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Research and development in jute (*Corchorus* sp.) and allied fibres in India-A review

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ABSTRACT

Jute and allied fibre farming, trading and industry provide sustenance to over 5 million people of our country. The productivity of jute had doubled from 1.10 t/ha during independence to about 2.24 t/ha during 2006-07. Development of high-yielding varieties along with relatively cheaper and user friendly location specific technologies using locally available materials made this possible. Identification of promising herbicides had increased the net return of the production system while judicious use of local organic nutrient sources had improved the productivity as well as soil-health in jute and allied fibre systems. The mechano-microbial retting technology developed at CRIJAF had reduced the water requirement of retting, while the machines developed like multi-row seed drill, bast fibre extractor, flax extractor, nail weeder, herbicide brush, etc. had increased the efficiency and profitability of the production system. Successful models of *ramie* and *sisal* based multitier systems have been developed for both traditional and non-traditional areas. Significant achievements have been made in fibre quality research also, as it is the prime requirement for product diversification and value addition. In this paper, attempts have been made to summarize and present the achievements made so far in the jute and allied fibre research and also to highlight the constraints faced by this sector and its possible mitigation options.

Key words : *Corchorus capsularis, Corchourus olitorius*, Fibre crops, Nutrient uptake, Quality, Weeds, Yield

Jute and allied fibres are natural fibres of commercial importance which play an important role in Indian economy. The fibre of commerce is extracted from the stem of two cultivated species of jute - *tossa* jute (*Corchorus olitorius* L.) and white jute (*C. capsularis* L.), mesta - *kenaf* (*Hibiscus cannabinus* L.) and roselle (*H. sabdariffa* L.), sunnhemp (*Crotalaria juncea* L.), ramie (*Boehmeria nivea* L. Gaud.) and flax (*Linum usitatissimum* L.) and from leaf of sisal (*Agave* sp.). *Ramie* and *sisal* are plantation crops of 5 to 10 years duration and the rest are annuals. Jute and mesta, together known as raw jute, are cultivated extensively in India. Bangladesh has a strong heritage of jute cultivation. India is a major grower of roselle, while bulk of the *kenaf* is produced in China, Indonesia and Thailand. China is the major producer of *ramie* fibre at present. Maximum *sisal* cultivation is observed in Brazil and Tanzania and in India. The cultivation of *sisal* in India is restricted to Orissa, Madhya Pradesh and Chattishgarh. The cultivation of sunnhemp is concentrated in Orissa, Maharastra, Madhya Pradesh, Uttar Pradesh, Bihar and Tamil Nadu while cultivation of flax for fibre is restricted in pocket areas of Himachal Pradesh . The world production of jute and allied fibres varied between 2.7 and 3.18 million tonnes during 2000-01 and 2003-04. India, Bangladesh and China are the three major producing countries and accounted for 60 - 65, 23 - 30, 3.4 - 5.4 % of world production, respectively. Area of cultivation is highest in India (varying between 0.87 and 1.03 m ha during 2000-04), followed by Bangladesh (0.43–0.52 m ha) and China (0.05–0.058 m ha). Raw jute occupies only 0.55% of the gross cropped area of the country but contributes significantly to our national exchequer. India had produced 1.6 m t of jute goods in 2000s which was around 54% of the global production. Our export market share is around 30% of the global market and we have earned Rs 12,000 millions during 2005-06 as foreign exchange from export of jute goods as against Rs 2,330 millions in the early sixties.

Despite its commercial importance, the area of jute and mesta is stagnated around 1.0 m ha and is confined to a few states till date. Though there has been a significant increase in productivity, there is still a wide disparity in the yield level of the crop between the states as well as between the agro-climatic zones of the same state. Jute and jute-based production systems under the present system of cultivation is labour intensive and costly. Around 65-70% of the total cost of production in jute is due to weed management and retting. Lack of large volume of clean and slow moving water required to produce good quality fibre, is gradually becoming a hurdle as well as costly

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proposition for the resource poor farmers. Similarly the increased cost of phosphatic (P) and potassic (K) fertilizers are creating a severe imbalance in fertilizer use which has affected the productivity and fibre quality as well. The fibre of *ramie*, *sisal* and flax are many-fold costlier than jute but, the area under these crops is meagre. Non-availability of good quality planting materials, *i.e.* rhizomes in *ramie* and bulbils in *sisal*, are the major obstacles in increasing the acreage of these crops. The fibre of *ramie*, *sisal* and flax has to be extracted mechanically. Therefore, development of portable, light weight, low cost power / diesel operated machines and making those available to the growers at subsidized rate is essential to promote these crops in both traditional and non-traditional areas. Moreover almost all jute diversified products require better quality fibre and we need to produce good quality fibre to the tune of 1.0 to 5.0 m bales to satisfy the needs of the industry. Thus it becomes essential to analyze our research achievements, identify the constraints and develop location specific research strategies in a time targeted manner to make the jute and allied fibre sector globally viable.

SIGNIFICANT RESEARCH ACHIEVEMENTS

Growth and physiology

The critical photoperiod for flowering in jute is around 12.5 hour and *tossa* jute in general, is more responsive to short-light period for flowering when compared with white jute. White jute varieties exhibit higher growth rate at the early stage, while the reverse is true in *tossa* jute (Gopalkrishnan and Goswami, 1970). The dry matter production potential of jute has been estimated as 25-30 g/m^2/day at 90-95% light interception level (Palit, 1993). The average value of leaf area index (LAI) in jute was reported to be 4, 6 and 4 at 40, 60 and 110-120 days crop age, respectively (Palit and Bhattacharya, 1982 and 1987). The crop growth rate of jute also follows a similar trend, the average value over the growth period being 15 g/m^2/day (Palit, 1993). *C. olitorius* plants, in general, have deeper tap root system when compared with *C. capsularis* while the roots of the latter have extensive lateral branching. Goswami and Saha (1969), using P^{32} tracer, found that the root of both the species penetrated up to 60 cm soil depth or more with the lateral roots confined mostly to 10 cm.

The LAI, CGR and biomass production was found to increase with increased spacing and N rate in roselle (Krishnamurthy *et al.*, 1992) but in *kenaf*, all the parameters were affected more with moisture stress than N shortage (Muchow, 1992). The mean number of leaves in *sisal* bulbils after transplanting in nursery was found to increase significantly with mulching and maximum number of leaves (20) was observed with black polythene mulch (Singh *et al.*, 1985).

Production technology

The results of All India Network Project on Jute and Allied Fibres (AINPJAF) trials revealed that sowing of *olitorius* jute from mid-March to mid-April and harvesting the crop at 120 DAS in general recorded maximum fibre yield while the suitable sowing time for seed jute was found to be between mid-May and mid-June. The optimum seed rate in *olitorius* and *capsularis* jute, for fibre crop were 4 to 6 and 6 to 8 kg/ha while the same for seed jute were 3 to 4 and 4 to 5 kg/ha, respectively. The multi-location trials in different jute growing states further revealed that the optimum row spacing for *C. olitorius* and *C. capsularis* varied between 22 to 25 cm and 25 to 30 cm, respectively (Mitra *et al.*, 2006). Seedling emergence, seedling vigour and seed yield showed positive and significant correlation to seed size in jute (Bhattacharjee *et al.*, 2000). The optimum plant population for seed jute and mesta was found to be 0.22 to 0.25 million/ha in a spacing of 45 x 10 cm (Bera *et al.*, 2009). Maximum fibre yield of sunnhemp (0.92–1.02 t/ha) was observed in Uttar Pradesh when the crop was sown during 2nd fortnight of April at 15 cm x 10 cm spacing using a seed rate of 25 kg/ha and was harvested at 90 days age. The crop could also escape from the attack of pests (CRIJAF, 2008). Planting of rhizomes (10 to 15 cm long and 1.0 cm dia weighing 10 to 15 g) at 60 cm × 30 cm spacing recorded optimum growth and fibre yield in *ramie* (Mitra *et al.*, 2006). About 90 to 95% sprouting and survival of the new plants was observed when waste canes (left during harvesting) were used as alternate planting material in place of rhizomes (Saha, 2003). Pre-planting treatment of ramie rhizomes with hot water (50 + 1^{0}C) for 60 seconds or with carbendazim (Bavistin 50WP) @ 5% recorded better sprouting and emergence (CRIJAF, 2008). *Sisal* is commercially propagated through bulbils and suckers. In single row planting, about 5,000 and 6,250 *sisal* plants can be accommodated in 1 ha of land with 2 m x 1 m and 2 m X 0.8 m spacings, respectively. In double row planting, 3 m + 1 m x 1 m, 3 m + 1 m x 0.8 m, 2 m + 1 m x 1 m, 2 m + 1 m x 0.8 m and 2 m + 1 m x 0.6 m spacings can accommodate 5,000, 6,250, 6,666, 8,333 and 11,111 plants /ha, respectively (Saha *et al.*, 2007). Flax when sown in November produces finer and longer fibres with higher productivity (Gupta *et al.*, 2006).

The promising location-specific jute and allied fibre based crop sequences for both rainfed and irrigated conditions have been identified which had certainly strengthened the stability of production systems. Some of the iden-

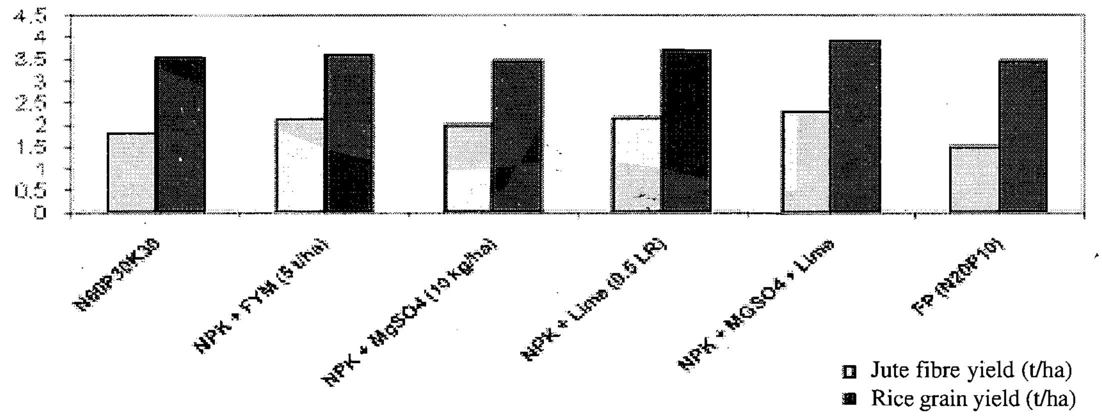

Fig. 1. Effect of integrated nutrient management on productivity of jute-rice cropping system in acid soils of Orissa

tified jute based crop sequences under rainfed condition are – jute-lentil, jute-blackgram, jute-*toria* for north and south Bengal; jute-blackgram-*toria*, jute-blackgram-wheat, jute-*toria*, jute-rice-*toria* for Assam; jute-mustard-cowpea for Orissa, Bihar and Uttar Pradesh, respectively. Under irrigated condition, the promising crop sequences identified are jute-rice-potato, jute-rice-vegetables and jute-rice-mustard for north and south Bengal; jute-rice-potato/ wheat/pea for Assam; Jute-rice-lentil, jute-rice-wheat for Bihar, Orissa and West Bengal, respectively (Mitra *et al.*, 2006). Mixed cropping of jute, red amaranth, white amaranth and summer raddish produced 3.6 t jute fibre, 1.9 to 2.9 t red amaranth (at 21 days after emergence), 0.7 to 0.9 t white amaranth and 0.57 to 0.90 t summer raddish/ ha under irrigated condition and fetched additional net return of around Rs. 4,000/ha at Barrackpore, West Bengal (Ghorai, 2007). Similarly in farmers' field at North 24 Pargana district of West Bengal, maximum net return was observed in jute-paddy-tomato sequence (Rs 38,898/-) followed by jute – paddy-mustard (Rs 25,191/-) (Chapke and Jha, 2006). In sunnhemp, maximum system rice equivalent yield (16.94 t/ha) was obtained with rice-potato-sunnhemp sequence (Table 1) followed by by rice-gram-sunnhemp sequence (15.79 t/ha) at Pratapgarh, Uttar Pradesh, (CRIJAF, 2008). Commercial cultivation of both *ramie* and *sisal*, as sole crop or under intercropping system had been found to be very profitable. A sole crop of *ramie*, in Assam, fetched a net return of Rs 25,000 to Rs 35,000/ha/year from sale of fibre from 2 to 4 year and in the 5 year the net return was around Rs 3,00,000/ha of which about Rs 2,75,000-2,80,000 came from sale of rhizomes only. Some of the successful ramie based multi-tier cropping systems introduced in the non-traditional areas are – *ramie* + rubber and *ramie* + cinnamon in Tamil Nadu, *ramie* + coconut and *ramie* + coconut + black pepper in Goa and *ramie* + mango or *ramie* + mango + black pepper at Ratnagiri, Maharastra while at Assam the most successful model was *ramie* + arecanut. The net return from a well managed *sisal* plantation of 4 ha was found to be around Rs 1,00,000 to Rs 1,20,000 / year with an additional earning of Rs 50,000/year at the end of 11 or 12 year from sale of bulbils. *Sisal* could be successfully grown as an intercrop in agroforestry systems. Fibre yield of *Agave sisalana* was found to be more (Table 2) when grown with teak (*Tectona grandis* L.) (604.5 kg/ha),

Table 1. Performance of sunnhemp based cropping sequences

Cropping sequences	Rice equivalent yield (t/ha)
Rice-wheat-sunnhemp	12.52
Rice-mustard-sunnhemp	13.09
Rice-potato-sunnhemp	16.94
Rice-gram-sunnhemp	15.79
CD (P=0.05)	1.50

Source : CRIJAF Annual Report, 2008

Table 2. Performance of sisal in agro-forestry system in western Orissa

Intercropping	fibre yield (kg/ha)
Teak + *Agave sisalana*	604.5
Gambhar + *Agave sisalana*	502.5
Teak + hybrid sisal	539.2
Gambhar + hybrid sisal	645.0

Source : CRIJAF Annual Report, 2008

Table 3. Fibre yield of jute as influenced by NPK in different jute growing areas

Treatments	Fibre yield of jute (t/ha)			
	Barrackpore (South Bengal)		Coochbeher (North Bengal)	
	2003	2004	2003	2004
T_1 (Control)	1.94	1.79	1.45	1.61
T_2 ($N_{60}P_{30}$)	3.19	2.69	2.31	2.88
T_3 ($N_{60}K_{30}$)	3.21	2.52	2.23	2.29
T_4 ($P_{30}K_{30}$)	2.46	2.22	2.00	1.89
T_5 ($N_{60}P_{30}K_{30}$)	3.48	2.86	2.59	3.22
CD (P=0.05)	0.45	0.40	0.29	0.26

Source : AINPJAF Annual Reports, 2003, 2004

while hybrid *sisal* showed better fibre productivity (502.5 kg/ha) with gambhar tree (CRIJAF, 2008).

Around 80% of the total jute area of our country is under rainfed condition and the crop is exposed to both deficit and excess water stress during its growth. The *capsularis* varieties when subjected to acute moisture stress at early stage under field condition at Jhargram, West Bengal, produced 54 to 89% more plant height and accumulated 67% more biomass when compared with *olitorius* ones which indicated that *C. capsularis* can withstand natural drought better than *C. olitorius* in its early growth stage (Mitra *et al.*, 2004). Application of elemental sulphur @ 30 kg/ha, higher seed rate (8 kg/ha) and one post-sowing irrigation yielded 4.07 t fibre/ha of jute (Ghorai, 2009). Irrigation applied to *tossa* jute varieties on the basis of IW/CPE ratio of 0.9 recorded significantly higher fibre yield of the crop (3.04 t/ha) and also recorded maximum water use efficiency of jute (5.97 kg/ha-mm) under south Bengal condition (AINPJAF, 2006). Waterlogging in jute reduced the yield attributing characters and provision of drainage led to 2 to 3 fold increase in fibre yield of the crop (Ghorai *et al.*, 2003). Scheduling of irrigation to *ramie* increased the fibre yield of the crop to the tune of 27 to 34% during pre-monsoon and by about 30% during post-monsoon periods (Mitra *et al.*, 2009). Besides, irrigation increased the number of cuts in *ramie* (5 cuts) at south Bengal when compared with 3-4 cuts/year, usually obtained under rainfed situation in north eastern states. Maximum value of LAI, net photosynthesis, fibre yield and water use efficiency of *ramie* was recorded when irrigation was scheduled to *ramie* irrigation at 0.6 – 0.9 IW/CPE ratio. Ridge planting was also found to increase the fibre yield and water use efficiency of the crop significantly. Maximum quantity of rhizomes was produced

Table 4. Sustainable Yield Index (SYI) of jute under long term fertilizer experiment at CRIJAF

Treatments	Mean (1972-76)	Mean (2001-05)
50% NPK	0.56	0.28
100% NPK	0.73	0.47
150% NPK	0.80	0.56
100% NPK + FYM	0.72	0.59
Control	0.40	0.14

Source : CRIJAF, 2005

when crop was irrigated under IW/CPE ratio of 0.6-0.9 (CRIJAF, 2007). Provision of irrigation to *sisal* through drip irrigation system increased the leaf number and fibre productivity of the crop significantly at Bamra, Orissa (CRIJAF, 2008).

A critical overview of the fertilizer trials conducted on jute and allied fibre crops revealed that the response (in fibre yield) to applied nutrients varied with dose, time and method of application, locations, soil type, crop combinations, etc. Jute, during its growth adds about 15 t green leaves to the soil which finally adds around 53, 9, 58, 22 and 15 kg/ha of N, P, K, Ca and Mg and considerable amount of organic matter to soil. So inclusion of jute in most of the cropping systems showed an increase in soil organic C as well as improved microbial and enzymatic activity of the soil. The results of fertilizer trials of AINPJAF revealed that maximum yield depression in *tossa* jute was observed with omission of nitrogen in fertilizer schedule followed by the exclusion of phosphorus and potassium, respectively both in neutral and acid soil situations (Table 3). Fibre yield of existing *tossa* jute cultivars were found to increase significantly upto 60 kg N/ha in Orissa (Nayak *et al.*, 1996), Assam (Borthakur *et al.*, 1981) and other jute growing areas while the new *C. olitorius* genotypes responded upto a fertilizer dose of 80:17.6:33.3 and 100:22:41.7 (N:P:K, kg/ha) in south and north Bengal conditions, respectively (AINPJAF, 2008). White jute cultivars, on the other hand, were found to respond upto 80 kg N/ha at Barrackpore, West Bengal (CRIJAF, 1976) and at Nagaon, Assam (AINPJAF, 2008). Application of N:P:K @ 60:13.2:25 kg/ha along with $MgSO_4.7\ H_2O$ (@ 10 kg/ha) and lime (at 0.5 LR) in *capsularis* jute – rice cropping system increased the fibre yield of jute by 27 and 52% over recommended dose of fertilizer and farmer's practice, respectively and also the grain yield of succeeding rice crop in acid lateritic clay loam soil (Fig. 1) of Kendrapara, Orissa, (Paikaray *et al.*, 2006). Application of lime possibly had neutralized the soil pH and increased the availability of nutrients through in-

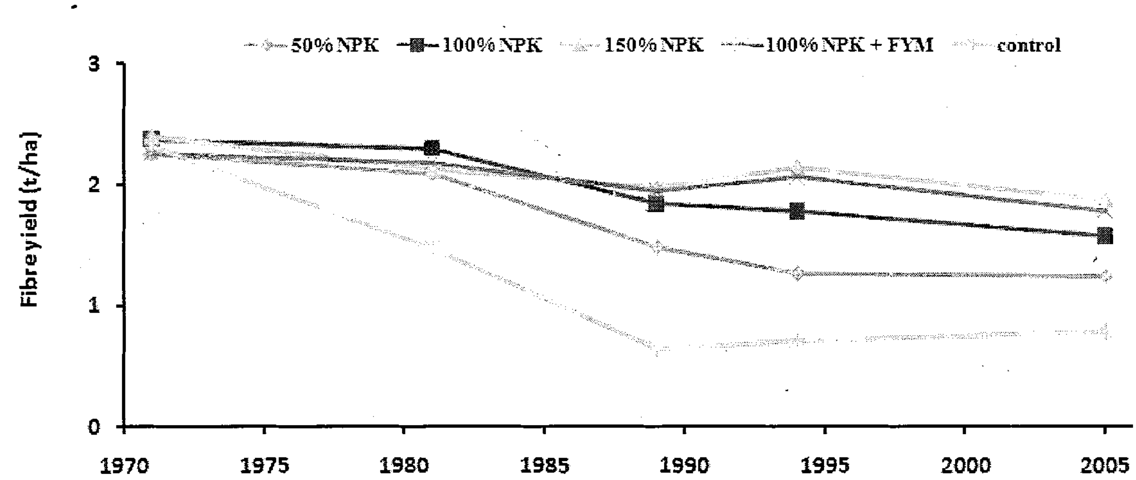

Fig. 2. Yield trend of jute over 34 years under different modes of nutrition

creased microbial activity. Jute plants were found to utilize 10-12% of fertilizer P only which clearly indicated the preference of jute to soil P. The critical limit of soil P for jute has been estimated as 10.6 kg P/ha (Goswami *et al.*, 1971). The response of jute to applied K is lesser than N and P particularly in the alluvial tracts, probably because the soils are dominated by illite which leads to higher availability of K to plants (Mandal *et al.*, 1979). Application of N:P:K @ 40:26.4:50.0 kg/ha recorded maximum seed yield in jute (Bera *et al.*, 2009). Saha *et al.* (1998) reported that the critical limit of soil available S was 8.5 ppm SO_4^{-2} S. In the sulphur deficient soils, application of 1 kg sulphur was found to produce an additional fibre yield of 18 kg/ha in jute in Bangladesh and 21 kg/ha at CRIJAF, Barrackpore, West Bengal. Kumar and Borthakur (1980) observed that the fibre yield of *tossa* and white jute increased significantly with magnesium application upto 40 kg MgO/ha in Assam while the response to applied Zn and Mn was observed upto 4 and 5 kg/ha, respectively in alluvial clay loam soil (Sarkar and Chakraborty, 1980). The results of 'Long-term Fertilizer Trial' in jute–rice–wheat cropping sequence on new Gangetic alluvial soil at Barrackpore revealed that application of 100% NPK based on soil test values increased the available N, P and K of soil significantly after 10 cropping cycles (Mandal *et al.*, 1983, 1985a and 1985b) but the soil organic C, total N as well as soil mineralizable N showed an increasing trend after 29 years of continuous cropping only when FYM was applied along with NPK (Saha *et al.*, 2007). The yield trend of jute had shown a steady but slow decline in the productivity of the crop in all the fertilizer treatments though the magnitude of decline was less when organic matter was added to the soil (Fig. 2). During the first five years (1972-76), the sustainable yield index (SYI) value of the system was found to be maximum (0.80) in plots receiving 150% NPK treatment while after 29 years of continuous cultivation, plots receiving 100% NPK + FYM recorded maximum SYI (0.59) from 2001 to 2005, (CRIJAF, 2005). Combined application of FYM and fertilizer N increased the activity of acid phosphatase, alkaline phosphatase, dehydrogenase in soil (Table 4), and dry matter production, fibre yield and P uptake by both *capsularis* and *olitorius* jute (Tarafdar *et al.*, 1989). Similar results were also observed in the LTFE trials also after 35 years of cropping (Table 5), (CRIJAF, 2005). Substitution of 25% of the recommended N through water hyacinth compost or pressmud recorded significant increase in fibre yield and nutrient uptake in jute over recommended dose of fertilizer, (AINPJAF, 2008) and it also improved the available nutrient status of soil. Single inoculation in jute with *Azospirillum* (Mishra *et al.*, 1989) or combined inoculation with *Glomus macrocarpum* and *Azospirillum brasilense* (Bali and Mukherjee, 1991) had resulted in significant increase in plant height, dry biomass, chlorophyll and N content in *olitorius* jute.

The slow release N fertilizers increased jute yield over urea and reduced the N requirement for subsequent rice crop (Sarkar *et al.*, 1987). Split application of nitrogen recorded significantly higher fibre (Gupta and Bhattacharya, 1981) and seed yield (Bhattacharjee *et al.*, 2000) in both *tossa* and white jute. Similarly split application of potash (K) in two equal doses (basal and 3-4 WAS) resulted in better fibre yield, K uptake and K use efficiency in jute (Maitra *et al.*, 1999). Placement of P at 10 cm depth in soil recorded significantly higher fibre yield in both *olitorius* and *capsularis* jute (Sinha and Saha, 1973).

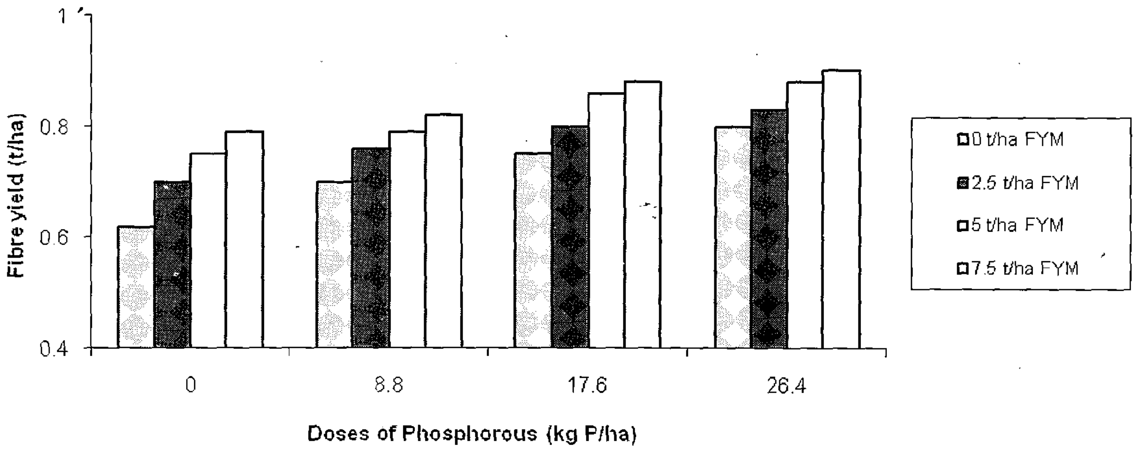

Fig. 3. Effect of phosphorous and farmyard manure on fibre yield of sunnhemp

Table 5. Effect of fertilizer treatments on microbial enzymatic activity of post-harvest jute soil in LTFE

Treatment	Fluorescence diacetate hydrolyzing activity (μg/g)	Dehydrogenase activity (μg/g)	Urease activity (μg/g)	Acid phosphatase activity (μg/g)	Alkaline phosphatase activity (μg/g)
50% NPK	90	238	408	248	457
100% NPK	113	299	446	310	486
150% NPK	93	282	439	259	464
100% NPK + FYM	122	353	458	455	353
Control	64	217	418	79	330

Table 6. Effect of soil test based fertilizer application on fibre yield of *olitorius* jute

Treatment	Fertilizer dose (kg/ha)			Fibre yield (t/ha)
	N	P	K	
Target 3 t/ ha + farmyard manure @ 5 t/ha	59	0.0	63.3	3.31
Target 3 t/ ha	59	0.0	63.3	2.80
60:13.2:25, kg N:P:K/ha	60	13.2	25.0	2.63
Farmer's practice (FP)	20	0.0	0.0	1.92

Source : Maitra *et al.* (2009). Initial available nutrient in soil : 279-35.5-189 kg N-P-K/ha

About 2.06 kg N, 1.66 kg P_2O_5, 5.18 kg K_2O, 4.70 kg Ca and 1.04 kg MgO was required to produce 1 kg dry fibre in *olitorius* jute while in *capsularis* jute it was 3.14 kg N, 1.50 kg P_2O_5, 7.97 kg K_2O, 4.99 kg Ca and 2.15 kg MgO, respectively. The average nutrient removal by *tossa* jute (cv. JRO 632) producing 3.1 t/ha of dry fibre was about 65 kg N, 52 kg P_2O_5, 163 kg K_2O, 128 kg CaO and 33 kg MgO/ha, while the same for *capsularis* jute (cv. JRC 212) producing 2 t/ha of fibre was 84 kg N, 37 kg P_2O_5, 117 kg K_2O, 120 kg CaO and 49 kg MgO/ha, respectively (Mandal *et al.*, 1976). In acid soils, liming based on lime requirement of the soil increased the nutrient utilization by jute crop significantly. Application of N:P:K (@ 60:13.2:25, kg/ha) along with $MgSO_4.7\ H_2O$ (@ 10 kg/ha) and lime (at 0.5 LR) recorded maximum uptake of N, P and K by jute and succeeding rice crop as compared to that under recommended dose of fertilizer or farmers' practice (Paikaray *et al.*, 2006). Location specific fertilizer prescription equations were developed for the targeted yield for jute and mesta (3 t/ha) and its component crops like rice (4 t/ha), pulses, etc. for different agro-ecosystems through extensive Soil Test Crop Response (STCR) trials conducted by CRIJAF. The targeted yield for jute and rice in jute–rice cropping sequence, could be achieved with fertilizer application based on soil test values along with FYM (100% NPK on ST-TY + FYM @ 5 t/ha) in farmers' field in neutral alluvial soil of West Bengal. Soil test based fertilizer application, particularly when combined with addition of organic matter, recorded extra fibre yield, saved 13.2 kg P/ha and fetched additional profit over both recommended fertilizer dose and farmer's practice (Table 6), (Maitra *et al.*, 2009). On the other hand, in the acid laterite soils of Kendrapara, Orissa, the targeted yield of jute (3.0 t/ha) could be achieved only with fertilizer application based on 150% NPK on ST-TY + FYM @ 5 t/ha. The higher soil acidity might have affected the nutrient availability at Kendrapara and higher dose of fertilizer was required to attain the yield target at that site. The nutrient uptake pattern of the crop followed the fibre yield trend at both the locations (CRIJAF, 2008).

Table 7. Important weed species associated with jute

Botanical Name
Group A : Abundant and Pernicious
Cyperus rotundus L.
Eleusine indica (L) Gaertn
Group B : Frequent and often difficult to control
Echinochloa colona (L) Link
Digitaria sanguinalis
Dactyloctenium aegypticum (L) Beauv
Cynodon dactylon (L) Pers
Cyperus iria L.
Eragrostis uniloides (Retz) Nees & Stevd.
Leptochloa chinensis (L) Nees
Panicum repens L.
Eragrostis tenella (L) P. Beauv.
Group C : Occasional to frequent
Brachiaria ramosa (L) Stapf.
B. repens (L) Gard.
Axonopus compressus (Sw) P. Beauv.
Echinochloa crusgalli
Paspalum commersoni Lam.
P. scorbiculatum L.
Setaria glauca (L) P. Veauv.
Fimbristylis dichotoma Vahl.
Phyllanthus niruri L.
Euphorbia hirta L.
Eclipta alba (L) Hassk.
Amaranthus viridis L.
Borreria hispida L.
Digeria sp.
Melilotus alba Desr

Source: Ghosh (1983)

Application of 20:17.6:33.3 kg N:P:K/ha had been recommended in sunnhemp for higher fibre yield in Uttar Pradesh (Mitra *et al.*, 2006). Fibre yield and nutrient uptake of sunnhemp increased significantly with application of P and FYM at Pratapgarh, Uttar Pradesh. The effect of farmyard manure on fibre yield was found to be significant upto 5 t/ha only while fertilizer P increased fibre yield significantly upto 17.6 kg P/ha only (Fig. 3). Application of farmyard manure and P might have increased the nutrient supply to plants which increased the uptake of N and K by sunnhemp apart from fibre yield (Fig. 4). The organic carbon as well as available N and P content of soil improved with application of manure and phosphorus thereby indicating increased biological N-fixation (Maitra *et al.*, 2008). Application of K and S individually @ 40 kg/ha each was found to increase fibre yield of sunnhemp by 20 and 21%, respectively while combined application of both ($K_{60}S_{40}$, kg/ha) recorded maximum fibre yield (0.72 t/ha) of the crop. The response of sunnhemp to S was observed up to 40 kg/ha dose at all levels of K. Maximum uptake of K (71.6 kg/ha) and S (16.79 kg/ha) was recorded with combined application of potassium and sulphur. Sulphur application (@ 40 kg/ha) was found to reduce the incidence of wilt disease in sunnhemp by 11% and intervenal chlorosis by 23% (Saha *et al.*, 2009). The uptake of nitrogen and phosphorus by fibre flax crop was found to increase significantly with application of organic matter and S in south Bengal condition though there was no significant influence on available nutrient status of the soil (CRIJAF, 2008).

Ramie had been found to be highly responsive to applied fertilizers and also remove a large quantity of nutrients particularly that of calcium from soil. To produce 1 tonne of dry fibre, *ramie* removed 153 kg N, 18.7 kg P, 77.6 kg K, 274.4 kg CaO and 66.1 kg MgO from soil (Saha *et al.*, 2006). Application of 10 to 15 t/ha of FYM after stage back followed by fertilizer application as N: P: K @ 30:6.6:12.5 (kg/ha) after each cutting was found to give maximum fibre yield of *ramie* (Mitra *et al.*, 2006). Integrated nutrient management in *ramie* (50% N from RDF + 50% N from *ramie* compost) recorded significantly higher fibre yield as well as water use efficiency of *ramie* when compared with 100% N from chemical source. The INM treatment increased the available N and K of soil and also improved the soil microbial biomass carbon, Fluorescence Diacetate Hydrolizing Activity and Dehydrogenase Activity in *ramie* soil (Mitra *et al.*, 2009). Fibre yield of *ramie* was found to increase significantly

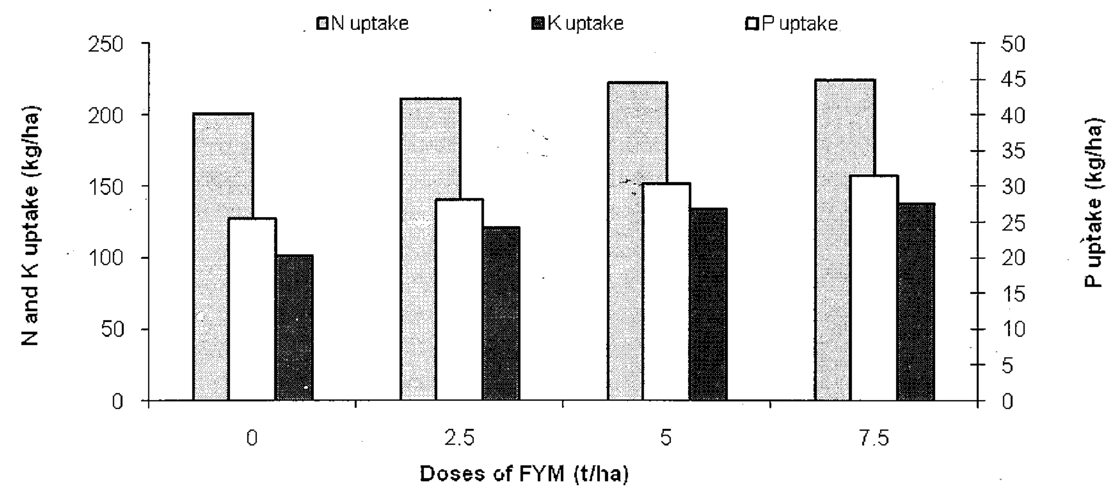

Fig. 4. Effect of farmyard manure on nutrient uptake (kg/ha) by sunnhemp

when 50% of recommended N was supplemented through organic sources like *Glyricidia* at Assam (CRIJAF, 2007) or through *ramie* compost at Coochbehar, West Bengal (AINPJAF, 2006).

Sisal in our country, is mostly grown in wastelands under low input conditions which affect the fibre yield of the crop. Adequate nutrient supply with supplemental irrigation can increase the productivity of the crop significantly. *Sisal* bulbils are kept in nursery for 1 year before they are transplanted to the main field and nutrient management during this period is very important. Application of fertilizer NPK was found to promote the growth of *sisal* bulbils. At lower level of N (20 and 40 kg/ha), application of NPK at 2:1:1 ratio ($N:P_2O_5:K_2O$, kg/ha) increased the bulbil green weight significantly while at higher N doses (60 and 80 kg N/ha) fertilizer application at 1:1:1 ratio was found suitable when compared with 2:1:1 ratio (Jain *et al.*,1965). Leaf number and fibre yield of *sisal* increased with application of inorganic fertilizer upto 60 kg N, 30 kg P and 60 kg K/ha level while the microbial population in the soil of *sisal* plantation was found to increase upto 120-30-60 kg N-P-K/ha when N was applied in combination with organic matter under irrigated condition at Bamra, Orissa (CRIJAF, 2008). Application of poultry manure @ 4 t/ha along with 50% of RDF recorded significantly higher green leaf weight (5.72 kg/plant) than (5.19 kg/plant) that obtained with 8 t/ha of poultry manure at Amadalavalasa, Andhra Pradesh (AINPJAF, 2006). Application of FYM @ 10 t/ha or vermicompost @ 5 t/ha increased fibre yield of flax by 22 and 16%, respectively while the increase in fibre yield due to S application was significant upto 40 kg/ha level only. Maximum fibre yield in flax (586 kg/ha) was observed with FYM + S @ 40 kg/ha + Zn @ 1 ppm which was 85% higher than unfertilized control (CRIJAF, 2007).

Jute crop suffers from heavy weed infestation during the early stage of its growth, which significantly reduces the fibre yield. The magnitude of yield loss ranged between 52 and 55% in *C. capsularis* and 59-75% in *C. olitorius* (Sarkar *et al.*, 2005). The survey conducted on weed flora associated with jute in 5 major jute growing states of India *viz.*, West Bengal, Bihar, Assam, Orissa and Uttar Pradesh identified about 190 different species of weeds belonging to 37 families (Kundu, 1980) and the dominant weeds were mostly annual grasses and sedges. The important weed species associated with jute crop are listed in Table 7 (Ghosh, 1983). The growth of weeds in jute field showed a sigmoidal pattern and maximum dry biomass weight of grassy weeds was observed at 87 days in *C. olitorius* and at 112 days in *C. capsularis* jute (Sarkar and Bhattacharya, 2005). The critical period of crop – weed competition in jute was found to be between 15 and 60 days after sowing (Gogoi and Kalita, 1992). Manual weeding in jute is costly incurring around 35% of total cost of cultivation (Saraswat, 1980) and energy requirement for weeding is quite high (543 MJ/ha) (Borkar *et al.*, 1999).

Extensive research has been carried out to manage the weeds through manual, cultural, chemical and also by an integrated approach. Maximum control of weeds was achieved with two manual weedings at 3 and 5 week after sowing (Guha, 1999) or with hoeing at 15 DAS and 2 hand weeding at 3 and 5 weeks after sowing at Kalyani, West Bengal (Prusty *et al.*, 1988). Red amaranth when grown (seeding @ 10-30 kg/ha) with jute in mixed cropping system resulted in 22-25% more suppression of

Table 8. Fibre yield and economics of *olitorius* jute under different weed control methods

Weed control method	Dose (kg a.i./ha)	Weed dry weight (g/m^2)	Fibre yield (t/ha)	B:C ratio	Reference
2 Hand weeding (Hw) at 3 and 5 WAS	-	8.83 (45 DAS*)	2.44	0.79	Sarkar *et al.* (2005)
Trifluralin (PPI at 1 DBS)	0.75	27.2 (45 DAS*)	1.79	2.19	Sarkar *et al.* (2005)
S- Metolachlor (PE)	0.50	9.70 (45 DAS*)	2.49	-	Sarkar (2007)
Quizalofop ethyl 5% EC at 21 DAE + adjuvant + 1 HW at 35 DAE	60 (g/ha) + 0.5-0.6 (l/ha)	141	3.87	1.66	Ghorai *et al.* (2008)
Mulch @ 10 t/ha + red and white amaranth + radish + 2 HW	-	82	3.90 (1.1 + 0.64+0.94#)	2.19	Ghorai *et al.* (2008)
Jute + red and white amaranth + radish + 2 HW	-	192	3.57 (2.9+0.77+0.63#)	1.57	Ghorai *et al.* (2008)

PPI : Pre-plant incorporation, PE : Premegence, DAE : Days after emergence, DBS : Day before sowing
* : stage of sampling; # : yield of intercrops

Table 9. Important retting microbes in jute

Bacteria		Fungus
Aerobic	Anaerobic	
Bacillus subtilis, B. polymixa , B. macerans	*Clostridium sp.*	*Aspergillus niger, Macrophomina phaseolina, Phoma* sp., *Trichoderma sp.*
Sources: Kundu and Roy (1962); Bhattacharya (1974)	**Source** : Alam (1970)	**Sources** : Kundu and Roy (1962); Haque *et al.* (2002)

weed biomass than two hand weedings and also recorded an additional return of Rs 3,853/ha (Ghorai, 2007). Better weed control in jute was observed with pre-emergence application of S-Metolachlor @ 0.5 kg a.i./ha resulting in better control of sedges (Sarkar, 2007) or with fluchloralin @ 1.0 kg a.i./ha followed by one hand weeding at 28-35 DAS (Rajput, 2000). Pre-plant soil incorporation of trifluralin @ 0.75 kg a.i./ha one day before sowing was found to give 90% control of grassy weeds and some broadleaf weeds upto 35-42 DAS without any residual toxicity in soil when the soil had adequate moisture (Sarkar *et al.*, 2005). The *Azotobactor* and *Azospirillum* population in jute soil recovered, but could not reach to their respective initial population after application of trifluralin (Majumdar *et al.*, 2006 and 2007). Post-emergence spray of quizalofop ethyl 5% EC (40-50 g a.i./ha) + adjuvant @ 1ml/litre of water at 15 to 21 days after emergence (DAE) controlled the grassy weeds very effectively (Ghorai *et al.*, 2004). Pre-emergence (4-7 days before sowing) application of butachlor granule @ 1.0-1.5 kg a.i./ha controlled the monocot weeds while application of glyphosate @ 0.8-1.2 kg/ha + 2% urea or glyphosate @ 0.8-1.2 kg/ha + paraquat @ 0.48 kg/ha or glyphosate @ 0.8-1.2 kg/ha + 2% ammonium sulphate effectively controlled the composite weed flora in between jute, mesta and roselle seed crops respectively when sprayed exactly at the middle of the row through hooded and guarded nozzle keeping the nozzle 3-4" (7.5 to 10 cm) above ground surface (Bera *et al.*, 2009). The weed control, fibre yield and economics of *olitorius* jute under different methods of weed control are listed in Table 8. One hand weeding at 20-30 DAS was found optimum for sunnhemp (Mitra *et al.*, 2006). In *ramie*, application of atrazine @ 1kg a.i./ha + paraquat @ 2 l/ha per cutting recorded excellent weed control when sprayed between rows after each cutting (Saha *et al.*, 2006). Two hand weeding, one at 21 to 25 DAS and the second on 42-45 days crop age controlled the weeds efficiently in flax (Maitra *et al.*, 2007).

Despite the effectiveness of chemical weeding in jute and allied fibre crops, the phyto-toxic effect of the chemical (if any) and its interaction with soil microbes must be taken into consideration while selecting the dose and method of application.

Farm mechanization and post-harvest technology

In retting, efficient microbes were identified by different workers (Table 9). The effects of different factors like age of plants, fertilizer dose, quality of retting water particularly its pH and temperature, use of activators, covering materials, etc. on retting process and its subsequent effect on fibre quality had been documented (Kundu, 1964). The mechano-microbial retting technology developed at CRIJAF requires less water (25% of the conventional system), is cheaper than conventional retting and reduce the retting duration significantly. The CRIJAF Bast Fibre Extractor can extract 25 and 15 kg ribbons/machine hr compared to 5 and 4 kg/man hr under conventional retting system in jute and mesta respectively. The ribbons thus extracted can be retted in 5-7 days as against 15-20 days required under conventional retting. This system has been proved very effective in areas where there is shortage of good quality retting water, which is now a common phenomenon in most of the jute growing areas. The fibre of *ramie* and *sisal* is extracted by 'Raspador Decorticator' which is powered by a 5 H.P. electric motor/diesel engine and its capacity is around 6 kg fibre/machine hour (Borkar, 2007). Machines are in developmental stage at CRIJAF which will be portable and have higher capacity. The CRIJAF flax extractor machine is a 0.5 H.P. power driven machine and its capacity is 3 kg dry fibre /hour and it's in the process of further improvement. A promising pectinolytic bacteria *Bacillus pumilus* (strain DKS 1) had been isolated for degumming of *ramie* fibre which was found to reduce the gum content of *ramie* fibre significantly as indicated by weight loss of *ramie* fibre by 25% in small-scale and 24% in large-scale degumming (CRIJAF, 2008).

FUTURE AREAS OF RESEARCH

The biodegradability and eco-friendliness of jute and allied fibres had always given them an edge over their cheaper synthetic counterparts, though the competition from synthetic fibres is increasing every day. So to protect the interest of jute and allied fibre sector, the fibre production system should be made more remunerative and cost effective. Apart from yield enhancement, the fibre quality also needs to be improved as it the basic requirement of the value added end products. The share of value added diversified products in the global market of jute goods are growing very fast and to compete with our major competitor Bangladesh, the quality parameters needed for different product categories must be met. To attain these targets successfully, we need to address the following issues at the earliest :

- The area under jute and mesta is about 1.0 m ha while the acreage of *ramie* and *sisal* fibres are still negligible. There is an ample scope for increasing the area under these crops, if proper support price along with other incentives can be given to the farmers. Mini Mission II of Jute Technology Mission has a significant role to play as considerable incentives are being offered on seed/planting material, implements, technology demonstration, farmers' training and other aspects in this programme.
- The share of jute diversified products (JDP) has increased from 2% during mid-eighties to 18% of total jute good production during 2000s. Both conventional and molecular breeding approach has to be utilized to improve the strength and fineness of jute fibre which are pre-requisites for manufacturing of JDP.
- The production factors responsible for variability in productivity as well as fibre quality has to be identified and location / situation specific strategies has to be devised at the earliest to improve the yield and quality of the fibre. The cost of cultivation of jute and allied fibre crops has to be reduced by at least by 30 to 40% to make the systems remunerative.
- Jute seed is produced in Andhra Pradesh and Maharastra while the crop is cultivated in the eastern part of the country. The physical distance is primarily responsible for the artificial shortage of seed to the growers and to avoid this recurring problem, it is essential to try seed production in the red lateritic belt of West Bengal, parts of Bihar and Orissa which can ensure the early arrival of seed in the market. It is essential to develop cheap alternative sources of planting materials in *ramie* and *sisal.*
- Mechanical interventions in field operations and fibre extraction is essential as it will reduce the cost of cultivation and will also improve fibre quality. The 'Multi-Row Seed Drill' and 'CRIJAF Bast Fibre Extractor' have certainly enhanced the efficiency of seeding and fibre extraction in jute. The fibre extraction machines for flax, *ramie* and *sisal* are in the process of development.
- The growing demand of newsprint (about 8.53 million MT on 2010) can not be met from forest resources alone due to its severe negative impact on environment. Jute and allied fibres are rich in cellulose, have similar strength of hardwood, and can be well utilized as raw material for paper industries. The high amount of biomass of jute and mesta varieties can be successfully utilized for paper pulp provided photo-insensitive varieties of jute and mesta are developed which will ensure

the year round supply of the raw material to the industry.

- Successful utilization of the byproducts developed during various stages of fibre extraction and processing, particularly in *ramie* and *sisal* will create value addition and will make the entire production chain more profitable. *Ramie* leaves are potential source for natural antioxidants, food supplements, etc. Good quality enzymes and biofertilizers can be developed from the degumming waste of *ramie*. Similarly the huge amount of biomass waste during fibre extraction in *ramie* and *sisal* can also be effectively utilized for paper pulp making, composting, bio-gas generation, etc.

Raw jute industry is facing a stiff competition from its cheaper synthetic counterparts. However, the consumers now-a-days are more concerned about environmental pollution which is a boon for the natural fibres. To reap the benefit, the entire production system of natural fibres must be more efficient and cost effective. Besides, significant improvement needs to be made at quality front as it is the pre-requisite for product diversification and value addition. Finally, a significant amount of profit generated in the entire value chain must go to the farmers to sustain their interest in jute and allied fibre farming.

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