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Response of Yield and Quality of Soybean (cv. BARI Soybean-6) to Phosphorus and Sulphur Fertilization under Old Brahmaputra Floodplain Soil of Bangladesh

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ABSTRACT

Background: Soybean is a potential oil seed crop in Bangladesh due to its heavy consumption throughout the country. The lower yield of soybean in Bangladesh compared to the world context might be due to non-judicious fertilization especially phosphorus (P) and sulphur (S). Hence, the study was undertaken to find out the influence of P and S on yield and quality of soybean.

Methods: An experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Bangladesh. The study comprised four levels of phosphorus *viz.* 0, 20, 40 and 60 kg P ha^{-1} and four levels of sulphur 0, 15, 30 and 45 kg S ha^{-1}. The experiment was laid out in a factorial randomized completed block design with three replications.

Result: The highest number of branches plant^{-1}, pods plant^{-1}, 100-seed weight, seed yield, harvest index, protein and oil content were found in 60 kg P along with 30 kg S ha^{-1} while the lowest seed yield, protein and oil content were found in control. Therefore, application of 60 kg P with 30 kg S appeared as the promising practice for obtaining higher seed yield and better quality of BARI Soybean-6.

Key words: Fertilizer, Protein, Quality, Seed yield, Soybean.

INTRODUCTION

Soybean (*Glycine max* L.) is one of the leading oil and protein containing crops of the world. It covers 120.30 million ha worldwide with the production of 333.67 million tons (FAO, 2021). Soybean seed contains oil 20-22%, protein 42-45%, carbohydrates 30-35% and total sugar 10-12% and also high amount of the amino acid, thiamin, vitamins, niacin, riboflavin, phosphorus, calcium and iron (Wahhab *et al.,* 2001). It contributes 25% of the global edible oil production (Jaybhay *et al.*, 2021). Soybean seeds are used for preparation of soy tofu, soya milk, soya sprouts, soya nuts, *etc.* (Sikka *et al.*, 2018). In Bangladesh, soybean occupies 0.051 million ha of land with the production of 0.091 million tones (BBS, 2019). The average yield of soybean in Bangladesh is low (1.2 t ha^{-1}) compared to world average (BARI, 2007). Bangladesh imports 1.8 million tons of soybean cooking oil each year at the cost of more than 1.5 billion USD and soybean meal with about 25.51 million USD per year (Quaiyum *et al.*, 2015). Among oilseeds in Bangladesh, soybeans are the fourth-ranked crop that covers the 9.82% of total oilseed planted area. The lower production costs, coupled with good market prices, give farmers a premium for soybeans compared to other seasonal crops.

Soybean can form a symbiotic association with root rhizobium bacteria and fix atmospheric nitrogen through nodulation. Nodulation in legumes involves a series of biochemical interactions between the bacterium and the plant (Ciafardini and Barbieri, 1997). Phosphorus and sulphur also play a vital role in increasing the nodulation of soybean (Singh and Bansal, 2000). Phosphorus deficiency is now considered one of the major constraints to successful production of legumes in Bangladesh. In soybeans, the demand for P is the greatest during pod and seed development where more than 60% of P ends up in the pods and seeds. It has been proven that P increases weight and number of root nodules and also can enhance the pod yield (Khanam *et al.*, 2016). Phosphorus plays a role in photosynthesis, respiration, energy storage and transfer, cell division and enlargement, it is important for the growth, development and yield of soybean (Kakar *et al.*, 2002). Soybean is a sulphur loving plant and like other oilseed crops, its sulphur requirement is more than that of many other crops for proper growth and yield. The response of soybean to sulphur application has been reported by Akter *et al.* (2013). However, limited information is available on the role of phosphorus and sulphur on the growth and yield of soybean. Therefore, a field experiment was conducted to find out the optimum doses for maximizing the yield and

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quality of soybean under the Old Brahmaputra Floodplain soil of Bangladesh.

MATERIALS AND METHODS

The experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh (24°75 N, 90°45 E), Bangladesh from January to May 2019. The site belongs to the Sonatola Soils Series of Non-calcareous Dark Grey Floodplain soil under the Old Brahmaputra Floodplain Agro-ecological Zone (AEZ 9) (UNDP and FAO, 1988). The experimental field was a high land having silty-loam soil with pH 6.10. The initial soil (0-15 cm depth) test result showed that the soil contained 0.117 % total nitrogen, 0.95 % organic matter, 3.19 ppm available phosphorus, 9.52 ppm available sulphur, 0.092 ppm exchangeable potassium and 233 µS/cm electrical conductivity. The study comprised four levels of phosphorus *viz.* 0, 20, 40 and 60 kg P ha^{-1}and four levels of sulphur *viz.* 0, 15, 30 and 45 kg S ha^{-1}. The experiment was laid out in a factorial randomized complete block design with three replications. There were total 48 plots each of 2.5 m × 2.0 m having plot-plot and block-block distance of 0.5 m and 1.0 m, respectively. BARI soybean-6 was used as the test crop.

The land was prepared thoroughly and the field was laid out consequently. The individual plots were prepared and the seeds were sown (40 kg ha^{-1}) continuously with 30 cm line spacing on 19 January, 2019. Urea- MoP-boron were applied @ 60-100-10 kg ha^{-1}, respectively. Phosphorus and sulphur fertilizers were also applied as per treatment specification. The full dose of urea, MoP and boron were applied during final land preparation. Intercultural operations were done to ensure the normal growth of the crop. Before harvesting, ten plants were randomly selected from each plot for collecting data on plant characters and yield components. The crop was harvested on 2 May, 2019 when the color of the leaf turned yellow and dropped off. The harvested plants were dried, threshed, cleaned and seeds were dried in the sun for 2-3 days to 9% moisture basis. The grain and straw were weighed and subsequently converted to t ha^{-1}.The harvest index (%) was calculated by the empirical formula given below.

$$\text{Harvest index (\%)} = \frac{\text{Seed yield}}{\text{Biological yield}} \times 100$$

Total nitrogen in the seeds was determined by the Micro Kjeldhal method (AOAC, 1984) and the protein percentage was calculated by multiplying the factor 6.25. The oil content was estimated by Soxhlet apparatus method following the procedure of Singh *et al.* (1960). The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of the computer package program MSTAT-C and the mean differences were adjudged by "Duncan's multiple range test" (DMRT) (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Crop characters, yield components and yield of soybean

Crop characters, yield components and yield of soybean were significantly influenced by P fertilization except for the number of branches plant^{-1} and seeds pod^{-1} (Table 1). The tallest plant (51.58 cm) was recorded in 40 kg P ha^{-1} which was at par with 20 kg P ha^{-1} and 60 kg P ha^{-1} while the lowest one (49.25 cm) was recorded in control. The progressive enhancement of plant height due to phosphorus application was reported by Afzal *et al.* (2010) who also found similar results for plant height. However, the number of branches plant^{-1}and seeds pod^{-1} did not show significant variation where numerically the highest number of branches plant^{-1} (8.50) and seeds pod^{-1} (2.66) were found when the crop was fertilized with @ 60 kg P ha^{-1} showing the lowest in control. The highest number of pods plant^{-1} (48.33), the heaviest seeds (9.11 g), the highest seed yield (1.71 t ha^{-1}), stover yield (1.87 t ha^{-1}) and harvest index (47.90 %) were found when the crop was fertilized with 60 kg P ha^{-1}while, 40 kg P ha^{-1} gave the statistically similar heaviest seeds (9.05 g) and stover yield (1.87 t ha^{-1}). The control treatment gave the corresponding lowest values for yield and yield contributing parameters. Application of sufficient phosphorus enhanced the performance of the yield attributes of soybean as reported by Singh and Menon (2021) and who also found a significant increase of yield upto 60 kg P ha^{-1}. Similar observation was reported elsewhere (Singh *et al.*, 2001: Kumari *et al.*, 2018; Suman *et al.*, 2018).

Sulphur fertilization significantly impacted all the vegetative and yield characters of soybean except the number of seeds pod^{-1} (Table 1). Application of 15, 30 and 45 kg S ha^{-1} statistically produced the tallest plants and the highest number of branches plant^{-1}. The shortest plant (48.50 cm) and lowest number of branches plant^{-1} (7.83) were found in control. These findings are similar to those of Ghosh *et al.* (1997) who reported that sulphur application enhanced the plant height and branches plant^{-1}. Though the heaviest seeds (9.95 g) was found in 30 kg S ha^{-1}, the highest number of pods plant^{-1} (48.33), the highest seed (1.51 t ha^{-1}) and stover yield (1.84 t ha^{-1}) were found in 45 kg S ha^{-1} whereas sulphur had no significant influence on the number of seeds pod^{-1}. The highest seed yield might be due to the cumulative effect of the yield contributing characters because of sulphur fertilization. Farhad *et al.* (2010) reported that the number of pods of soybean increased significantly due to increased levels of sulphur. Shubhangi *et al.* (2014) found that sulphur application had increased 100-seed weight of soybean. Babhulkar *et al.* (2000) obtained higher seed yield with 45 kg S ha^{-1} and Kumari *et al.* (2018) observed increased seed yield with successive S application up to 45 S ha^{-1}. Tomar *et al.* (1997) observed that increasing the doses of sulphur increased the stover yields of soybean. The highest and lowest harvest index were observed in 15 kg S ha^{-1} (45.91%) and control (43.44 %) treatments, respectively.

A significant interaction effect of phosphorus and sulphur on all the plant characters and seed yield but number of seeds pod^{-1} were observed (Table 2). Almost all the treatment combinations gave the statistically tallest plants while control produced the shortest one. The highest number of branch plant^{-1} (9.33), pods plant^{-1} (51.00) and the heaviest 100-seed (11.00 g) were found in 60 kg P×30 kg S ha^{-1} and the lowest values were found in control (0 kg P×0 kg S ha^{-1}). The highest seed yield (1.78 t ha^{-1}) was recorded in 60 kg P×30 kg S ha^{-1}which was as good as 60 kg P×45 kg S ha^{-1}. The highest stover yield (2.28 t ha^{-1}) was recorded in control while 0 kg P×15 kg S ha^{-1} produced the lowest stover yield (1.43 t ha^{-1}). The result exhibits that 60 kg P along with 30 kg S ha^{-1}gave the highest the harvest

Table 1: Effect of level of phosphorus and sulphuron yield components and yield soybean (cv. BARI Soybean-6).

Treatment	Plant height (cm)	Branches plant^{-1} (no.)	Pods plant^{-1} (no.)	Seeds pod^{-1} (no.)	100-seed weight (g)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Harvest index (%)	Protein content (%)	Oil content (%)
Level of phosphorus (kg ha^{-1})										
0	49.25b	8.08	46.50b	2.41	7.99c	1.25d	1.718b	42.76c	40.30c	19.85b
20	51.08a	8.33	46.92b	2.50	8.65b	1.31c	1.732b	43.21c	41.17b	20.00b
40	51.58a	8.25	45.50c	2.58	9.05a	1.50 b	1.87a	44.62b	42.00a	20.60a
60	50.83a	8.50	48.33a	2.66	9.11a	1.71a	1.87a	47.90a	41.95a	20.60a
Level of sig.	**	NS	**	NS	**	**	**	**	**	**
Level of sulphur (kg ha^{-1})										
0	48.50b	7.83b	45.00c	2.41	7.67d	1.41c	1.85a	43.44c	41.27b	19.15c
15	51.08a	8.41a	47.00b	2.58	8.30c	1.41c	1.66b	45.91a	42.65a	20.05b
30	51.42a	8.58a	46.92b	2.66	9.95a	1.45b	1.83a	44.08bc	41.58b	21.02a
45	51.75a	8.33a	48.33a	2.50	8.86 b	1.51a	1.84a	45.06ab	39.93c	20.83a
Level of sig.	**	**	**	NS	**	**	**	**	**	**
CV (%)	2.90	6.23	2.48	21.90	3.92	2.55	5.86	3.33	2.12	2.66

Figures in a column under each factor and treatment having the same letter or without letter do not differ significantly whereas figures with dissimilar letter(s) different significantl (as per DMRT). ** = Significant at 1% level of probability, NS = Not significant.

Table 2: Effects of interaction between level of phosphorus and sulphur on yield components and yield of soybean (cv. BARI Soybean-6).

Interaction (phosphorus ×sulphur)	Plant height (cm)	Branches plant^{-1} (no.)	Pods plant^{-1} (no.)	Seeds pod^{-1} (no.)	100-seed weight (g)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Harvest index (%)	Protein content (%)	Oil content (%)
$P_0 \times S_0$	45.00d	7.00c	45.33fgh	2.00	7.20i	1.18i	2.28a	34.14g	35.80h	18.20h
$P_1 \times S_0$	49.00c	8.33b	43.33h	2.66	7.63hi	1.26h	1.57gh	44.47cd	43.10abc	18.80gh
$P_2 \times S_0$	49.33bc	8.33b	44.67gh	2.33	8.13fgh	1.51d	1.78de	46.01bcd	44.10ab	20.30b-e
$P_3 \times S_0$	50.67abc	7.66bc	46.67d-g	2.66	7.73ghi	1.70b	1.76def	49.12a	42.10cd	19.30fg
$P_0 \times S_1$	51.00abc	8.33b	46.67d-g	2.66	7.43i	1.23hi	1.43h	46.32bc	39.90ef	19.50efg
$P_1 \times S_1$	52.67a	8.66ab	47.67cde	2.33	8.10fgh	1.26h	1.63efg	43.57c-f	42.50bcd	19.60d-g
$P_2 \times S_1$	51.67abc	8.00b	46.67d-g	2.66	9.43cd	1.53d	1.79de	46.09bcd	44.10ab	20.60a-d
$P_3 \times S_1$	49.00c	8.66ab	47.00c-f	2.66	8.30efg	1.63c	1.80de	47.67ab	44.10ab	20.50a-e
$P_0 \times S_2$	51.00abc	8.66ab	45.00fgh	2.66	8.83de	1.26h	1.59fgh	44.23cde	42.01cd	21.30ab
$P_1 \times S_2$	50.67abc	8.00b	46.67d-g	2.33	9.50c	1.3g	1.88cd	41.55ef	41.30de	21.10abc
$P_2 \times S_2$	52.67a	8.33b	45.00fgh	2.66	10.4b	1.42e	2.04bc	41.10f	38.50fg	20.20c-f
$P_3 \times S_2$	51.33abc	9.33a	51.00a	3.00	11.0a	1.78a	1.82de	49.45a	44.50a	21.50a
$P_0 \times S_3$	50.00abc	8.33b	49.00abc	2.33	8.50ef	1.35fg	1.56gh	46.34bc	43.50abc	20.40b-e
$P_1 \times S_3$	52.00ab	8.33b	50.00ab	2.66	9.36cd	1.40ef	1.83d	43.27def	37.80g	20.50a-e
$P_2 \times S_3$	52.67a	8.33b	45.67efg	2.66	8.23e-h	1.55d	1.87cd	45.28bcd	41.30de	21.30ab
$P_3 \times S_3$	52.33a	8.33b	48.67bcd	2.33	9.36cd	1.74ab	2.10b	45.34bcd	37.10gh	21.10abc
Sx	0.849	0.298	0.671	0.321	0.197	0.021	0.061	0.859	0.506	0.311
Level of significance	**	*	**	NS	**	**	**	**	**	**
CV (%)	2.90	6.23	2.48	21.90	3.92	2.55	5.86	3.33	2.12	2.66

In a column, figures with same letter or without letter do not differ significantly whereas figures with dissimilar letter(s) different significantly (as per DMRT).

** = Significant at 1% level of probability, * = Significant at 5% level of probability, NS = Not significant.

P_0 = 0 kg, P_1 = 20 kg, P_2 = 40 kg, P_3 = 60 kg, S_0 = 0 kg, S_1 = 15 kg, S_2 = 30 kg, S_3 = 45 kg.

index (49.45 %) which was statistically identical with 20 kg P×30 kg S ha^{-1}. The results are in agreement with the findings of Shubhangi *et al.* (2014) who reported that phosphorus and sulphur interaction had significant effect on harvest index. The lowest seed yield (1.18 t ha^{-1}) and harvest index (43.14 %) were found in control. Better performance of different yield attributes of soybean resulted in the highest seed yield. Soybean yield rise owing to different levels of S and P fertilization was observed by some other researchers (Kumar *et al.* 2017, Kumari *et al.* 2018 and Suman *et al.* 2018).

Quality parameters of soybean

Phosphorus and Sulphur had a significant effects on the protein and oil content of soybean individually and in interaction (Table 1 and 2). The highest protein (42.00%) and oil content (20.60%) were found in 40 kg P ha^{-1} which was statistically identical with 60 kg P ha^{-1} (Table 1). The findings are similar to those of Deliboran *et al.* (2011) and Dubey and Khan (1991), who reported that application P increased total protein and oil content substantially in soybean. The control treatment gave the corresponding lowest values. Treatment of 15 kg S ha^{-1} was enough to produce the highest protein content (42.65%) while the highest oil content (21.02%) was found in 30 kg S ha^{-1} which was at par with 60 kg S ha^{-1}. In both cases, the lowest protein (39.93%) and oil content (19.15%) were found in the control. The interaction of 60 kg P×30 kg S ha^{-1} produced the highest protein (44.50%) and oil content (21.50%) while the lowest protein (35.80%) and oil content (18.20%) were found in control (Table 2). Sulphur had a remarkable influence on the protein and oil synthesis of soybean. A similar observation was reported elsewhere (Tomar *et al.* 1997; Babhulkar *et al.* 2000; Haq *et al.* 2005).

CONCLUSION

The yield components, seed yield, protein and oil content of soybean were significantly influenced by phosphorus and sulphur application. The highest seed yield, protein and oil content in seeds of BARI Soybean-6 were recorded when the crop was fertilized with 60 kg P ha^{-1} along with 30 kg S ha^{-1}. Therefore, application of P @ 60 kg ha^{-1} with S @ 30 kg ha^{-1} might be suggested for higher yield and seed quality of BARI Soybean-6 under Old Brahmaputra Floodplain Soil of Bangladesh.

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