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Integrated nutrient management in jute (*Corchorus* sp) based cropping system: A review

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ABSTRACT

Jute (*Corchorus* sp) is the single most economically and socially important commercial crop for the livelihood of 40 lakh small and marginal farm families of eastern Indian states like West Bengal, Assam, Bihar, Odisha, Meghalaya and Tripura. Farmers were not following appropriate nutrient management practices for the crop due to lack of awareness and to some extent for theire conomic inability to provide required inputs to the crop. However, gradually jute farmers are gaining knowledge in this regard and started using fertilizers for jute. For the last five decades and more, sufficient research and developmental work of nutrient management for jute were undertaken. But there was scanty effort to summarize the work on nutrient management of jute for the benefit of the farmers as well as researcher and extension personnel. Therefore, this review documented the research and development work efforts on nutrient management in jute over a period of about 50 years (1967–2017).The paper discussed about nutrient requirement for jute, work on N, P, K, S need and fertilizer schedule, role and rate of micronutrients like Zn and B, nutrient management in jute based cropping system, findings of long term fertilizer experiment (LTFE) in jute based crop rotation, soil test crop response (STCR) results and equations for jute based cropping system, soil microbial studies related to nutrient management of jute.

Key words: Capsularis, Olitorius, Jute, Nutrient Management

It is well established that jute (*Corchorus* sp) is an important commercial crop of eastern Indian states like West Bengal, Assam, Bihar, Odisha, Meghalaya and Tripura and also integrated into the social life of 40 lakh small and marginal farm families of this part of India.For the last decade the jute area in India remained between 7.5 to 8.0 lakh ha and the total jute production in the country also varied between 96.34 and 115.38 lakh bales (Sarkar and Majumdar 2016). In the early 1970s, the crop duration of the varieties were more than 150 days, which later reduced to 120 or even lesser duration due to development of newer varieties and supported agronomic management systems including nutrient management. Most of the earlier varieties were less fertilizer responsive, hence poor fibre yielder (20-24 q/ha). Whereas, with the advent of newer research tools, development of newer varieties take place that are fertilizer responsive, increased the fibre yield (28-32 q/ha even more) as well as farmers' profitability. To be competitive with Bangladesh in the export oriented jute market, India surely need much more attention on this crop especially yield and quality enhancement with lower cost of production. It may be noted that jute showed several merits such as positive residual effect of jute on yield and energy output of subsequently grown crops were observed as well as maintained or improvement of soil properties such as soil organic matter, available P etc. (Biswas *et al.* 2006). It may be mentioned, that the fibre crop and seed crop of jute are grown at different times with different sets of management practices. The fertilizer management practices of fibre crop and seed crop are also quite different. Over time with the development and popularization of newer varieties and with increased information reachability coupled with farmers' awareness, and the fertilizer use in jute crop has been increased. Not only nitrogen (N), phosphorus (P) and potassium (K), but also secondary nutrient like sulphur (S) and micronutrients (mainly Zn and B) are applied to the jute crop by the farmers. Therefore, the present article put effort to document the research and development strategies framed on fertilizer and micronutrient use in jute cultivation over a period of about 50 years (1967 to 2017).

Characteristics of jute growing soils

The jute growing tracts of West Bengal are dominant in illitic type of clay minerals with kaolinite as next abundance and montmorillonite in trace. Soil acidity, coarse texture, poor water retention capacities are considered the major

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factors limiting the fibre yield of jute in Coochbehar and Jalpaiguri (Mitra and Samajdar 2013). In Dakshin Dinajpur area several production constraints for jute cultivation are observed. In this district, the soil is acidic in reaction. In Balurghat block, the surface soil pH varies from 4.42 (Boaldar) to 5.37 (Danga), whereas in Kumarganj block soil pH varies from 4.58 (Jakhirpur) to 5.66 (Bhomar). Lower soil pH was considered as one of the important limiting factor for lower jute fibre yield in this region (Maji *et al.* 2012a).

The mean available N content of different jute growing soils (of West Bengal, Assam, and Odisha) varied between 103.4 and 205.6 ppm representing 14.1 to 24.7% of total N (Doharey 1973).The critical limits of soil available P evaluated through radio isotopic studies were worked out as 24 kg P_2O_5 /ha (Goswami *et al.* 1971) in jute growing soils. The highest fixation of P (85.6%) was observed in soils with kaolinite as the dominant and montmorillonite as the associate minerals. The soils which contained illite as the dominant mineral showed lowest (41.4%) P fixation capacity (Ray *et al.* 1995). Some pocket areas of southern Bengal jute field are found to be S deficient (Saha *et al.* 1998). One of the major reasons of lower productivity (22 q/ha) in Dakshin Dinajpur is deficiency of sulphur (Maji *et al.* 2013a). In Hooghly, jute is grown after potato which is highly fertilized and the fertilizer applied in a year is skewed towards potassium (202 kg/ha/year) might be supporting higher productivity of jute through lesser disease incidence as reported earlier by Mondal *et al.* (2004a). In case of North 24 Parganas, the total fertilizer use is good (388.8 kg/ha/year) and in general the N:P:K ratio followed is favourable for better agriculture (1.9:1.1:1.0). Chapke (2012) reported that farmers of North 24 Parganas continued to use balanced fertilizer for jute (N:56, P_2O_5:29 and K_2O:31 kg/ha).

It was a matter of concern that the organic carbon (OC) status of majority jute seed producing soils of Andhra Pradesh (Guntur), Tamil Nadu (Erode) and Maharashtra (Ahmednagar) were low to medium. The OC values were 0.49 0.50 and 0.70% for Guntur, Erode and Ahmednagar districts, respectively. Regarding the available nitrogen status of the soils, it was observed that except Guntur (564 kg/ha) all other places were low in nitrogen (152 kg for Maharashtra and 148 kg for Tamil Nadu). Whereas, available phosphate status was high in Tamil Nadu (27 kg/ha) and low in Maharashtra (12.3 kg/ha) and Andhra Pradesh (9.6 kg/kg). Unlike nitrogen and phosphorus, potassium status was medium (275 kg/ha in Maharashtra and 255.7 kg/ha in Andhra Pradesh) to high (311.3 kg/ha) in Tamil Nadu (Sarkar *et al.* 2008).

Most surface soils of the jute growing areas contained adequate amounts of total and available Fe, Mn, Cu and Zn. Studies in six profiles showed that available Fe, Mn, Cu and Zn decreased with soil depth(Saha *et al.* 1982). The available Zn content in some villages of Dakshin Dinajpur district was as low as 0.35 mg/kg (Balurghat block) and the same for villages of Kumarganj block was 0.47 mg/kg. Another important micronutrient, boron (B) was also deficient (0.12 - 0.42 mg/kg) in Dakshin Dinajpur (Maji *et al.* 2013b).

Table 1 Important enzymatic characteristics of jute growing soil

Parameter	*Capsularis* jute soil	*Olitorius* jute soil
Acid phosphatase activity (E.U. × 10^{-2})	2.05	2.49
Alkaline phosphatase activity (E.U. × 10^{-2})	4.05	3.06
Dehydrogenase activity (μg TPF/g/h)	7.52	7.12

Source: Tarafdar *et al.* (1989)

The acid and alkaline phosphatase and dehydrogenase activities were estimated in the soil under *capsularis* and *olitorius* jute (Table 1).

Nutrient requirement of jute

It was found that *capsularis* jute requires 3.2 kg N, 1.62 kg P_2O_5 and 8.0 kg K_2O for producing one quintal of fibre and the same values for *olitorius* jute are 2.2 kg N, 1.66 kg P_2O_5 and 4.5 kg K_2O (Doharey1973). Mandal *et al.* (1976) reported that the nutrient requirement per quintal of dry fibre production for *capsularis* jute was 3.14 kg N, 1.5 kg P_2O_5, 7.97 kg K_2O, 4.99 kg CaO and 2.15 kg MgO, while for *olitorius* jute the nutrient requirement per quintal of dry fibre production was 2.06 kg N, 1.66 kg P_2O_5, 5.18 kg K_2O, 4.70 kg CaO and 1.04 kg MgO.The critical limit for soil available S was estimated to be 8.5 ppm SO_4-S (Saha *et al.* 1998).The required amount of Fe, Mn, Cu, and Zn to produce one quintal of fibre from *capsularis* jute was 78.4, 25.1, 2.6 and 21.4 g, respectively. The corresponding value for *olitorius* jute was 36.7, 11.2, 1.8 and 13.9 g, respectively (Saha *et al.* 1983,Saha *et al.* 1985). Critical limit of available Zn for jute crop was estimated as 0.5 ppm (Saha *et al.* 1985).

Nutrient management in jute

Nitrogen: Application of 80 kg N/ha in drought year and in the normal (or excess) rainfall year application of 40 kg N/ha produced the highest fibre yields in *olitorius* jute (Patel and Mandal 1983). Fibre quality was decreased with more than 60 kg N/ha and was not improved by addition of P and/or K to the N fertilizer (Gupta *et al.* 1981). In Kalyani, biomass production increased in jute up to 80 kg N/ha at 90 days after sowing and with increasing sowing rate. Gotyal *et al.* (2016) reported that higher fibre yield in cv. JRO 8432 could be achieved with N:P_2O_5:K_2O @ 120:40:40 (26.9 q/ha), followed by N:P_2O_5:K_2O @ 120:30:30 (25.4 q/ha). But at higher doses of N fertilizer, the harmful yellow mite population increased by 16.9% in 100 kg N and further increased by 126.4% in 120 kg N/ha as compared to recommended dose of N fertilizer (60 kg/ha). It was recorded that for a targeted jute (cv. JRO 204) fibre yield of 35 q/ha, application of fertilizers as per soil test based values *et al.* 89:40:19 kg/ha N:P_2O_5:K_2O gave fibre yield of 34.0 q/ha. However, if FYM @5 t/ha is considered, to get targeted yield, the fertilizer requirement (under soil test based values) reduced to 82:36:18 kg/ha

$N:P_2O_5:K_2O$ and the fibre yield obtained was 37.1 q/ha which was 28.8% more as compared to the yield (28.8 q/ha) obtained in farmers' practice (Mazumdar *et al.* 2018a).

Application of NPK @ 60:60:60 kg/ha with 3 splits (25, 45 and 65 DAS) of N fertilizer to jute seed crop gave the best results in terms of pod number, pod weight, seed yield, plant nutrient content and proportion of larger seeds produced (Bhattacharjee *et al.* 2000). For jute seed production in Andhra Pradesh, 120 kg N/ha was found to be the optimum for higher seed yield with better quality (Indulekha 2012) and for Coochbehar area (West Bengal), 40 kg N (along with 20 kg P and 30 kg K/ha) was the best for obtaining better yield parameters (Patra 2013). In the red and laterite zone of Paschim Medinipur district, the highest seed yield (481 kg/ha) of *tossa* jute (JRO 204) was obtained with 60 kg N, 60 kg P_2O_5 and 60 kg K_2O/ha, where N was applied in 3 equal split doses after 30,45 and 65 DAS (Sarkar and Banerjee 2014). Similarly, in the plateau region of western Odisha, application 60 kg/ha each of N, P_2O_5 and K_2O gave the highest seed yield of 993 kg/ha in JRO 8432, 875 kg in JRO 524 and 767 kg in JRO 128 (Sarkar 2017).

Phosphorus: Ray and Gupta (1979) studied correlation between soil P fractions, yield, P uptake and it was concluded that Olsen's method (0.5 M $NaHCO_3$, pH 8.5) is the most suitable for determining the alkaline phosphorus status of jute growing soils of southern Bengal followed by NH_4HCO_3 and NaOH-$Na_2C_2O_4$ extractants. Soil P fractions such as Al-P and Fe-P were significantly and positively correlated with jute fibre yield and P uptake (Table 2), which indicates their greater participation in regulating the available pool of soil P (Doharey *et al.* 1980).

Jute grown on an acid soil (pH 5.3), application of 7 t lime/ha at 1-4 week before sowing markedly increased the fibre yields and P uptake by plants (Table 3). No adverse effect of reduced reaction period of lime and soil was observed on growth and P uptake, P utilization and fibre yield in jute (Sinha 1981).

It was observed that percentage P derived from applied fertilizer was the highest at the highest rate of N application (Chaudhury and Ray 1998).

Potassium: In *olitorius* jute (cv. JRO 524), 20-30 kg K_2O/ha was optimum in medium available potassium (190 kg) soil condition along with other nutrients for achieving higher fibre yield (34.3 q/ha) in lower Gangetic alluvium (Mondal *et al.* 2004a). In jute-rice-chickpea sequence, the K content of plants was positively correlated with crop yields (r = 0.95, 0.84, 0.89 for jute, rice and chickpea, respectively). The maximum positive balance of K (577.4 kg/ha) was maintained with application of 20, 30 and 15 kg of K_2O to jute-rice-chickpea crops grown in sequence (Mondal *et al.* 2004a). Incidence of root and stem rot of jute (caused by *Macrophomina phaseolina*) was inversely proportional to application of K levels. The highest seed yield of 759 kg/ha was obtained with 40 kg K_2O along with 40 kg S/ha which was at par with 40 kg K_2O along with 20 kg S/ha yielding 747 kg of jute seed/ha (Mondal *et al.* 2003).

Sulphur: Application of 20 kg/ha S along with K was needed for crop yield improvement and reduction in disease incidence in the lower Gangetic alluvium soils (Mondal *et al.* 2004b). Application of sulphur @30 kg/ha (1½ months prior to cropping) increased the jute fibre yield by 21-37% at various locations of Dakshin Dinajpur with a reduction in disease incidence (Maji *et al.* 2013a). In a sulphur × nitrogen interaction study, synergistic interaction was found for jute in multi-locational trial and application of 60 kg N and 30 kg S/ha was recommended for yield maximization, nutrient uptake and leaf protein content of jute (Majumdar *et al.* 2016).

In case of main jute seed crop, the highest seed yield of 759 kg/ha was obtained with 40 kg S/ha (along with 40 kg K_2O) which was at par with 20 kg S/ha along with 40 kg K_2O yielding 747 kg of jute seed/ha (Mondal *et al.* 2003). Whereas, in jute seed crop grown from top cutting, application of 20 kg S (along with 20 kg K_2O/ha) produced the highest seed yield of 496 kg/ha (Mondal *et al.* 2007).

Calcium and magnesium: Application of 10 kg Mg/ha (in the form of $MgSO_4$along with 40 kg K) to *olitorius* jute increased plant height up to 180.3 cm and fibre yield (3.22 g/plant). Calcium ($CaCO_3$) application (0.5-1.0 t/ha) to jute crop (*capsularis* and *olitorius*) under southern Bengal condition had no effect on fibre yield (Chaudhury *et al.* 1999).

Integrated management

The *capsularis* and *olitorius* jute varieties of 1960's

Table 2 Simple correlation (r) and multiple correlation (R) coefficients of methods of P extraction, fibre yield and P uptake by capsularis jute with different P fractions

	Al-P	Fe-P	Ca-P	Red Fe-P	R
	(r)				
Olsen P	0.792**	0.464**	0.086	0.045	0.833**
Bray P1	0.527**	0.727**	0.593**	0.211	0.813**
Fibre yield	0.438**	0.505**	0.295	0.235	0.598**
P uptake	0.404**	0.464**	0.240	0.406	0.647**

Source: Doharey *et al.* (1980)

** Significant at 1% level

Table 3 Effect of application of lime (7 t/ha) at different times on fibre yield of jute (q/ha)

Treatment	Jute fibre yield (q/ha)	
	Capsularis	Olitorius
No liming	18.1	19.9
Lime @ 7 t/ha at 1 week before sowing	31.9	29.5
Lime @ 7 t/ha at 2 week before sowing	29.4	24.9
Lime @ 7 t/ha at 3 week before sowing	29.6	26.7
Lime @ 7 t/ha at 4 week before sowing	29.8	27.2
CD 5%	7.27	6.71

Source: Sinha (1981)

were less responsive to inorganic fertilizer application. It was reported that complete package including seed treatment, line sowing, liming based of LR, balanced fertilizer use (NPK @ 60:30:40 kg/ha), $ZnSO_4$ @ 20 kg/ha, borax @ 10 kg/ha and S @ 30 kg/ha and weed management could able to increase jute fibre yield by 26% in Coochbehar and Jalpaiguri (Mitra and Samajdar 2013).The highest jute fibre yield was obtained with FYM (10 t/ha), which was at par with that obtained with liming (based on lime requirement) in acid soil (Bandyopadhyay (2003). Integration of 100% NPK with 10 t FYM/ha proved to be better option for higher jute fibre productivity and maintenance of soil fertility status over 150% NPK in slightly alkaline soil (Majumdar *et al.* 2014).

Micronutrient management

Available phosphorus exerted maximum influence on the availability of Zn, Fe and Cu, whereas, available N had the maximum influence on the availability of Mn (Majumdar 2012). Application of Zn (10 ppm Zn-EDTA) increased *olitorius* jute fibre yield by 39.1% in Nadia district of West Bengal (Mandal and Sarkar 1993). The fibre yield of jute was increased by borax and gave finer fibre at Nagaon, Assam (Sarma *et al.* 1999). In Coochbehar, application of 10 kg B along with 45 kg K produced fibres with a good combination of strength and fineness in *capsularis* jute at 120 days (Sarkar and Banyopadhyay 2000).The micronutrient content and uptake by *capsularis* jute (Table 4) was studied by Saha *et al.* (1983). It was opined that application of Zn coupled with soil test based fertilizer application will certainly enhance the jute fibre productivity, resistance against disease and increase the benefit:cost (B:C) ratio in the constrained Zn deficient soils of old alluvial tracts of this region (Maji *et al.* 2012b). For sustainable production of quality jute fibre with acceptable level of profitability in B deficient soils of Dakshin Dinajpur, the soil acidity problems need to be addressed first and thereafter, balanced fertilizer application along with supply of deficient micro and secondary nutrients are to be ensured positively (Maji *et al.* 2013b).

In a jute-rice-wheat cropping sequence, application of FYM in conjugation with balanced dose of inorganic fertilizer, helped to counter the depletion of available micronutrients to some extent and to increase the status of DTPA-Zn and Cu, in the soil (Majumdar 2012).

Table 4 Micronutrient content and uptake by capsularis jute

Plant parts	Micronutrient content (ppm)				Micronutrient uptake (g/ha)			
	Fe	Mn	Cu	Zn	Fe	Mn	Cu	Zn
Leaf	206.5	172.8	5.2	64.0	738.6	218.9	28.6	201.5
Bark	146.2	42.9	5.7	39.8	1052.3	213.9	32.6	276.3
Wood	153.4	31.2	4.9	41.1	265.1	222.9	6.7	87.5

Source: Saha *et al.* (1983)

Nutrient management of jute based cropping system

The highest fibre yield of jute (33.5 q/ha) and grain yield of rice (38.5 q/ha) were obtained when jute and rice crops in sequence received both organic and inorganic sources of nutrients (N:P:K at 40:20:30 kg/ha for jute; and 60:30:30 kg/ha for rice and 10 t farmyard manure (FYM)/ha for both crops. The maximum nutrient uptake of N (120.9 kg/ha), P (65.3 kg/ha), K (204.6 kg/ha) and S (19.9 kg/ha) by jute and rice was recorded under the FYM + NPK treatment (Brahmachari and Mandal 2000). Under irrigated conditions in potato-jute-rice cropping sequence, the highest fibre yield of jute (3.40 t/ha) and grain yield of rice (4.40 t/ha) and tuber yield of potato were recorded with higher N, P, K and S uptake when all the crops in the sequence received NPK in combination with FYM (Mondal and Roy 2001). In lower Gangetic alluvium soil, the highest agronomic efficiency (11.73) was recorded in treatment receiving 20, 30 and 15 kg K_2O/ha to jute-rice-chickpea cropping sequence (Mondal *et al.* 2004a).

In a crop residue management study, higher system productivity of all crop systems was recorded with 100% RDF with crop residue incorporation; and 25% nutrients may be saved by adding crop residue in different jute based cropping system besides crop residue has beneficial effect on soil quality in long run (Kumar *et al.* 2016). It was found that soils of Hooghly district have much lower organic carbon (6.9 to 9.3 g/kg) and higher available nitrogen, phosphorus and potassium status as compared to Nadia and North 24 Parganas (Manna *et al.* 2017). Among various jute based cropping systems studied, jute-rice-potato recorded highest organic carbon (14.1 g/kg) content followed by jute-rice-lentil (13.2 g/kg) in North 24 Parganas district and jute rice-garden pea (12.98 g/kg) of Nadia district. Soils of Hooghly district recorded higher acid phosphatase activity while the soils of Nadia and North 24 Parganas recorded higher alkaline phosphatase activity. Jute-rice-potato, jute-rice-coriander and jute-rice-garden pea can safely be recommended for achieving higher soil quality in Hooghly, North 24 Parganas and Nadia district, respectively (Manna *et al.* 2017).

Long Term Fertilizer Experiment (LTFE)

After 25 years of intensive cropping under long term fertilizer experiment with jute-rice-wheat cropping system, the yield in control was declined to the extent of 16 to 5 q/ha (65%) in jute, 24 to 13 q/ha (44%) in rice and 11 to 8 q/ha (28%) in wheat. Response in yield due to application of N and P was found to be the highest in rice followed by wheat and jute (Chaudhury *et al.* 1999). After 36 years of experimentation, it has been found that yield decline was less in NPK treatments containing single super phosphate (33.24%) as compared to the same containing di-ammonium phosphate as P source (43.2%). The results further corroborated the positive impact of sulphur in augmenting in fibre yield of jute and also in sustaining the performance of jute based production system (Saha *et al.* 2008). After 42 years of long term fertilizer experimentation with jute-rice-wheat sequence revealed that crop yields (jute, rice and wheat) were lowest in the control where neither fertilizers nor manures were applied for the last four decades and highest in 150% NPK and there was significant difference among the different treatments with respect to potassium fractions. Moreover, K fractions were significantly decreased with increasing depth of soil, with exception in non-exchangeable K. The contribution of different K fractions in two soil depths studied was in the order of non-exchangeable-K>exchangeable-K>water soluble-K. The mean annual removal of K by crops surpassed the amount of total K applied to the soil in all treatments, thus showing negative apparent K balance (Kundu *et al.* 2016). The potassium imbalance in the soil resulted in build-up of plant parasitic nematodes (Saha and Laha 2004).

Soil Test Crop Response (STCR)

Investigations on soil test crop response (STCR) revealed that out of several extractants tried for P estimation, only Olsen's extractant gave significant correlations with P uptake, 'A' value percent yield of jute and Fe- P fraction of soil.The targeted yield equations on prescription based fertilizer application in jute (JRC 212, JRO 632, JRO 7835 and JRO 524), rice (Jaya, Ratna, Pankaj and CR 1094) and wheat (*Sonalika*) were derived and validated under farmers 'field condition (Ray *et al.* 1996). Soil-test-based fertilizer prescription for jute fibre, rice grain, and garden pea was developed on alluvial soil, Typic Eutrochrept, of eastern India.The higher nutrient requirement was observed in jute (2.88:0.97:5.07 kg NPK) followed by rice (2.34:0.47:3.48 kg NPK) and garden pea (0.52:0.11:0.39 kg NPK) for the production of 100 kg yields of jute fibre/rice grain/green pod, respectively. It was found that soil has contributed the maximum percentage of N (20.6%) and K (47.29%) toward the total N and K uptake by rice followed in jute, whereas the higher percentage contribution of P (21.1%) occurred in jute. By following ready reckoner table, a farmer can save N, P_2O_5 and K_2O in amounts of 3.2, 3.9 and 10.9; 6.3, 7.0 and 9.1; 34.0, 26.0 and 34.4 % more as compared to without IPNS respectively in jute, rice and garden pea (Singh *et al.* 2015).

Soil microbial studies for nutrient management

Application of NPK @ 20:20:40 kg/ha + 20 t FYM to *capsularis* and *olitorius* jute increased the activities of acid phosphatase, alkaline phosphatase and dehydrogenase in soil and increased fibre yield and P uptake (Tarafdar *et al.* 1989). Chaudhury *et al.* (1997) reported that the inoculation of *A. brasilense* or dual inoculation of *A. brasilense* + *B. megaterium* was found to increase fibre yield of jute in jute-cowpea –wheat cropping system. There was simultaneous increase in bacterial count and N_2 fixation and the total N fixation in post-harvest jute soil was varied between 7-17 mg/kg soil. A study on effect of herbicides and fungicides applied on jute (*Corchorusolitorius* L.) revealed that it had temporary detrimental effect on enzyme activities (dehydrogenase, urease, fluorescein di-acetate hydrolyzing activity and acid and alkaline phosphatase) and other microbial properties of jute soil, which were replenished at the time of harvest of the crop (Majumdar *et al.* 2010). In a long term field study with jute-rice-wheat rotation, significantly higher level of fluorescein-di-acetate (FDHA) activity was recorded in NPK + FYM treatments. Higher amount of protease, lipase and esterase enzymes were observed in FYM amended soil, which substantiates the role of organic amendments as favourable niche for microbial activity vis-à-vis soil health (Majumdar 2012). The population of beneficial microbes and enzymatic activities, viz. dehydrogenase, urease, fluorescein di-acetate hydrolyzing activity, acid and alkaline phosphatase in jute rhizosphere after 60 days of sowing were significantly higher with 100% NPK + 10 tonnes FYM/ha over all treatments including 100 and 150% NPK. Integration of recommended dose of fertilizer with 10 tonnes FYM/ha proved to be the best possible option for sustainable jute fibre production and maintenance of soil microbial health and fertility status (Majumdar *et al.* 2014).

Carbon dynamics and soil quality under jute based cropping system

Impacts of 43-year nutrient management on carbon (C) and nutrient dynamics were studied in a rice-wheat-jute system in tropical India (Mazumdar *et al.* 2018b). Labile, slow and total C content was found highest in 100% NPK + FYM. Enhanced C indices under 100% NPK + FYM over 100% NPK and other treatments signified the importance of long-term balanced fertilization on soil C stabilization. Lability indexes were lower at sub-soil (30-45cm). Incorporation of jute in cropping sequence in this region entrusted sustainability both in respect of C build up and nutrient dynamics as it provides considerable amount of biomass in very less time and relatively drier period of the year.

Conclusion

The nutrient requirement for producing each q of fibre in *capsularis* jute were 3.17 kg N, 1.56 kg P_2O_5, 7.98 kg K_2O, 4.99 kg CaO and 2.15 kg MgO. Similarly the nutrient requirement for producing one q of *olitorius* jute fibre were 2.13 kg N, 1.66 kg P_2O_5, 4.84 kg K_2O, 4.70 kg CaO and 1.04 kg MgO. In general, the optimum N fertilizer dose for *olitorius* jute for fibre was suggested as 50-60 kg/ha. However, with timely assured irrigation 80-90 kg N/ha showed better growth in *olitorius* jute. It was recorded that N dose more than 60 kg/ha decreased the fibre quality. For *capsularis* jute 80 kg N/ha gave higher fibre yield. For jute seed crop the N requirement was 60 kg/ha (in 3 splits at 25, 45 and 65 DAS) for southern Bengal condition; for north Bengal condition, the N requirement is 40 kg/ha and for Andhra Pradesh, even up to 120 kg N/ha was suggested for higher seed yield.

Al-bound phosphate (and sometimes Fe-P) was the most significant for jute fibre yield and P uptake in majority of jute growing soils. In acid soil (pH ± 5.0) liming @ 7 t/ha at 2-4 weeks before sowing, markedly increased the fibre yield and P uptake. For *olitorius* jute the phosphate fertilizer requirement was about 45 kg P_2O_5/ha and for *capsularis* jute it was about 40 kg P_2O_5/ha. For better fibre productivity, the optimum fertilizer dose suggested was 40 kg K_2O/ha. If the soil having better available potassium (>200 kg/ha), application of 20-30 kg K_2O/ha was suggested. Critical limit for soil available sulphur was estimated to be 8.5 ppm SO_4-S for jute. In S deficient areas application of S @ 20-30 kg/ha (1-1½ month prior to cropping) increased the fibre yield by 21-31.7%. Application of S along with balanced NPK fertilizer decreased the disease incidence by 34-100%. Synergistic interaction between S × N was found in jute and suggested application of 30 kg S/ha and 60 kg N for yield maximization, nutrient uptake and leaf nutrient content. For jute seed crop 20-40 kg S/ha (along with 40 kg K_2O) was recommended for higher seed yield with better quality.

Zn and B were the major limiting micronutrients in jute growing soils. Application of 20 kg $ZnSO_4$ and 10 kg Borax found beneficial in soil deficient for the micronutrients. In some cases Mn @ 5 kg/ha (as $MnSO_4$) increased the fibre yield by 28%. In 40 years of jute-rice-wheat crop rotation, balanced application of NPK along with FYM countered depletion of available micronutrients. Continuously growing jute-rice-wheat in sequence for the last 42 years in the same experimental setup revealed that the highest crop yields were obtained with 150% NPK but there was significant difference among the different treatments with respect to K fractions which significantly decreased with increasing depth of soil. Depletion of available micronutrients was countered in treatments having inclusion of organic manure with balanced dose of fertilizers. It was reported that by following the ready reckoner table, through soil test based fertilizer prescription farmers could save 3.2% N, 3.9% P_2O_5 and 10.9% K_2O for jute as compared to general recommended fertilizer dose.

It was observed that more than 30% yield increase in jute was obtained with *Azospirillum* inoculation with limited N dose. Higher amount of protease, lipase and esterase enzymes were observed in FYM amended soil in jute-rice-wheat sequence. Integration of 100% NPK with 10 t FYM/ha proved to be the best option for sustaining higher jute fibre yield coupled with better soil health. Population of beneficial microbes and enzyme activities, acid and alkaline phosphatase was significantly higher with 10 t FYM+100% NPK treatment. Incorporation of jute in cropping sequence in this region entrusted sustainability both in respect of C build up and nutrient dynamics.

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