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Interactive Effect of Sulfur and Nitrogen on Fiber Yield, Nutrient Uptake and Quality of Jute (*Corchorus olitorius*)

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Abstract The interaction effect of nitrogen and sulfur application on fiber yield, nutrient uptake and quality of jute (*Corchorus olitorius*) was evaluated in two field experiments conducted at two different locations viz. Barrackpore and Budbud, West Bengal, India during 2008 and 2009 cropping seasons. Application of nitrogen and sulfur significantly increased fiber yield, nutrient uptake, protein content of leaf and fiber strength of jute at both the locations. The combined application of 60 kg N and 45 kg S significantly increased the N, P and K uptake and protein content of jute leaf. The crop yield response was higher for added N at Barrackpore and for added S at Budbud and higher values were recorded at $N_{40}S_{15}$ application. Higher N and S use efficiency of jute was recorded at N_{20} and N_{60} respectively at Barrackpore and Budbud.

Keywords Sulfur, Nitrogen, Jute, Fiber yield, Nutrient use efficiency.

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Introduction

Jute, the golden fiber is one of the important cash crops of India and most particularly of eastern Indian states namely West Bengal, Bihar and Assam. About 4 million farm family depends on jute cultivation for their livelihood. The decline in factor productivity under intensive cropping system over the years was found to be associated with deficiencies of secondary and micronutrients. S is a constituent of various essential amino acids, such as cysteine, cystine and methionine involved in chlorophyll production and is thus required for protein synthesis [1]. At present, sulfur is considered an important plant nutrient in quality crop production in Indian agriculture dominated by very high use of non-sulfur containing fertilizers and less use of organic manures [2]. Removal of S by crops in India is about 1.26 million tonne (Mt), whereas its replenishment through fertilizers is only about 0.76 Mt [3] and the use efficiency of externally added sulfur is in between 8–10% [4]. Sulfur deficiency is one of the major constraints for sustainable

Table 1. Initial soil fertility status of experimental sites at Barrackpore and Budbud.

Barrackpore	Budbud
Texture: Sandy loam	Texture: Silty clay loam
pH-7.05	pH-5.8–6.2
Organic carbon-6.35 g/kg	Organic carbon-5.80 g/kg
EC-0.17 dS/m	EC-0.11 dS/m
CEC-17.2 cmol (p_+)/kg	CEC-10.0 cmol (p_+)/kg
Available N-302.5 kg/ha	Available N-291.5 kg/ha
Available P-30 kg/ha	Available P-13 kg/ha
Available K-189 kg/ha	Available K-116.5 kg/ha
Available S-6.8 ppm	Available S-5.3 ppm

growth and productivity of several field crops. The area under jute cultivation is not an exception, also suffers from sulfur deficiency. Sulfur deficiency in jute crop was reported long way back in 1962 [5]. The use of S-free high analysis fertilizers, like urea, TSP, MP, high yielding varieties, higher cropping intensity without any replenishment and limited use of organic manures are the most probable reasons for sulfur deficiency [6]. Due to limited mobility of sulfur it produces chlorosis in the plant. Plants in low lying areas are more prone to chlorosis than those in the mid and upland areas. *Capsularis* jute is more tolerant to water logging and hence, grown extensively in pocket areas on wet and low lying soils. Sulfur and nitrogen are closely linked in protein metabolism; hence the combined effect of S and N may be synergistic in crop production. Sulfur requirement and strong interaction between S and N have been reported by several workers on agricultural crops [7, 8]. However meager information is available on sulfur requirement and its interaction with nitrogen in fiber crops especially in jute. Keeping this view, the present study was undertaken to evaluate the optimum dose of sulfur and its interaction with nitrogen on yield, nutrient uptake and quality of jute.

Materials and Methods

Two field experiments were conducted simultaneously in sandy loam and silty clay loam soils of Barrackpore (22°45´N 80° 26´E) and Budbud (23° 24´N 87° 32´E) with four levels of nitrogen (0, 20, 40 and 60 kg/ha) and four levels of sulfur (0, 15, 30 and 45 kg/ha). A total of sixteen treatment combinations were laid out in factorial randomized block design replicated thrice with jute (cv JRO 8432) as test crop for consecutive two years during 2008 and 2009. The initial soil status of experimental sites is given in Table 1.

Table 2. Effect of combined application of S and N on fiber yield and nutrient uptake by jute at Barrackpore.

S levels	N levels (kg/ha)				
(kg/ha)	0	20	40	60	Mean
		Fiber yield (q/ha)			
0	28.4	31.4	36.3	35.2	32.1
15	30.0	32.2	36.3	38.0	34.1
30	32.1	34.8	37.6	39.1	35.9
45	32.7	35.1	38.6	40.8	36.8
Mean	30.8	33.4	36.5	38.3	
CD (p=0.05)	S & N=0.92, S×N=NS				
		N uptake (kg/ha)			
0	69.4	73.8	83.4	86.6	78.3
15	81.7	90.9	99.9	104.2	94.2
30	88.6	99.3	105.4	112.8	101.5
45	94.1	99.4	113.3	116.6	105.8
Mean	83.4	90.8	100.5	105.0	
CD (p=0.05)	S & N=1.12, S×N=2.24				
		P uptake (kg/ha)			
0	31.7	35.1	38.7	41.9	36.8
15	35.7	40.9	45.0	44.2	41.4
30	40.5	46.1	49.0	53.7	47.3
45	43.4	47.1	53.4	56.3	50.0
Mean	37.8	42.3	46.5	49.0	
CD (p=0.05)	S & N=1.00, S×N=2.0				
		K uptake (kg/ha)			
0	104.5	112.8	122.2	129.5	117.2
15	122.4	131.0	144.7	149.5	136.9
30	131.8	148.6	156.3	165.2	150.5
45	148.2	153.4	168.7	175.4	161.4
Mean	126.7	136.4	148.0	154.9	
CD (p=0.05)	S & N=1.44, S×N=2.88				
		S uptake (kg/ha)			
0	9.2	11.7	14.3	20.5	13.9
15	14.2	15.3	17.7	24.1	17.8
30	16.9	18.9	22.4	26.5	21.2
45	18.7	20.9	25.2	28.0	23.2
Mean	14.7	16.7	19.9	24.8	
CD (p=0.05)	S & N=1.24, S×N=NS				

The recommended dose of P and K for jute was 30 kg/ha supplied through potassium di-hydrogen phosphate and muriate of potash respectively as basal dose during land preparation. Nitrogenous fertilizer as per treatment was applied through urea in two equal splits after 21 and 35 days of emergence of jute crop.

Table 3. Effect of combined application of S and N on fiber yield and nutrient uptake by jute at Budbud.

S levels (kg/ha)	N levels (kg/ha) 0	20	40	60	Mean
	Fiber yield (q/ha)				
0	27.5	28.7	30.1	31.5	29.4
15	28.8	30.5	31.9	33.2	31.1
30	31.6	32.4	34.4	35.2	33.4
45	31.9	33.8	35.4	37.2	34.6
Mean	30.0	31.3	33.0	34.3	
CD (p=0.05)	S & N=1.22, S×N=NS				
	N uptake (kg/ha)				
0	59.8	69.2	74.2	86.1	72.3
15	70.7	76.5	84.2	89.5	80.2
30	78.1	86.9	91.5	101.4	89.5
45	81.7	90.8	95.2	108.8	94.1
Mean	72.6	80.8	86.3	96.4	
CD (p=0.05)	S & N=1.34, S×N=2.68				
	P uptake (kg/ha)				
0	23.7	29.6	31.5	36.6	30.3
15	27.9	31.5	35.0	37.9	33.1
30	31.8	37.6	40.3	44.9	38.6
45	35.8	41.5	44.2	48.5	42.5
Mean	29.8	35.0	37.7	42.0	
CD (p=0.05)	S & N=1.80, S×N=3.60				
	K uptake (kg/ha)				
0	98.2	104.3	113.7	130.6	111.7
15	115.9	126.9	128.3	138.3	127.3
30	125.3	133.2	140.5	150.8	137.4
45	132.1	141.0	147.4	157.4	144.5
Mean	117.9	126.3	132.5	144.3	
CD (p=0.05)	S & N=1.44, S×N=2.88				
	S uptake (kg/ha)				
0	8.3	9.9	12.2	14.7	11.3
15	11.7	15.4	17.2	19.0	15.8
30	14.9	17.5	20.0	22.2	18.6
45	16.8	18.2	21.5	23.6	20.0
Mean	12.9	15.2	17.7	19.9	
CD (p=0.05)	S & N=1.24, S×N=NS				

Sulfur was applied as elemental sulfur in granular form, 15 days prior to sowing of crop. The jute crop was sown during 2nd week of April in every year with a seed rate of 5 kg/ha in a row to row and plant to plant spacing of 25 and 5 cm respectively in both locations. The jute crop was harvested after 120 days of sowing, kept 3–4 days for defoliation of leaves in the field and thereafter retted in retting tank following standard procedure. The fiber was extracted manually, washed in clean water, air dried after completion of retting within 18–20 days of immersion in retting tank. The plant samples collected at harvest were processed and analyzed for total N, P, K and S following standard procedure [9]. The dry weight of fiber was taken and the fiber samples were analyzed for fiber strength [10]. The leaf samples collected at 60 DAS (days after sowing) were analyzed for total protein [11]. Agronomic efficirency, physiological efficiency and apparent recovery of nutrients were calculated [12].

$$\text{Agronomic efficiency (kg fiber/kg nutrient)} = \frac{\text{[Fiber yield from treated plot (kg/ha)]} - \text{[Fiber yield from control plot (kg/ha)]}}{\text{Amount of nutrient added (kg/ha)}}$$

$$\text{Physiological efficiency (kg fiber/kg nutrient uptake)} = \frac{\text{[Fiber yield of treated plot (kg/ha)]} - \text{[Fiber yield of control plot (kg/ha)]}}{\text{[Nutrient uptake of treated plot (kg/ha)]} - \text{[Nutrient uptake of control plot (kg/ha)]}} \times 100$$

$$\text{Apparent recovery (\%)} = \frac{\text{[Nutrient uptake of treated plot (kg/ha)]} - \text{[Nutrient uptake of control plot (kg/ha)]}}{\text{Amount of nutrient added (kg/ha)}} \times 100$$

The experimental data were statistically analyzed by using SPSS10 software (SPSS Inc., Chicago, IL, USA).

Results and Discussion

Fiber yield and response

The fiber yield of jute increased significantly with increasing doses of nitrogen and up to 30 kg/ha compared to Budbud irrespective of N and S application, might be because of higher initial fertility status. Application of 15 and 30 kg S significantly increased fiber yield respectively by 5.8 to 6.2 and 11.8 to 13.6% over no sulfur and there was no significant difference between 30 and 45 kg S/ha indicating the fact that sulfur is an indispensible nutrient for jute fiber production. The interaction between N and S was non-significant at both the locations. The data on crop response study indicated that, the agronomic efficiency of jute was higher (14.25 and 13.3 kg fiber yield/

Table 4. Effect of combined application of S and N on nutrient use efficiency by jute at Barrackpore and Budbud.

Levels of nutrients	Agronomic efficiency (Δ kg yield/kg fertilizer added)	Physiological efficiency of nitrogen (Δ kg yield Δ/kg N uptake)	Physiological efficiency of sulfur (Δ kg yield Δ/kg S uptake)	Apparent nitrogen recovery (%)	Apparent sulfur recovery (%)
			Barrackpore		
N (kg/ha)					
0	–	–	–	–	–
20	13.0	35.1	130.0	37.0	10.0
40	14.25	33.3	109.6	42.75	13.0
60	12.5	34.7	74.25	36.0	16.8
S (kg/ha)					
0	–	–	–	–	–
15	13.3	12.6	51.3	106.0	26.0
30	12.7	16.4	52.1	77.3	24.3
45	10.4	17.1	50.5	61.1	20.7
			Budbud		
N (kg/ha)					
0	–	–	–	–	–
20	6.5	15.8	56.5	41.0	11.5
40	7.5	21.9	62.5	34.2	12.0
60	7.2	30.2	102.8	39.7	11.7
S (kg/ha)					
0	–	–	–	–	–
15	11.3	21.5	37.8	52.7	30.0
30	7.7	13.4	31.5	57.3	24.3
45	11.5	23.8	59.8	48.4	19.3

ha) and (7.5 and 11.3 kg fiber yield/ha) for applied N and S at $N_{40}S_{15}$ application respectively at Barrackpore and Budbud. Further additions of N and S reduced the application of sulfur at Barrackpore and Budbud (Tables 2, 3).

Nutrient uptake

Nitrogen (N) uptake by jute increased significantly with applied N and 60 kg/ha N application increased the N uptake by 25.9 and 32.8% respectively at Barrackpore and Budbud (Tables 2, 3) over their respective control (N_0). Similarly sulfur (S) application significantly favored the N uptake, and application of 45 kg S increased the N uptake by 35.1 and 30.1% over S_0 (control) respectively at Barrackpore and Budbud. The higher N uptake with S application might be because of the fact that both N and S are involved in protein biosynthesis and vital processes determining yield, so if the uptake of one nutrient increases, the uptake of other will also increase by the crop. The interaction effect of N and S was significant at both locations, and the maximum N uptake at both locations was recorded at $N_{60}S_{45}$ treatment combination.

The phosphorus (P) and potassium (K) uptake by jute increased significantly with N and S application at both locations (Tables 2, 3). The P uptake with applied N was significant and P uptake (49 and 42 kg/ha) at N_{60} was higher by 29.6 and 40.9% over N_0 (control) respectively at Barrackpore and Budbud. The increase in P uptake with N application was related to increased yield and complimentary effect of N on P availability. Similarly, as P and S are absorbed by plants as anions, higher availability of S led to the similar increase in P uptake with S application. The interaction between N and S was significant for P uptake and the maximum uptake of P (56.3 and 48.5 kg/ha) was recorded at $N_{60}S_{45}$ which was higher by 77.6 and 104.6% over N_0S_0 respectively at Barrackpore and Budbud.

The combined application of N and S increased significantly the K uptake by jute and maximum uptake (175.4 and 157.4 kg/ha) was at $N_{60}S_{45}$, which was higher by 67.8 and 60.3% t over control (N_0S_0) respectively at Barrackpore and Budbud. The S uptake by the jute crop increased significantly with S application and application of N also significantly favored higher S uptake at both locations (Tables 2, 3). The higher S uptake with N application might be attributed to the fact that both N and S are involved in protein biosynthesis and vital processes determining yield, so increasing uptake of nitrogen has enhanced the uptake of S by the crop.

The sulfur recovery increases with addition of S and the highest recovery of S was recorded at S_{15} at both locations, while addition of N up to 40 and 60 kg/ha increases apparent S recovery respectively at Budbud and Barrackpore (Table 4). Higher S use efficiency was recorded at S_{30} (52.1) and N_{20} (130) at Barrackpore and S_{45} (59.8) and N_{60} (102.8) treatments which indicated better utilization of applied nutrients for fiber production at Budbud compared to

Table 5. Effect of combined application of S and N on leaf protein content at 60 DAS and fiber strength of jute.

S levels (kg/ha)	N levels (kg/ha) 0	20	40	60	Mean
	Protein content (%) in jute leaf at Barrackpore				
0	3.4	4.1	3.3	2.9	3.4
15	3.4	3.2	3.8	3.7	3.5
30	4.1	4.6	4.2	4.1	4.2
45	3.4	3.9	4.1	3.0	3.6
Mean	3.6	3.9	3.8	3.4	
CD (p=0.05)	S & N=0.13, S×N=0.48				
	Protein content (%) in jute leaf at Budbud				
0	2.8	2.9	3.0	3.9	3.1
15	3.3	3.2	3.5	3.5	3.4
30	3.4	4.2	4.2	3.9	3.9
45	4.2	4.1	4.4	4.6	4.3
Mean	3.4	3.6	3.8	4.0	
CD (p=0.05)	S & N=0.16, S×N=0.52				
	Fiber strength (g/tex) of jute at Barrackpore				
0	24.5	25.3	25.5	24.7	25.0
15	26.3	27.2	27.4	26.8	26.9
30	27.0	27.5	27.6	28.0	27.5
45	26.3	27.8	28.0	27.6	27.4
Mean	26.0	26.9	27.1	26.8	
CD (p=0.05)	S & N=0.40, S×N=NS				
	Fiber strength (g/tex) of jute at Budbud				
0	23.6	23.8	24.8	24.3	24.1
15	24.9	25.4	25.5	24.6	25.1
30	25.7	26.3	27.3	26.4	26.3
45	26.0	26.5	26.9	25.8	26.3
Mean					
CD (p=0.05)	S & N=0.32, S×N=NS				

Barrackpore. The apparent N recovery was higher at N_{40} (42.75) and S_{15} (106) at Barrackpore and at N_{20} (41) and S_{30} (57.3) at Budbud (Table 4). The higher N use efficiency of N_{20} (35.1) and S_{45} (17.1) at Barrackpore indicates better utilization of S for fiber production.

Leaf protein content

The protein content of jute leaf at 60 days after sowing (DAS), increased significantly with N application up to N_{20} and S_{30} at Barrackpore; and up to N_{60} and S_{45} application at Budbud (Table 5). The interaction effect between N and S was significant for protein content at both locations and the maximum protein content (4.6%) was recorded at $N_{20}S_{30}$ and $N_{60}S_{45}$ respectively at Barrackpore and Budbud. Both N and S are constituents of protein and for every 15 parts of protein N, one part S is needed.

Fiber strength of jute

The fiber strength of jute is significantly improved with S and N application (Table 5) at both locations. Application of N significantly increased fiber strength up to 20 and 40 kg application respectively at Barrackpore and Budbud, which was 3.5% higher over their respective control (N_0). S application also significantly increased fiber strength up to 30 kg/ha application at both locations, although fiber strength was higher at Barrackpore (27.5 g/tex) compared to Budbud (26.3 g/tex) at S_{30} application. Sulfur application might have produced sulfur-adenosyl-methionine compound which synthesizes lignin in the plant body resulting in increasing strength of fiber.

It may be concluded that there is a synergistic interaction between nitrogen and sulfur. Application of 60 kg N and 30 kg S/ha may be recommended for yield maximization, nutrient uptake and leaf protein content at both locations. The crop yield response was higher for added N at Barrackpore and for added S at Budbud.

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