Sasmal (1992) studied the heterosis in relation to gca and sca in a 14 times 14 diallel for fibre strength in tossa jute (*C. olitorius*). Manifestation of heterosis in general was very low, but a definite trend was observed in relation to genetic divergence of the parent. The importance of both additive and non-additive gene effects was evident in the inheritance of fibre strength. The per se performance of the parents was highly associated with their gca effects. Among the parents Tanganika-1, 1C, 15901, JRO 632 and Bangkok were the best general combiners for fiber strength. In most of the crosses with significant sca effects involved one parent with high gca effect. The promising crosses were JRO 632 times JRO 620, Bangkok times Tanganika-1, Tanganika-1 times JRO 620, Bangkok times JRO 524 and Bangkok times JRO 620. As both additive and non-additive gene effects played role in the inheritance of fiber strength, their simultaneous exploitation through adoption of biparental approach in early generation mating is advocated (Chaudhury and Sasmal, 1992).

From an eight parent diallel cross in *C. olitorius*, the genetic architecture of some induced mutants (crinkle leaf, palmate leaf, tobacco leaf, short internode and tall mutant) was studied (Dastidar, 1990) for plant height only. A significant negative correlation between parental measurements and parental order of dominance indicated that the mutated locus in the heterozygous condition showed no deleterious effect on plant height. It is suggested that the mutants, palmate and crinkle can be used as parents in future hybridization programme. Rate of out crossing was estimated in F-2 generation of 5-parent half diallel including parents as well as in F-2 of 5 times 5 line times tester crosses of jute (*C. olitorius*). The nature of variability among different crosses of two mating designs suggested polygenic control for the rates of out crossing. Heritabilities in broad sense for this character were 19.1 and 22.1% in diallel and line times tester mating designs, respectively (Basak and Paria, 1989). From a nine parent diallel cross in olitorius (*C. olitorius*) jute the genetic architecture of some radiation induced mutants (Dwarf, Ornamental, palmate, Crinkle and Irregularis) was studied (Dastidar *et al.*, 1989) for various characters. While the mutant palmate was found to be a good general combiner for base, middle and wood diameters; the mutants crinkle and irregularis were good general combiners for earliness. Crinkle and palmate were good general combiners for fibre: wood ratio and branch number, respectively. On the basis of the per se performance, most of the best five crosses were either intermutant, or in combination with a mutant, as one of the parents. Presence of the mutant crinkle is marked in all the characters. It is suggested that three intermutant crosses (Palmate times Irregularis, Dwarf times Palmate and Dwarf times Crinkle) and two crosses with one of the parents as mutant (JRO-632 times Crinkle and Ornamental times Sudan green) could be used for exploitation of heterosis.

Microbiological study: Akhter and Mandal (1996) isolated a number of aerobic and anaerobic bacteria assessed at the rhizosphere of three species of jute, (*C. capsularis* var. CVL 1, *C. olitorius* var 0-4 & 0-9897), Mesta (*H. sabdariffa* var. Hs-24) and Kenaf (*H. cannabinus* var. C-95) grown in field at different stages of growth varied significantly. The density of bacteria was remarkably higher for tall plants than dwarf plants irrespective of the varieties of plants and stages of growth. Number of bacteria appeared in the strain order CVL-1> 0-4> 0-9897> HS-24> C-95 and seed stage > vegetative stage > flowering stage for aerobic and vegetative stage > flowering stage > seed stage for anaerobic bacteria. The single and combined effects of *Azospirillum brasilense* and *Bacillus megaterium* were studied by Ganguly *et al.* (1999) where inoculations were seen in pot trials for two consecutive years taking jute (*C. olitorius*), cowpea (*Vigna unguiculata*), wheat (*Triticum durum*) in clay loam soils of *Aeric haplaquept*, to test the

agronomic potential by application of different amounts of nitrogen and phosphorus. The inoculation as well as nutrients at lower doses produced considerable yields including the biometrics like height and base diameter in jute. The residual crop yields (cowpea and wheat) also increased accordingly. The nitrogen fixation and *A. brasilense* count in the root rhizosphere after harvest of jute increased under low fertility regime and both of them maintained significant correlation (r= 0.745). The pH of retting effluent of three varieties of jute (*C. capsularis* and *C. olitorius* var. 0.4 and 0-9897). Kenaf (*H. cannabinus* var. C-95) and mesta (*H. sabdariffa* var. HS-24) the application of retting effluent and urea showed a sharp fall within 7 days followed by a rapid rise at 14 days and thereafter a moderate increase at the end of retting. Addition of this retting effluent and urea to fresh samples reduced about one third of the retting period. Number of both aerobic and anaerobic bacteria, and fungi in the retting effluent decreased with increase in retting period. Incorporation of urea improved the colour of the fibre too (Akhter and Mandal, 1997). *In vitro* antifungal activities of volatile and non-volatile metabolites of 14 isolates of blue-green algae have been screened against three jute pathogens. Antifungal activity of volatile metabolites was detected in 11, 14 and 13 isolates of blue-green algae against *Macrophomina phaseolina* (Tassi) Goid, *Rhizoctonia solani* Kuhn, and *Sclerotium rolfsii* (Succ.) Curzi respectively. No antifungal activity was detected in the volatile metabolites of *Calothrix marchica* Dh160, *Fischerella muscicola* Dh145, *Nostoc* sp. Dh148 on *M. phaseolina* and of *Hapalosiphon* sp. Dh147 on *S. rolfsii*. Non-volatiles of all the jute field blue-green algae showed less inhibitory activity or no inhibition against the jute pathogens.
Changes in carbohydrate, amino acid and phenolic contents in jute plant on inoculation with *Macrophomina phaseolina, Colletotrichum corchori* and *Botryodiplodia theobromae* were studied. Total sugars, non-reducing sugars, starch and total free amino acids were found to decrease on inoculation with all the three test pathogens of jute, while reducing sugars, total phenols and orthodihydric phenols increased (Shahabuddin and Anwar, 1992). Retting of jute plants in pond water brings about ecological changes due to biochemical degradation and consequent release of nutrients in the ambient water. Sharp increase in bacterial load of different groups of bacteria has been observed both in water and bottom sediment during retting. Counts for heterotrophic bacteria, phosphate solubilizing bacteria, aerobic nitrogen fixing bacteria and denitrifying bacteria, prior to retting, during retting, and 75 days after the release of fish in the pond have been presented in the paper. Decrease in DO and pH, and increase in organic carbon, carbon dioxide, bicarbonate, ammonia, nitrate and phosphate in water are the attendant conditions to the process of retting (Das *et al.*, 1989).

Biochemical investigation: Islam *et al.* (1996) studied that in hemicelluloses, isolated from the different jute samples at different intervals starting from unretted green ribbons to over retted fibres, it appeared that the percentage of hemicelluloses decreased gradually with the increase of retting time. The paper chromatographic identification of sugars from hydrolysates of the isolated hemicelluloses indicated that some compositional changes of hemicelluloses took place during retting of jute. Mohiuddin *et al.* (1978) estimated the lignin contents of jute cuttings in the white and Tossa varieties of Bangladesh jute by H_2SO_4 method where the White varieties were found to contain more lignin then the Tossa varieties. It was also found that the harder and stiff cuttings contain more lignin than the softer jute cuttings and lignin and ash content were found higher in cuttings before retting than that of cuttings after retting.

Virus infestation: Rice necrosis mosaic virus inoculation on both *C. olitorius* and *C. capsularis* induced different reactions on the incidence of jute stem weevil (*Apion corchori* M.) and jute semilooper (*Anomis sabulifera* G.) under different fertilizer levels in fields. The virus upon inoculation (with sap from rice necrosis mosaic virus-infected rice plant leaf but not with sap from healthy plant) increased plant growth but did not predispose such jute plants to higher insect pest attack (Pradhan and Ghosh, 1995). Rice necrosis mosaic virus when mechanically inoculated into *Ludwigia perennis* and other fibre crop plants, including *H. cannabinus* enhanced plant growth through enhancing all major physiological processes and also triggered the synthesis of an endogenous cytokinin-like material and IAA. Apparently as a result, the infected plants increased in height by 50% and in the area and weight of leaves by over 100%. The resulting increased yields of fibre and seeds could all be imitated in part by spraying with partially purified preparation of the cytokinin-like material. This material, termed Viralin, also caused a darker green colour of the leaves and a net increase in chlorophyll content. It is suggested that Viralin treatment may be of value for fibre crops in the field (Ghosh, 1995). A mosaic disease of Kenaf (*H. cannabinus*) has been described for the first time by Sardar (1995) where he stated causal virus was readily transmitted by grafting, but not by sap and *Nisotra orbiculate* was found to be the vector of the causal virus which was not seed-borne.

New innovative technology:
Jute-polyester composite: Polyester resin forms an intimate bond with jute fibres up to a maximum fibre resin ratio (volume/volume) of 60:40. At this volume fraction, the Young's modulus of the composite is approximately 35 GN/m^2. For higher volume fraction of fibre, the quantity of resin is insufficient to wet fibres completely. In order to overcome the poor adhesion between resin matrix and jute fibres, a multi functional resin like polyesteramide polyol has reportedly been used as an interfacial agent. Significant improvement in mechanical properties of jute fibre composites was observed by incorporation of polyesteramide polyol. Also, hybrid composites of glass (facing) and modified jute fibre (core) can be a good alternative. There are several types of unsaturated polyester resin general purpose, flexible, resilient, low-shrinkage (low profile), weather resistant, chemical resistant and fire resistant varieties. These polyester resins are prepared from a blend of phthalic anhydride and maleic anhydride esterified with propylene glycol to form linear polyester chains having molecular weights in the range 1000-3000. For Curing of such unsaturated polyester resin with fibre, azo type initiators (R-N= N-R) and organic peroxides (R-O-O-R) are generally used.

Fabrication of composites: Hybrid composite of glass and jute fibre can be fabricated by the hand lay-up technique using a laboratory compression moulding machine. Hybrid laminates (10-ply) containing 8 inner plies of untreated/silane/titanate/TDI treated jute fibre sandwiched between two outer plies of glass fibre (weight content of jute : 25-27%) are made. Curing is done at 80°C under a pressure of approximately $2x10^5$N/m^2 for a period of 90 min. Jute composites are at present being used commercially in India for applications like automobile interiors. There are also some temporary outdoor applications like low cost housing for defense etc. However, use of jute alone as reinforcing fibre would not be suitable for high strength applications. jute-glass fibre combination can be well suited for such applications. Incorporation of glass with jute brings about large increases in mechanical properties of composites. Although there exists a good potential of jute-glass hybrid composites. A report from National Institute of Research on Jute and Allied Fibre Technology (NIRJAFT) reveals that, usually for moulded jute composites with polyester resin, the resin intake is up to 40% maximum. Both hot press moulding and hand lay-up technique can be used for its fabrication. In the later process, the resin take up may go up to 300-400% on the basis of jute fibre used which is not economical. Also, it is seen that some pre-processing of jute/treatment of fibre is required so that the interface problem could be solved. Generally, when unsaturated polyester resin is used with glass fibre, the ratio maintained is 2.5:1. Whereas, for resin with jute, the ratio maintained is 3.5-4:1. However, increase in temperature increases the productivity. Even with unsaturated polyester resin, hot condition impregnation is usually done for higher productivity. A US patent (# 5663216) granted in 1997 to a German company describes the process of fabricating a bio-degradable composite. This involves using a thermoplastic starch and a hydrophobic biologically degradable polymer reinforced with natural fibres such as ramie, cotton etc. Pradom Ltd., London, UK in its patent (US patent # 5218012) granted in 1993 described an innovative approach to electrical pre-treatment of reinforcing fibres for their application in composite. The treatment involves coating the fibre with a conductive or semi-conductive material and then subjecting it to an electric field with a DC supply (50-150,000 V) or AC (10,000-30,000 V; frequency: 50-1000 Hz). The process of moulding thermoset composite reinforced with natural fibres was patented (US patent # 5231121) by a German company in 1993. The inventors used a resin mixture comprising unsaturated polyester with styrene and acrylic acid esters. The process involves impregnating the natural fibre with the aforesaid resin formulation and hot pressing it to a desired shape. A composite has three entities that are susceptible to failure - the reinforcement, the matrix and the interface. The failure of one can initiate failure of the others and the actual process that takes place in any particular case is determined by the stress required to activate each individual mechanism. The mechanism activated by the lowest stress will normally govern composite failure. Thus, In order to increase the potential application area of jute fibres as reinforcement in composites, it is necessary to concentrate more on three major aspects (a) fibre modification (b) resin matrix and C) coupling agents.

Potential applications of jute composites: The jute composites can be very cost-effective material especially for building & construction industry (panels, false ceilings, partition boards etc.), packaging, automobile and railway coach interiors and storage devices. A survey of international patents establishes the potential applications of jute composites in various sectors. In their application dating back to 1974, M/s. Care Inc., N.Y, USA patented (# 3819466) double-wall reinforced & insulating building panel with a combination of glass & jute composites. The panels comprise of an inner skin of woven jute layers saturated in polyester resin and an outer skin of woven jute with an exterior coating of chopped glass fibre both impregnated with polyester resin. The intermediate layer bonding inner and outer skin is made of corrugated woven jute composite. The panel is of light weight and has high durability even in extreme temperature conditions. In a US patent (# 5285957) of 1994, the Mead Corporation Dayton, Ohio, USA described the use of jute mesh as the intermediate reinforcing material for a corrugated container such as bulk storage bins. The reinforcing material may be placed in between the outer & inner lines of two-faced corrugated board construction. A US patent (# 5037690) granted in 1991 to M/s. De Groot Automotives B.V. of Netherlands describes the process of fabricating a sheet material. The sheet comprises polyurethane resin reinforced with binder free natural fibres such as jute, flex, hemp, coir, ramie, cotton etc. possibly combined with polypropylene, polyethylene and/or glass fibre. The preferred natural fibre is jute in the form of needled jute felt. The application lies in fabricating a sandwich panel with two outer walls made of jute composite sheets. The Marlo Company Inc., Newton, Connecticut, USA in their patent (US patent # 4559862) in 1985 describe a packing material comprising glass in combination with organic fibre such as sintered polytetrafluroethylene (TFE) with or without impregnant. A preferred impregnant could be a lubricant with a binder. The process also talks of substitution of sintered TFE fibre by natural and other fibres. A US patent (# 9831626 A1) granted to a US company in 1998 describes the method for fabricating wet-laid non-woven webs using jute fibre as reinforcement. Composites of the unpulped fibre webs with cellulosic and spun bonded sheets find applications as thermoformed trim products for vehicle interiors. The process for making a multi-layer composite body comprising a thermoplastic layer and layers of natural fibre bonded to thermoplastic resin was patented (# 9836900 A1) by a German company in 1998. The composite body has at least one reinforcing layer made of an open-cell fabric of melting fibres penetrated on one or both sides of the melting thermoplastic materials. The composite body has excellent mechanical properties particularly bending stress and impact resistance.

Due to an occurrence of a wide variety of natural fibres researchers have directed efforts for quite some time in developing innovative natural fibre composites for various applications where researchers carried out extensive work on pre-treatment of jute fibres with acrylonitrile for improving their compatibility with thermoset plastics. They developed a whole set of novel jute and other natural fibre composite products based on hot press moulding and hand lay-up technique. IIT-Delhi has been quite active in developing jute-based geo-textiles for applications in prevention of soil erosion, leaching etc. CGCRI-Calcutta has worked on jute-glass hybrid components for cost-reduction without sacrificing the mechanical properties. An excellent example for commercial exploitation of jute composites has been the fabrication of automobile interiors (door panels) by Birla Jute Industries Ltd. While the national research agencies in India have excellent scientific achievements to their credit for development of jute composites, efforts on their commercialization have been limited so far. In order to improve upon the laboratory-industry linkages towards application development and commercialization, The Advanced Composites Mission was conceptualized by Department of Science and Technology and Defense Research & Development Organization. The Mission mode activities are being implemented by Technology Information, Forecasting and Assessment Council (TIFAC), an autonomous organization under DST. Among a wide array of composite product development, the Mission has launched a few projects focussing on jute composites. The project on 'Jute-based Composites - An Alternative to Wood Products' has been launched in collaboration with M/s Duroflex Limited, Bangalore, a leading manufacturing industry in rubberized coir materials. The project aims at development of oriented jute face layer for coir-ply board. Natural hard fibres such as coir and jute impregnated with phenolic resins are used for its manufacture. The project activities will enable the production of coir-ply boards with proper orientation of jute having a very similar appearance of wood. The average production capacity of coir-ply plant planned under the project would be around 1000 sheets of 2.4 x 1.2 m^2 of 12mm thickness. In this project 80% of the material used in the composite are natural fibres such as jute and coir. Such a composite will be a good alternative for wood and wood products using 100% indigenous technology, which in turn saves the foreign exchange of our country. These natural materials have all the properties required for a general purpose board and can be used in the place of wood or MDF Synthetic resin boards for surface paneling, partitioning, false ceiling, etc. The products made of jute-glass hybrid composites can be used as a replacement of high-cost sheet moulding compound & low-strength dough moulding compound based glass-fibre composites. The technology for the fabrication and evaluation of hybrid composites incorporating jute felt and glass fibre using polyester resin as a matrix has been developed successfully by CGCRI. In these hybrid composites, jute can play the role of filler fibre where strength and modulus requirement are not demanding. Moisture absorption limits can also be reduced from 25 to 2% by weight using glass layer on either side of the jute fibre layer. It can thus be inferred that jute fibre can be a very potential candidate in making of composites, especially for partial replacement of high-cost glass fibres for low load bearing applications. As such, commercial exploitation of jute composites for non-structural applications promises excellent potential. From the point of view of wood substitution, jute composites could be an ideal solution. With ever depleting forest reserves, a composite based on renewable resources such as jute, coir, sisal etc. is poised to penetrate the market. Indigenous wood supply for plywood industry having been stopped virtually and with increasing landed cost of imported plywood veneers, the jute composite boards provide very good value for the customers without any compromise in properties. With increasing emphasis on fuel efficiency, jute composites would enjoy wider applications in automobiles and railway coaches. In fact, the market segment for railway coaches in India has a vast potential, which is yet to be tapped to a good extent. Value-added novel applications such as jute composites would not only go a long way in improving the quality of life of people engaged in jute cultivation, but would also ensure international market for cheaper substitution.

Marwaha *et al.* (1998) stated that jute rope-immobilized *P. chrysosporium* showed better performance than cotton and wheat carriers in terms of decolorization and chemical oxygen demand (COD) reduction. Buwalda and Kim (1994) used small plugs of organic, fibrous material (jute) as a propagation medium for spray chrysanthemum cuttings instead of the more conventional, pre-fertilized compressed peat blocks. A complete nutrient solution was supplied to the jute plugs by means of ebb-and-flow irrigation. It was observed that shoots of rapidly growing cuttings contained relatively high levels of nutrients and low level of non-structural carbohydrate and had a high turgor demonstrating that during propagation from cuttings, growth may be limited by the availability of water and minerals. They also stated that in the case of chrysanthemum cuttings in small jute plugs, factors limiting growth can be overcome by frequent irrigation with a complete nutrient solution. Sabharwal *et al.* (1993) treated ground jute (*C. capsularis*), cellulose, ethanol lignin and holocellulose from jute strands with an argon plasma under various conditions to estimate the free-radical generation (ESR) and chemical changes (ESCA) at the surface of the various samples. On the basis of plasma treatments of isolated preparations, it was shown that lignin is the primary site of free-radical formation however, the carbohydrate fraction also shows considerable relative free-radical intensity. The experimental data suggest new possibilities for in situ and second-stage surface modification or grafting of lignocellulosic fibers for potential application to new composite materials.

Useful product from jute and its related plants: Kohoda *et al.* (1994a,b) isolated four flavonoid glycosides, astragalin (kaempferol 3-O-beta-D-glucopyranoside), tolifolin (kaempferol 3-O-beta-D-galactopyranoside), isoquercetin (quercetin 3-O-beta-D-glucopyranoside) and juglanin (kaempferol 3-O-beta-L-arabinopyranoside) oleanolic acid, glyceryl monopalmitate, beta-sitosterol and beta-sitosterol 3-O-beta-D-glucopyranoside from the leaves of *C. olitorius* locally called nalta jute in Egypt. Isoquercetin and beta-sitosterol glucoside showed a moderate inhibitory activity on retro-virus reverse transcriptase from AMV. Begum *et al.* (1993) obtained an acidic xylan from 4% alkali soluble fraction of unretted jute bark of Dhabdhabey S-718 jute (a hybrid derivative from intervarietal cross of *C. capsularis* and capsularis blue seeded). A tentative structure of the acidic xylan was established by sugar analysis, methylation studies and molecular weight determination. It appears that the acidic xylan is almost similar to those of *C. capsularis* and *C. olitorius* but contains greater proportion of uronic acid. A simple method for the extraction of tannin from lignocellulosic fibre and its assay by a colorimetric procedure have been described by Ghosh *et al.* (1990). It has been found that the acid-soluble lignin or lignin monomeric compounds do not interfere in the colorimetric assay reaction. A pure proteoglycan (F-1) has been isolated (Basak *et al.*, 1990) by cold water extraction of the cambium layer of freshly harvested jute plants (*Corchorus capsularis*). The carbohydrate moiety of the proteoglyan (F-1) contains mannose, rhamnose, glucose, arabinose and galactose in a mol proportion of 1.0:2.0:2.7:9.8:20.9. The structural information about the carbohydrate moiety have been obtained from methylation analysis, Smith degradation, chromium (VI) trioxide oxidation and proteolytic and alkaline borohydride degradation studies. The carbohydrate moiety appears to be an arabinogalactan with other minor sugars in the branches, galactosyl residue being linked to the protein chain. The structural features of the pectic acid fraction of crude pectin from the unretted mesta (Hibiscus cannabinus) fibres, have been investigated (Saha *et al.*, 1990) through methylation analysis and characterization of the oligosaccharides obtained by beta-eliminative degradation of its permethylated product. It has been found that the pectin is a heteroglycan containing a backbone of (1-fwdarw-4) linked alpha-D-galacturonic acid residues. The heterosugars are present only as side chains to the main polygalacturonan chain. Soda lignin isolated from spent soda liquor of jute stick pulp was used for the preparation of lignin phenol formaldehyde resins. The adhesives were used to prepare jute stick particle boards. It was observed that phenol in phenol formaldehyde resin could be replaced up to a maximum of 50% by jute stick soda lignin (Roy *et al.*, 1989). Dioxane acidolysis lignin (DAL) of jute stick was isolated by Roy *et al.* (1988). Based on its methoxyl content, elemental analysis, ultraviolet ionization difference spectra, and infrared spectra, the chemical characterization of two preparations was made. The C-9 formulae were calculated for dioxane acidolysis lignins of both varieties, which are quite similar and of the hardwood type.

Islam *et al.* (1996) stated that seed and roots of *C. olitorius* and *C. capsularis* have various types of sugars such as raffinose, sucrose, arabinose, fructose, galactose and glucose. They stated that arabinose and fructose were the most dominant sugars found both in roots and seeds of both the varieties of jute plants. The isolation of raffinose, jute seed oil beta-sitosterol, beta-sitosterol D-galactose, strophanthidine and corchorosides A, B and C were reported from the seed of *C. capsularis* (Islam *et al.*, 1996). Ahmed *et al.* (2001) studied on the hydrolysis of jute sticks to extract D-xylose and found D-xylose in small amount. Jute seed cake, (JSC), was low in protein and high in lysine, isoleucine and fibre content. Growth studies showed that JSC can replace 30 percent groundnut cake-N satisfactorily in growing quail ration, however, it resulted in high mortality, reduced growth and feed consumption in broiler chick even at lower level (25% N replacement) (Samanta and Samanta, 1997). Ghosh and Rakshit (1994a,b) found protein and amino acids in mutated and hybrid plants of white jute (*C. capsularis*). Rectified spirit extraction of defatted jute (*C. capsularis*) leaves led to the isolation of a bitter white powdery residue. Methanolysis and examination of the solid residue as volatile TMS - derivative involving gas chromatography-mass spectrometric technique led to the detection of six terpenoid and capsugenin compounds (Sarker *et al.*, 1993).

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