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Synergistic Effects of Sulphur And Boron on Growth, Yield and Economics of Jute

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Abstract

Appropriate sulphur and boron fertilizer application rates are important agronomic practices for maximum fibre development and yield of jute. A field experiment was conducted at Agronomy Field Laboratory, Department of Agronomy and Agricultural Extension, University of Rajshahi, during the period from May, 2018 to September, 2018 to evaluate the synergistic effects of sulphur and boron fertilization on growth, yield and production economics of jute.The experiment was conducted with three boron fertilizer (boric acid) rates *viz*. 15 kg $ha^{-1} = B_1$, 10 kg $ha^{-1} = B_2$ and 5kg $ha^{-1} = B_3$ and three sulphur fertilizer (gypsum) rate *viz*. 142.5 kg $ha^{-1} = S_1$, 95 kg $ha^{-1} = S_2$ and 47.5 kg $ha^{-1} = S_3$. The experiment was laid with split-plot experimental design with three replications. Except experimental treatments, standard agronomic practices were maintained for all plots. Considering boron fertilizer (boric acid) rates, maximum fibre yield (5.43 tha^{-1}), stick yield (12.44 tha^{-1}) and biological yield (17.87 tha^{-1}) was found with maximum boron fertilizer rate (15 kg ha^{-1}). In case of sulphur fertilizer (gypsum) rates, maximum fibre yield (5.66 tha^{-1}), stick yield (13.02 tha^{-1}) and biological yield (18.68 tha^{-1}) was found with maximum sulphur fertilizer rate (142.5 kg ha^{-1}).The interaction effect of sulphur and boron was maximum in combination B_1S_1 (15 kg B ha^{-1}+142.5 kg S ha^{-1}). From our observation, it can be suggested that 15 kg boric acid as a source of boron with 142.5 kg gypsum as a source of sulphur would be the best practice for jute production in this experimental area.

Keywords: Synergistic effect, Biological yield and fibre yield.

Introduction

Jute is a biodegradable and eco-friendly natural fibre. It is the cheapest and the most widely used fibre in the world. Nearly 20 percent of the world's annual output of natural industrial fibres comes from jute (Islam *et al.,* 2017). Bangladesh and India produce over 92% of the total jute fibre of the world (Ali *et al*., 2017). Among the jute growing countries of the world, Bangladesh ranks second in respect of production.

Jute and its trade is our heritage, a legacy and a matter of pride to Bangladesh. The geography of Bangladesh is perfect for jute cultivation, and Bengal historically has been known as a formidable player in the global jute industry. It is considered as the golden fibre of Bangladesh since it is the largest exporter of jute and jute goods with 40 percent global export and with around 30 percent of the total world production (JDPC, 2006). Today, Bangladesh still exports large quantities of jute, but the plight of jute mills reflect the decline this sector has suffered.

Once (during 80s) financial backbone of our country was based on agriculture and that time jute industry has had a bumpy ride. Nowadays the status of jute as a cash crop of Bangladesh is not at all satisfactory. Lack of proper government policies on jute, lack of production, random closures of jute mills, failure to modernize the cultivation system and manufacturing units, mismanagement and malpractice, fall of demand of jute in world market, use of alternative source of synthetic materials like polythene and plastics to jute etc. are found as the problems of jute cultivation in Bangladesh (Islam *et al.,* 2016). To overcome this situation, present government of Bangladesh has taken a series of steps to boost the industry. Therefore jute is still an important industrial sector for the economy of Bangladesh.

The practice of intensive cropping with modern varieties causes a marked depletion of inherent nutrient reserves in soils of Bangladesh. Consequently, in addition to N, P and k deficiencies of some other nutrients such as S, Zn and B are being observed in many parts of the country (Sharma *et al*., 2009; Jahiruddin *et al*., 2007). Sulphur is a macronutrient, required for plant growth as in the same order as that of Phosphorus (Zhao *et al*., 1999). Sulphur is required for synthesis of some vital amino acids and protein. It is also a constituent of certain vitamins and co-enzymes. It helps to maintain the proper N: S ratio which is important for protein synthesis (Satter, 1998). Lack of S containing amino acids is the main factor limiting the biological value of proteins. Application of additional N may influenced the protein content but not the content of S-bearing amino acids, whereas S improves both (Saraf *et al*., 1993). It was further reported that the uptake of different micronutrients drastically reduced when the crop was not fertilized with S along with N, P, K (Mondol *et al*., 1998).Continuous removal of S from soils through plant uptake has led to widespread S deficiency and affected soil S budget all over the world (Aulakh, 2003). Sulphur deficiency in Bangladesh soils is becoming widespread and acute. Use of high analysis fertilizers, such as urea, TSP, MoP, and ammonium phosphate, cultivation of modern varieties, increasing cropping intensities and limited application of organic manure have all contributed to the intensification of the S deficiency problem in Bangladesh soils (Islam, 2008). Sulphur improves the fibre yield and quality by increasing the plant height, stem diameter (Saha *et al*., 2002).

Positive responses to boron application have been reported in 80^{th} countries which is very important elements for cell division. Boron ranks third place among micronutrients in its concentration in seed and stem as well as its total amount after zinc (Shill *et al*., 2007). Boron helps in the normal growth of plant and in absorption of nitrogen from soil, translocation of sugars, cell wall synthesis, root elongation and nucleic acid synthesis (Chakraborty, 2000; Chadha, 2003). Plant height, basal diameter, K-uptake and yield increased with boron application (Sarkar, 2000). On the other hand, boron ensures strength and fineness of the fibre (Bandyopadhyay, 2000). Keeping in view the importance of sulphur as a macro nutrient element and boron as micronutrient, the present investigation was carried out to assess the synergistic effects of sulphur and boron for maximizing yield and profitability from jute cultivation. Therefore the objectives were:

1. To find out optimum sulphur and boron fertilizer rates for maximizing growth and yield of jute.
2. To find out the interaction effect between sulphur and boron on growth and yield of jute fibre.
3. To analyze the cost and return by optimum application of sulphur and boron on jute in order to assess financial benefit.

Materials and Methods

The experiment was conducted at the Agronomy Field Laboratory, Department of Agronomy and Agricultural Extension, University of Rajshahi, Rajshahi during the period from May 2018 to September 2018 to study on jute growth and yield as influenced by boron and sulphur. The experimental field was situated at the western side of Agronomy and Agricultural Extension Department. Geographically the experimental field was located at $24^{0}22'36''$ N latitude and $88^{0}38'$ $36''$E longitude at an elevation of 20m above the sea level belonging to the agro ecological zone (AEZ-11). The experimental field was flat, well drained and above flood level (Medium high land). The soil was sandy loam textured having pH value of 8.1. A popular *tossa* jute variety O-9897 released by Bangladesh Jute Research Institute (BJRI) was used for the study.

The experiment was conducted with three boron fertilizer (boric acid) rates *viz*. 15 kg $ha^{-1} = B_1$, 10 kg $ha^{-1} = B_2$ and 5kg $ha^{-1} = B_3$ and three sulphur fertilizer (gypsum) rate *viz*. 142.5 kg $ha^{-1} = S_1$, 95 kg $ha^{-1} = S_2$ and 47.5 kg $ha^{-1} = S_3$. The experiment was laid out in a Split-Plot experimental design placing boron fertilizer rates in the main plot and sulphur fertilizer rates in the sub plot. Three boron fertilizer rates and three sulphur fertilizer rates were combined into nine treatments and those were replicated three times. Total number of plots were 27 where each unit plot was 10 m^2 (5m× 2 m).

Crop Cultivation and agronomic management

The land was first opened with power tiller on 14 May, 2018. Later on the land was ploughed and cross ploughed three times followed by laddering. The weeds and stubbles were removed to clean the land. In order to supply water, drainage channels were made around the experimental plots. The following quantities of fertilizer were applied. Sulphur and boron was applied in the form of gypsum and boric acid at the time of final land preparation. A 200 kg of urea (46% N) was applied in 3 splits *i.e.,* ½ at the time of sowing, ¼ at 20 DAS and ¼ at 45 DAS. A common dose of 50 kg P_2O_5 and 60 kg K_2O ha^{-1} was applied in the form of triple superphosphate (TSP) and muriate of potash (MOP), respectively, at the time of sowing. Thinning was done to maintain required plant population. Weeding was done manually at 20 and 45 DAS. Irrigation was given immediately after sowing for ensuring proper germination and plant stand. Incidence of hairy caterpillar was observed during crop growth period, which was controlled by spraying Diazinon 60 EC @ 1.5 ml/L twice at 30 and 45 DAS.

For collecting data on plant growth, five plants were randomly selected and marked in each plot. The field was under constant observation. At maturity, the experimental crops were harvested plot-wise at 5^{th} September, 2018. Prior to harvesting $1m^2$ plant samples were selected randomly and uprooted from each plant for data recording. The harvested crops from each plot were bundled separately, tagged and brought to clean threshing floor. The same procedure was followed for sample plant (5 plants from each plot). The Bundles of jute plants were put into Jag means by arranging the bundle in row and cross row pattern in retting pond. The jute fiber was stripped from stick manually after completion of proper retting. At final harvest, data on some morpho-physiological, yield components and yield were also collected.

The recorded data were compiled and tabulated for statically analysis. The collected data were analyzed statistically using the statistical package "STATVIEW". The mean differences were adjudged by Duncan's multiple range test (DMRT).

The field experiments were conducted for three consecutive years during the cropping season 2014-15, 2015-2016 and 2016-2017 at Masordia, Madukhali, Faridpur Sugar Mills area, Faridpur. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The plot size was 20 × 18m. The sugarcane variety Isd 39 was conventionally planted in December 2014, 2015 and 2016 respectively. Intercultural operations like weeding, mulching, detrashing, earthing up etc. were done as and when required (Rahman and Pal, 2003). Fertilizers were applied as per recommended dose, method and time (FRG, 2012) use fertilizer dose. There were six (6) treatments T_1 – Weeding and mulching at once month interval (March-July), $T_2 – T_1$ + Bio-neem plus @ 2.5L.ha^{-1} (May-July), $T_3 – T_1$ + Cypermethrin 10 EC @ 4.0 L.ha^{-1}(May-July), $T_4 – T_1$ + Nitro 505 EC @ 3.0 L.ha^{-1}(May-July), $T_5 – T_1$ + *Metarhizium anisopliae* @ 5.0 kg ha^{-1}(May-July) and T_0 – Control (Untreated) including one control.

Results and Discussion

Synergistic effects of sulphur and boron on growth, yield and economics of jute (*Corchorus olitorius* L.)" was investigated. The data was statistically analyzed with a view to find out the significant effect of different factors and also their interaction effects on plant characters and yield economics. Total dry matter (TDM) of jute was recorded at 21, 42, 63, 84 and 105 days after sowing (DAS) and the values varied significantly due to boron fertilization at all sampling dates except 21 DAS. The TDM increased progressively with increase of B fertilizer. At 21 DAS, maximum TDM (0.14 g $plant^{-1}$) was observed in B_1 and minimum TDM (0.12 g $plant^{-1}$) in B_2 treatment **(Table 1)**. At 42 DAS, the highest TDM (1.96 g $plant^{-1}$) was recorded in B_1 which reduced by 14.61% in B_2 and 33.25%

Table 1: Effect of sulphur fertilizer rates on growth parameters of jute

Sulphur rate	Total Dry Matter (g plant^{-1})					Crop Growth Rate (CGR) g m^{-2} day^{-1}			
	21 DAS	42 DAS	63 DAS	84 DAS	105 DAS	21-42 DAS	42-63 DAS	63-84 4DAS	85-105 DAS
S_1	0.14±0.01	2.22±0.19a	25.75±1.12a	54.83±2.19a	72.35±3.30a	7.93±0.72a	89.65±3.72a	110.18±4.52a	66.75±5.68a
S_2	0.13±0.01	1.56±0.01b	20.84±1.07b	47.50±1.56b	59.35±2.19b	5.45±0.36b	73.48±3.71b	101.55±2.85ab	45.16±2.74b
S_3	0.13±0.01	1.18±0.10c	17.07±0.62c	41.15±1.91c	49.82±2.41c	3.99±0.37c	60.55±2.06c	91.73±5.12b	33.02±2.88c
LS	NS	0.05	0.05	0.05	0.05	0.05	0.01	0.05	0.05
CV (%)	24.32	18.38	4.40	9.32	8.39	20.18	7.46	11.38	13.00
Boron rate									
B_1	0.14±0.01	1.96±0.21a	24.09±1.59a	52.35±2.47a	68.19±4.17a	6.95±0.79a	84.31±5.39a	107.62±3.90a	60.35±7.22a
B_2	0.12±0.01	1.68±0.20a	20.98±1.40b	48.22±2.38a	59.90±3.29b	5.93±0.74a	73.55±4.63b	103.75±4.36ab	44.51±3.74b
B_3	0.13±0.01	1.31±0.13b	18.59±1.06c	42.92±2.29b	53.44±3.41c	4.50±0.48b	65.82±3.60c	92.67±5.31b	40.08±5.15b
LS	NS	0.05	0.05	0.05	0.05	0.05	0.01	0.05	0.05
CV (%)	24.32	18.38	4.40	9.32	8.39	20.18	7.46	11.38	13.00

Mean values in a column having the same letter (s) or without letter do not differ significantly, whereas, with a dissimilar letter (s) differ significantly as per DMRT.
NS= Non significant, CV= Co-efficient of variation, LS= Level of significance. And S_1= 142.5 kg ha^{-1}, S_2= 95 kg ha^{-1}, S_3= 47.5kgha^{-1}

in B_3. At 63 DAS, maximum TDM (24.09 g plant^{-1}) was obtained in B_1, which reduced significantly 12.91% and 22.83% in B_2 and B_3 respectively. At 84 DAS, maximum TDM (52.35 g plant^{-1}) was observed in B_1 which reduced only 7.88% in B_2 but remarkably by 18.01% in B_3. At 105 DAS, the maximum TDM (68.19 g plant^{-1}) was found in B_1 and it reduced by 12.16% and 21.63% in B_2 and B_3, respectively.

33.7% in S_2 and S_3, respectively. At 84 DAS, the highest TDM (54.83 g plant^{-1}) was found in S_1 which reduced significantly 13.37% and 24.94% in S_2 and S_3, respectively. Finally, at 105 DAS, the maximum TDM (72.35 g plant^{-1}) was found in S_1 which reduced notably 17.97% and 31.14% in S_2 and S_3, respectively.

It was noticed that treatment combination of boron and sulphur fertilizer showed significant effect on TDM at all observations. At

Table 2. Interaction effect of boron and sulphur fertilizer rates on TDM and CGR of jute at different days after sowing (DAS)

Interaction Boron rate × sulphur rate	Total Dry Matter (g plant^{-1})					Crop Growth Rate (CGR) g m^{-2} day^{-1}			
	21 DAS	42 DAS	63 DAS	84 DAS	105 DAS	21-42 DAS	42-63 DAS	63-84 DAS	84-105 DAS
B_1S_1	0.14±0.02ab	4.52±0.27a	29.17±1.06a	60.39±2.67a	83.46±1.71a	16.67±1.09a	101.01±4.38a	118.95±6.46a	87.87±3.78a
B_1S_2	0.16±0.02a	1.85±0.12bc	24.42±0.96bc	51.25±2.65bc	65.14±2.50bc	6.43±.42bc	85.99±3.19bc	102.24±6.46ab	52.88±0.77bc
B_1S_3	0.19±0.02ab	1.40±0.17cde	18.70±0.98ef	45.39±1.42cd	55.96±1.85cde	4.86±0.63cde	65.92±3.09ef	101.67±1.69ab	40.29±1.65d
B_2S_1	0.13±0.004ab	2.33±0.23ab	25.84±0.92b	55.72±2.67ab	70.11±3.54b	8.41±0.86ab	89.54±3.22b	113.85±7.98ab	54.80±5.03bc
B_2S_2	0.09±0.01b	1.50±0.15cde	20.33±1.09de	46.98±2.15cd	58.47±3.62cde	5.37±0.56cd	71.72±3.55de	101.52±4.07ab	43.76±5.59cd
B_2S_3	0.16±0.03ab	1.19±0.17de	16.78±0.73f	41.96±2.82de	51.14±3.53e	3.99±0.58de	59.39±2.13f	95.91±7.99bc	34.96±3.49d
B_3S_1	0.14±0.01ab	1.67±0.20cd	22.25±0.98cd	48.38±2.58bcd	63.49±3.40bcd	5.82±0.79cd	78.41±2.99cd	99.54±6.20ab	57.58±3.28b
B_3S_2	0.13±0.03ab	1.32±0.09cde	17.78±0.65ef	44.27±2.28cd	54.46±2.98de	4.53±0.44cde	62.72±2.14ef	100.89±6.21ab	38.84±2.69d
B_3S_3	0.13±0.01ab	0.95±0.10e	15.73±0.96f	36.10±3.45e	42.35±2.50f	3.13±0.39e	56.33±3.61f	77.60±9.50c	23.82±3.77e
LS	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
CV%	24.32	18.38	4.40	9.32	8.39	20.18	7.46	11.38	13.00

NS= Non significant, CV= Co-efficient of variation, LS= Level of significance

Significant variation was observed due to different sulphur treatments in terms of TDM production at all observed days except 21 DAS **(Table 1)**. TDM also increased progressively with increase in S fertilizer. At 21 DAS, the highest TDM (0.14 g plant^{-1}) was observed in S_1 and the lowest TDM (0.13 g plant^{-1}) in S_2. At 42 DAS, maximum TDM (2.22 g plant^{-1}) was obtained in S_1 and minimum TDM (1.18 g plant^{-1}) in S_3. At 63 DAS, the best TDM (25.75 g plant^{-1}) was obtained in S_1 which reduced significantly 19.06% and

21 DAS, the highest TDM (0.16 g plant^{-1}) was observed in combination of $B_1$and S_1 and the lowest value (0.092 g plant^{-1}) in B_2S_2. At 42 DAS, the highest TDM (4.52 g plant^{-1}) was observed in B_1S_1 and the lowest value (0.95 g plant^{-1}) was observed in B_3S_3. At 63 DAS, maximum TDM (29.27 g plant^{-1}) was observed in B_1S_1 and minimum TDM (15.73 g plant^{-1}) in B_3S_3. At 84 DAS, the highest TDM (60.39 g plant^{-1}) was found in B_1S_1 and the lowest (36.10 g plant^{-1}) in B_3S_3. At 105 DAS, the highest TDM (83.46 g plant^{-1}) was

Table 3: Effect of sulphur fertilizer rates on yield and yield components of jute

Sulphur rate	Plant height (cm)	Stem diameter (mm)	Fibre area (mm)	Fibre yield (t/ha)	Stick yield (t/ha)	Biological yield (t/ha)	Harvest index (%)
S_1	338.17± 8.21a	18.12± 0.58a	3.99±0.14a	5.66±0.22a	13.02±0.48a	18.68±0.68a	30.51±0.16
S_2	314.50± 7.62b	16.32±0.61b	3.40±0.14b	4.88±0.16b	11.21±0.41b	16.09±0.56b	30.37±0.20
S_3	296.56± 6.39b	15.31± 0.61b	2.91±0.12c	3.93±0.21c	9.13±0.41c	13.06±0.61c	29.99±0.48
LS	0.05	0.05	0.05	0.01	0.01	0.01	NS
CV (%)	6.81	6.63	8.84	5.08	5.47	4.65	3.08
Boron rate							
B_1	329.72± 9.37a	18.06± 0.48a	3.78± 0.20a	5.43±0.27a	12.44±0.60a	17.87±0.87a	30.31±0.38
B_2	317.61± 8.52ab	17.00± 0.58a	3.39±0.17b	4.88±0.25b	11.17±0.64b	16.06±0.87b	30.59±0.22
B_3	301.89± 8.13b	14.68± 0.51b	3.13±0.17b	4.15±0.26c	9.76±0.54c	13.91±0.80c	29.91±0.30
LS	0.05	0.05	0.05	0.01	0.01	0.01	NS
CV (%)	6.81	6.63	8.84	5.08	5.47	4.65	3.08

Mean values in a column having the same letter (s) or without letter do not differ significantly, whereas, with a dissimilar letter (s) differ significantly as per DMRT. NS= Non significant, CV= Co-efficient of variation, LS= Level of significance. And $S_{1=}$ 142.5 kg ha^{-1}, S_2= 95 kg ha^{-1}, S_3=47.5kgha^{-1}

obtained in B_1S_1 and the lowest (42.35 g $plant^{-1}$) in B_3S_3. These results are in line with the findings of Karthikeyan and Shukla (2008) and Nadian *et al. (*2010). This result also agreed with Chowdhury (1998). He reported that dry matter accumulation at harvest and fibre yield varied significantly due to the application of different levels of sulphur. Jana and Ghorai, (2004) also reported the same results.

Different levels of boron have shown significant effect on crop growth rate at all observations **(Table 1)**. At 21-42 DAS, the highest CGR (6.95 g m^{-2} day^{-1}) was observed in B_1 which reduced 14.78% in B_2 but significantly 35.35% in B_3. At 42-63 DAS, the highest CGR (84.31 g m^{-2} day^{-1}) was observed in B_1 which reduced remarkably 12.76% and 21.92% in B_2 and B_3, respectively. At 63-84 DAS, the highest CGR (107.62 g m^{-2} day^{-1}) was observed in B_1 which reduced slightly (3.6%) in B_2 but significantly by 13.89% in B_3. At 84-105 DAS, the highest CGR (60.35 g m^{-2} day^{-1}) was obtained in B_1 which reduced significantly 26.14% and 33.58% in B_2 and B_3, respectively.

Crop growth rate was differed significantly due to the effect of different sulphur fertilizer rates at 21-42, 42-63, 63-84 and 84-105 DAS **(Table 1)**. At 21-42 DAS, the highest CGR (7.93 g m^{-2} day^{-1}) was obtained in S_1 and the lowest (3.99 g m^{-2} day^{-1}) was in S_3. At 42-63 DAS, the highest CGR (89.65 g m^{-2} day^{-1}) was observed in S_1 which reduced significantly 18.04 and 32.47% in S_2 and S_3, respectively. At 63-84 DAS, the highest CGR (110.18 g m^{-2} day^{-1}) was recorded in S_1 which reduced slightly (7.8%) in S_2 but significantly by 16.74% in S_3. At 84-105 DAS, the highest CGR (66.75 g m^{-2} day^{-1}) was obtained in S_1 and the lowest CGR (33.02 g m^{-2} day^{-1}) in S3.

The interaction between boron and sulphur also showed significant effect on CGR **(Table 2)**. At 21-42 DAS, the highest CGR (16.67g m^{-2} day^{-1}) was obtained in interaction of B_1 with S_1 and the lowest (3.13 g m^{-2} day^{-1}) was found in B_3S_3. At 42-63 DAS, maximum CGR (101.01 g m^{-2} day^{-1}) was obtained in interaction of B_1 with S_1 and minimum CGR (56.33 g m^{-2} day^{-1}) was found in B_3S_3. At 63-84 DAS, the highest CGR (118.95g m^{-2} day^{-1}) was observed in the interaction of B_1 with S_1 and the lowest (77.60 g m^{-2} day^{-1}) in B_3S_3. At 84-105 DAS, maximum CGR (87.87 g m^{-2} day^{-1}) was obtained in the interaction of B_1 with S_1 and minimum CGR (23.82 g m^{-2} day^{-1}) in B_3S_3.

Boron application significantly influenced the plant height of jute. At maturity (105 DAS), maximum plant height (329.72 cm) was obtained in B_1 which reduced only 3.67% in B_2 but significantly 8.44% in B_3 **(Table 3)**. Different rates of sulphur fertilization also

Table 4. Interaction effect of boron and sulphur fertilizer rates on yield and yield components of jute

Interaction Boron rate × sulphur rate	Plant height (cm)	Stem diameter (mm)	Fibre area (mm)	Fibre yield (t/ha)	Stick yield (t/ha)	Biological yield (t/ha)	Harvest index (%)
B_1S_1	349.50±15.37a	19.32± 0.77a	4.40±0.12a	6.36±0.13a	14.37±0.30a	20.72±0.18a	30.74±0.50ab
B_1S_2	331.17±16.95ab	17.67± 0.70abc	3.77±0.22bc	5.40±0.18b	12.58±0.42b	17.90±0.60b	30.04±0.13ab
B_1S_3	308.50±10.54abc	17.19± 0.67bcd	3.18±0.15de	4.54±0.16cd	10.37±0.19cd	14.90±0.32cd	30.33±0.18ab
B_2S_1	342.00±14.43a	18.65± 0.83ab	3.92±0.20ab	5.72±0.10b	13.38±0.39ab	19.10±0.38b	30.25±0.09ab
B_2S_2	314.00±7.94abc	17.02± 0.58bcd	3.30±0.17cde	4.88±0.12c	10.93±0.32	15.81±0.23cd	30.96±0.28a
B_2S_3	296.83±8.95bc	15.24± 0.55ef	2.94±0.20ef	4.05±0.13e	9.21±0.49e	13.26±0.63e	30.56±0.59ab
B_3S_1	323.00±13.43abc	16.38± 0.57cd	.66±0.15bcd	4.90±0.16c	11.33±0.25c	16.23±0.41c	30.54±0.08ab
B_3S_2	298.33±8.81bc	14.27± 0.56f	3.13±0.19def	4.36±0.08de	10.12±0.37de	14.48±0.45de	30.11±0.33ab
B_3S_3	284.33±12.33c	13.40± 0.37f	2.61±0.15f	3.19±0.19f	7.82±0.34f	11.01±0.44f	29.08±0.64b
LS	0.05	0.05	0.05	0.05	0.05	0.05	0.05
CV (%)	6.81	6.63	8.84	5.08	5.47	4.65	3.08

NS= Non significant, CV= Co-efficient of variation, LS= Level of significance showed remarkable differences in plant height. The superior plant height (338.17 cm) was observed in S_1 treatment (338.17 cm) and it reduced significantly 6.99% and 12.30% in S_2 and S_3, respectively. The interaction between boron and sulphur showed significant effect on plant height of jute. The highest plant height (349.50 cm) was obtained in interaction of B_1 with S_1 and the lowest plant height (284.33 cm) was recorded in B_3S_3 **(Table 4)**.

The effect of boron fertilizer significantly affects the stem diameter of jute **(Table 3)**. The highest stem diameter (18.06 mm) was observed in B_1 which reduced marginally (5.86%) in B_2 but significantly 18.72 % in B_3. Effect of sulphur fertilization on stem diameter of jute was also presented in **Table 3** and the highest stem diameter (18.12 mm) of jute was observed in S_1 which reduced significantly 9.92% and 15.50% in S_2 and S_3 respectively. Stem diameter of jute was statistically differed due to interaction of boron and sulphur fertilizer rate. The highest stem diameter (19.32 mm) was observed in treatment combination of B_1S_1 and the lowest (13.40mm) was obtained in B_3S_3.

Both boron and sulphur plays significant role in developing fibre area of jute **(Table 3)**.The highest fibre area (3.78 mm) was obtained in B_1 which reduced significantly 10.39% and 17.16% in B_2 and B_3 respectively. Increasing effect of sulphur fertilization on fibre area of jute was also reported and the highest fibre area (3.99 mm) was observed in S_1 and the lowest (2.91 mm) in S_3. Fibre area reduced significantly 14.85% and 27.13% for S_2 and S_3, respectively compared with S_1.The interaction effect for sulphur and boron was also remarkable for fibre area **(Table 3)**. The highest fibre area (4.40 mm) was obtained in treatment combination B_1S_1 and the lowest fibre area (2.61 mm) was found in B_3S_3.

The data recorded from fibre yield of jute presented in **Table 3**. Maximum fibre yield (5.43 t ha^{-1}) of jute was obtained in B_1 which reduced significantly 10.13% and 23.55% in B_2 and B_3, respectively. Sarkar *et al.* [19] confirmed the same results that B produced maximum fibres with a good combination of strength and fineness at 120 days. Data revealed that fibre yield also increased significantly with maximum gypsum application **(Table 3)**. The highest fibre yield (5.66 t ha^{-1}) was obtained in S_1 which reduced significantly 13.80% in S_2 and 30.64% in S_3, respectively. Different combination of sulphur and boron fertilization differed significantly in fibre yield of jute **(Table 4)**. Apparently, the highest fibre yield (6.36 t ha^{-1}) was achieved in interaction of B_1 with S_1 and the lowest fibre yield (3.19 t ha^{-1}) was found in B_3S_3. The present results are in agreement with the findings of many researchers [2, 19. 20. 21, 22,] (Sarker *et al*., 2002; Jana and Ghorai, 2004; Sekharan, 2009; Majumdar and Sarha, 2016; Ali *et al*., 2017).

The stick yield increased significantly with increasing boron level **(Table 3)**. The highest stick yield (12.44 t ha^{-1}) was obtained in B_1 which reduced significantly 10.16% and 21.56% in B_2 and B_3, respectively. **Table 3** also showed that stick yield of jute increased significantly with maximum sulphur level. Maximum stick yield (13.02 t ha^{-1}) was observed in S_1 which reduced significantly 13.92% and 29.88% in S_2 and S_3, respectively. Interaction effect of boron and sulphur fertilizer showed significant effect on stick yield of jute **(Table 4)**. Maximum stick yield (14.37 t ha^{-1}) was observed in treatment combination $B_1S_1$and minimum stick yield (7.82 t ha^{-1})

Table 5. Cost of cultivation of jute (Local market, Rajshahi region)

COST INVOLVED ON VARIABLE AND FIXED FACTORS (TK.)	
Two ploughings @ Tk. 3000 ha^{-1}	6000.00
Clod breaking, levelling and preparation of beds/channels, 40 labours @ Tk 450 labour^{-1}	18000.00
Seed sowing, 25 labours @ Tk. 450 labour^{-1}	11250.00
Three irrigations, 6 labours @ Tk. 450 labour^{-1}	8100.00
Weeding & thinning (2times), (2x30) 60 labours @ Tk. 450 labour^{-1}	27000.00
Application of fertilizer, 2 labours @ Tk. 450 labour^{-1}	900.00
Application of pesticide and top dressing of urea, 3 labours @ Tk. 450 labour^{-1}	1350.00
Harvesting, making bundles, carrying & retting, 80 labours @ Tk. 450 labour^{-1}	36000.00
Removal of fibre, washing of fibre, carrying of fibre & jute stick, 80 labours @ Tk. 450 labour^{-1}	36000.00
Drying of fibre and storage, 15 labours @ Tk. 450 labour^{-1}	6750.00
Drying and heaping of sticks, 10 labours @ Tk. 450 labour^{-1}	4500.00
Total labour cost	**155850.00**
Cost of Seed @ Tk. 160 kg^{-1} for 6 kg seed	960.00
Cost of fertilizer	
Urea 200 kg ha^{-1} @ 18 Tk. kg^{-1} TSP 50 kg ha^{-1} @ 22 Tk. kg^{-1} MoP 60 kg ha^{-1} @ 15 Tk.kg^{-1}	3600.00 1100.00 900.00
Cost of pesticides	600.00
Miscellaneous	1000.00
Total variable cost (labour cost+ fertilizer cost+ seed & pesticide cost)	**164010.00**
Fixed cost	
Interest on total input cost @ 13 Tk. annum^{-1}for a period of 6 months	10660.65
Interest on the value of land (250000 tk) @ 13Tk. annum^{-1} for a period of 6 months	16250.00
Miscellaneous overhead cost (5% of total input cost)	8200.5
Total fixed cost	**35111.15**

Table 6. Treatment wise comparative economics of Cost of cultivation in jute

Treatment	Fixed cost Tk.ha^{-1}	Variable cost Tk. ha^{-1}	Added cost Tk. ha^{-1}	Total variable cost Tk. ha^{-1}	Total cost of cultivation Tk. ha^{-1}
B_1S_1(15 kg ha^{-1} B + 142.5 kg ha^{-1} S)	35111.15	164010.00	9270	173280	208391.15
B_1S_2 (15 kg ha^{-1} B + 95 kg ha^{-1} S)	35111.15	164010.00	7180	171190	206301.15
B_1S_3(15 kg ha^{-1} B + 47.5 kg ha^{-1} S)	35111.15	164010.00	5090	169100	204211.15
B_2S_1(10 kg ha^{-1} B + 142.5 kg ha^{-1} S)	35111.15	164010.00	8270	172280	207391.15
B_2S_2(10 kg ha^{-1} B + 95 kg ha^{-1} S)	35111.15	164010.00	6180	170190	205301.15
B_2S_3(10kg ha^{-1} B + 47.5 kg ha^{-1} S)	35111.15	164010.00	4090	168100	203211.15
B_3S_1(5 kg ha^{-1} B + 142.5 kg ha^{-1} S)	35111.15	164010.00	7270	171280	206391.15
B_3S_2(5 kg ha^{-1} B + 95 kg ha^{-1} S)	35111.15	164010.00	5180	169190	204301.15
B_3S_3(5 kg ha^{-1} B + 47.5 kg ha^{-1} S)	35111.15	164010.00	3090	167100	202211.15

B_1 =15 kg ha^{-1}, B_2=10 kg ha^{-1}, B_3=5 kg ha^{-1} and S_1= 142.5 kg ha^{-1}, S_2= 95 kg ha^{-1}, S_3= 47.5 kg ha^{-1}

was observed in treatment combination B_3S_3. These results are in line with the findings of [23] Nasrin *et al.* (2008).

From **table 3**, it was observed that boron fertilizer had significant effect on biological yield of jute plant. Maximum biological yield (17.87 t ha^{-1}) was observed by B_1 which reduced significantly 10.15% and 22.17% in B_2 and B_3, respectively. Sulphur fertilizer also had significant effect on biological yield of jute and the highest biological yield (18.68 t ha^{-1}) was recorded in S_1 and the lowest biological yield was obtained in S_3 (13.06 t ha^{-1}). Combined effect of boron and sulphur fertilizer had significant effect on biological yield of jute plant. The highest biological yield (20.72 t ha^{-1}) was recorded in interaction of B_1 with S_1 and the lowest biological yield (11.01t ha^{-1}) was obtained in B_3S_3.

Income distribution and benefit cost ratio of jute

Cultivation cost of jute (per ha) in the study area was presented in **Table 5** and additional cost per experimental treatments are presented in **Table 6**. Maximum cost of cultivation (Tk. 208391.15 ha^{-1}) was calculated in treatment combination B_1S_1 (15 kg ha^{-1} B + 142.5 kg ha^{-1} S) and minimum cost was calculated in B_3S_3 (5 kg ha^{-1} B + 47.5 kg ha^{-1} S). Except boron and sulphur, standard or recommended dose of inorganic fertilizer (N, P, K) was used which accounted for Tk. 7200 ha^{-1}.

Income distribution and benefit cost ratio

Perusal of Table **7** revealed the position of input and output in terms of economics of jute production. The treatment wise cost of cultivation and their returns revealed that maximum net returns of Tk. 133758.00 were observed in treatment combination of B_1S_1 (15 kg ha^{-1} B + 142.5 kg ha^{-1} S) followed by B_2S_1 (10 kg ha^{-1} B + 142.5 kg ha^{-1} S), B_1S_2 (15 kg ha^{-1} B + 95 kg ha^{-1} S), B_3S_1 (5 kg ha^{-1} B + 142.5 kg ha^{-1} S) and B_2S_2 (10 kg ha^{-1} B + 95 kg ha^{-1} S) with returns per taka invested of 1.64, 1.49, 1.41, 1.28 and 1.27, respectively. However, the negative net return was observed in B_3S_3 (5 kg ha^{-1} B + 47.5 kg ha^{-1} S) with regular fertilizer dose 100% with returns of 0.86 Re^{-1} invested. In a previous study, Biswas *et al.* (2004) reported that the economic returns from sulphur fertilizer use were very attractive and benefits were much more when the residual effect on succeeding crops were also taken into account.

Table 7. Economic of production in jute

Treatment	Total cost of cultivation (Tk. ha^{-1})	Gross return (Tk.ha^{-1})	Net returns (Tk. ha^{-1})	Returns Re^{-1} invested (B:C ratio)
B_1S_1(15 kg ha^{-1} B + 142.5 kg ha^{-1} S)	208391.15	342150.00	133758.85	1.64
B_1S_2 (15 kg ha^{-1} B + 95 kg ha^{-1} S)	206301.15	292400.00	86098.85	1.41
B_1S_3(15 kg ha^{-1} B + 47.5 kg ha^{-1} S)	204211.15	244800.00	40588.85	1.19
B_2S_1(10 kg ha^{-1} B + 142.5 kg ha^{-1} S)	207391.15	310000.00	102608.85	1.49
B_2S_2(10 kg ha^{-1} B + 95 kg ha^{-1} S)	205301.15	262050.00	56748.85	1.27
B_2S_3(10kg ha^{-1} B + 47.5 kg ha^{-1} S)	203211.15	218175.00	32175.85	1.07
B_3S_1(5 kg ha^{-1} B + 142.5 kg ha^{-1} S)	206391.15	264900.00	58508.85	1.28
B_3S_2(5 kg ha^{-1} B + 95 kg ha^{-1} S)	204301.15	235900.00	31598.85	1.15
B_3S_3(5 kg ha^{-1} B + 47.5 kg ha^{-1} S)	202211.15	174675.00	27536.15	0.86

Net return = gross return – cost of cultivation, B**:** C ratio = Benefit cost ratio (Re^{-1}) B_1=15 kg/ha, B_2=10 kg/ha, B_3=5 kg/h and S_1= 142.5 kg/ha, S_2= 95 kg/ha, S_3= 47.5 kg/ha

Harvest index was not significantly influenced due to boron as well as sulphur fertilization **(Table 3)**. Numerically, the highest harvest index (30.59 %) was found in B_2 and the lowest harvest index (29.91%) was obtained in B_3. For sulphur, the highest harvest index (30.51 %) was obtained in S_1 and the lowest (29.99%) was found in S_2. There were significant effects between boron and sulphur fertilizer rates on harvest index of jute **(Table 4)**. Numerically, the highest harvest index (30.96 %) was obtained in interaction of B_2 with S_2 combination and the lowest harvest index (29.08 %) was obtained in B_3S_3.

Conclusion

Result revealed that application of gypsum (S) @ 142.5 kg ha^{-1} gave significantly higher plant height (338.17 cm), stem diameter(18.12 mm), fibre area (3.99 mm), fibre yield (5.66 t ha^{-1}), stick yield (3.02 t ha^{-1}) and biological yield (18.68 t ha^{-1}) of jute. Application of boron (boric acid @ 15 kg ha^{-1}) also showed significant influence in jute growth and yield which produced the highest plant height (329.72cm), stem diameter (18.06 mm), fibre area (3.78 mm), fibre yield (5.43 t ha^{-1}), stick yield (12.44 t ha^{-1}) and biological yield (17.87 t ha^{-1}).

The interaction effects between sulphur and boron were statistically non-significant but slightly higher and showed marginal effect on all the yield and yield contributing characters. Among the interactions between sulphur and boron, combination B_1S_1 proved superior over rest of the treatment combination with respect to improvement in plant height (349.50 cm), stem diameter(19.32 mm) and fibre area(4.40 mm), fibre yield (6.36 t ha^{-1}), stick yield (14.37 t ha^{-1}) and biological yield (20.72 t ha^{-1}).

Considering economic benefits, maximum net returns of Tk. 133758.85 ha^{-1}can be achieved from treatment combination of B_1S_1. Farmers in area usually apply 10 kg boric acid and 95 kg gypsum which is equivalent to treatment combination B_2S_2 that gives net returns of Tk. 56748.85 ha^{-1}. Therefore, farmers can be suggested to apply additional 50 % more boric acid and gypsum for jute cultivation in the experimental area (treatment combination B_1S_1) to achieve additional 77010.00 Tk. net return. However, soils in the experimental area might be less sulphur and boron containing. To arrive at a definite conclusion (appropriate dose of gypsum and boric acid) further investigation is needed focusing on soil nutrient and plant uptake.

Conflict of interest

There is no conflict of interest among the authors.

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