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Improvement of soybean growth and yield by foliar urea and boron application

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Abstract

The experiment was carried out to investigate the effect of foliar urea and boron application on soybean and it was laid out in split-plot design with two soybean varieties (BARI Soybean-5 and BARI Soybean-6) and five foliar application *viz.* Control (Recommended dose of fertilizer), RDF+ Foliar Spray of water at flower initiation, RDF+ Urea (2%) FS at FI, RDF+ Boron (1%) FS at FI, and RDF+ Urea (2%) + Boron (1%) FS at FI. Results obtained from the experiment showed that the variety, BARI Soybean-6 gave maximum plant height (47.13 cm), dry weight plant^{-1} (11.55 g), nodules plant^{-1} (21.27), pods plant^{-1} (57.47), seeds pod^{-1} (2.87), 100 seed weight (13.41 g) and seed yield (2.13 t ha^{-1}) compared to BARI Soybean-5. In terms of foliar urea and boron application, highest plant height (48.82 cm), dry weight plant^{-1} (12.18 g), nodules plant^{-1} (21.79), pods plant^{-1} (59.67), seeds pod^{-1} (2.89), 100 seed weight (13.45 g), seed yield (2.17 t ha^{-1}) and stover yield (2.73 t ha^{-1}) were obtained from treatment T_5 (RF+ Urea (2%) + Boron (1%) FS at FI, indicating its effectiveness in enhancing soybean growth and yield. Specifically, the combination of BARI Soybean-6 with treatment T_5 demonstrated the most promising results overall, suggesting it as the recommended approach for improving soybean yield in cultivation practices.

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Introduction

Soybean (*Glycine max* L. Merrill) is one of the most important oilseed pulse crops in the world for human being. It has become the miracle crop of 20th century on account of having high protein and oil content and known as "Golden Bean". It is the most important grain legume of the world and a new prospective crop for Bangladesh (Rahman *et al.*, 2011). The plant is classed as an oilseed rather than a pulse. Soybean seed contains 40-45% protein, 20-22% oil, 20-26% carbohydrate and a high amount of Ca, P and vitamins (Rahman *et al.*, 2011).

Foliar fertilization is gaining more importance in recent years due to availability of soluble fertilizers and is of great significance in rainfed areas and under changing climatic condition. Fertilizer applied to the crop at the time of sowing is not fully available to the plants as the crop approaches maturity so supplemental foliar application is one of the techniques to increase yield of the crop. Foliar application of nutrients for increasing and exploiting genetic potential of the crop is considered as an efficient and economic method of supplementing the nutrient requirement. Application of inorganic nutrient spray will also enhance the nutrient availability, quick absorption and in turn increases the productivity. Nutrients applied through foliage play a pivotal role in increasing the seed yield in pulses and oilseeds (Chandrasekhar and Bangaruswamy, 2003). Foliar application of major and micronutrients like NPKS and B is credited to be more advantageous than soil application and also avoiding the depletion of these nutrients in leaves, thereby resulting in an increased photosynthetic rate, better nutrient translocation to the developing seeds (Manonmani and Srimathi, 2009).

Most of the soil in Bangladesh is deficient in nitrogen. Nitrogen is responsible to increase the dry matter and protein percentage of grain as well as methionine and triptophen content in seed (Vidhate *et al.*, 1986). Utilization of the majority of this N occurs during seed development. Nitrogen sources for the soybean include mineralization, soil organic matter, symbiotically fixed N, and N incorporated into plant tissue. Under certain soil, climatic, and yield conditions, N supply may limit soybean seed production. However, N applications made before reproductive growth stages are reported to decrease Bradyrhizobia activity, exhibited by reduced growth of nodules and lower N fixation, thus further increasing the difference between N supply and demand (Yoneyama *et al.,* 1985). The flower and pod abortion in pulse crop is higher as reported by Patel *et al.* (1984) while they studied the physiology of mungbean. They opined that pulse crops stop symbiosis during its onset of flowering and support the reproductive units but due to lack of nitrogen nutrient at this stage aggravated the situation. Foliar spray of urea at flowering stage could be an alternate option to support flowering and pod setting in Soybean.

Among the micronutrients, boron has a direct impact on productivity of oilseed crops. Boron significantly improves the vegetative growth and quantitative parameters of oilseed crops. Boron plays an important role in new cell development in meristemetic tissues, proper pollination and fruit or seed set. It is also involved in translocation of sugars, synthesis of amino acids, protein and carbohydrate metabolism. Boron is one of the most commonly deficient micronutrients in agriculture, with reports of deficiencies in 132 crops and in 80 countries (Shorrocks, 1997). These deficiencies typically result from boron leaching occurring in humid areas with coarse textured soils (Mortvedt and Woodruff, 1993). In plant physiological response of B deficiency include the loss of membrane integrity and cell wall stability, which result in the development of structural damage in generative and vegetative organs of crop such as blossom wilting and necrosis. Srivastava *et al.* (1997) found that boron deficiency is responsible to flower drop and poor podding. Boron plays a vital role in symbiosis process to fix nitrogen.

Therefore, the current study was designed to compare the performance of varieties of soybean, to examine the effect of foliar spray of urea and boron and to study the combined effect of variety and foliar spray on growth and yield of soybean.

Materials and methods

Experimental site

The experiment was conducted at the Agronomy field of Sher-e-Bangla Agricultural University (SAU). It belongs to Madhupur Tract (AEZ 28). The soil of the experimental field belongs to the general soil type, shallow red-brown terrace soil with silty clay. Soil pH was 6.2 and has organic carbon 0.44%.

Treatments and experimental design

The variety BARI Soybean-5 and BARI Soybean-6 were used as planting material. The experiment consists of two factors: Factor A: Soybean variety, V_1= BARI Soybean-5, V_2= BARI Soybean-6, Factor B: Foliar fertilizer application, T_1= Control (Recommended dose of fertilizer), T_2= RDF+ Foliar Spray of water at flower initiation, T_3= RDF+ Urea (2%) FS at FI, T_4= RDF+ Boron (1%) FS at FI, T_5= RDF+ Urea (2%) + Boron (1%) FS at FI. The experiment was laid out in a split-plot design with three replications. Where variety and fertilizer application were assigned in main and sub plots, respectively.

Fertilization

Urea, Triple super phosphate (TSP), Muriate of potash (MOP), gypsum and boric acid were used as a source of nitrogen, phosphorous, potassium, sulphur and boron, respectively. Urea, Triple super phosphate (TSP), Muriate of potash (MOP), gypsum, zinc sulphate and boric acid were applied at the rate of 50, 120, 70, 110, 7 and 8 kg hectare^{-1}, respectively following the Bangladesh Agricultural Research Institute (BARI) recommendation.

Data collection

Data on the following parameters were recorded during the period of the experiment such as: Plant height (cm), Branches plant^{-1}(no.), Dry matter weight plant^{-1}(g), Nodules plant^{-1} (no.), Crop Growth Rate (g m^{-2} d^{-1}) plant^{-1}, Relative Growth Rate (g g^{-1} d^{-1}) plant^{-1}, Pods plant^{-1} (no.), Pod length (cm), Seeds pod^{-1} (no.), 100 seed weight (g), Seed yield (t ha^{-1}), Stover yield (t ha^{-1}), Biological yield (t ha^{-1}) and Harvest index (%).

Statistical analysis

The data obtained for different parameters were statistically analyzed following computer-based software Statistix 10 and mean separation will be done by LSD at 5% level of significance (Gomezm and Gomez, 1984).

Results and discussion

Plant height (cm)

Soybean varieties, foliar spray of urea and boron and their combination positively responded to the plant height of soybean at harvest (Table 1, 2 and 3). Out of varieties tallest plant (47.13 cm) was observed from BARI Soybean-6 and the shortest plant (41.89 cm) from BARI Soybean-5. These results were supported by Mandic *et al.*, (2008) who found that plant height show significant differences due to varietal differences. Among the foliar spray, tallest plant (48.82 cm) was observed in treatment T_5 [RF+ Urea (2%) + Boron (1%) FS at FI] and the shortest plant (41.05 cm) was observed in T_1 (Control) Treatment. Mahmoud *et al.* (2006) found that foliar application of boron at 25 ppm per acre recorded higher plant height. Similarly, tallest plant was observed at V_2T_5 combination and shortest plant was from V_1T_1.

Branches plant^{-1} (no)

Branches plant^{-1} showed non-significant variation among varieties, foliar application and their combined effect (Table 1, 2 and 3). This result contradicts with the findings by Venkatesh and Basu (2011) studied that foliar application of urea recorded higher number of branches plant^{-1} which was on par with one or two sprays of urea over control and water spray.

Dry weight plant^{-1} (g)

Soybean cultivars had a considerable impact on dry weight (Table 1). BARI Soybean-6 resulted highest (11.55 g) and BARI Soybean-5 gave lowest (10.44 g) dry weight. Foliar spray of urea and boron also exerts significant variation on dry weight where maximum value (12.18 g) was obtained from treatment T_5 and minimum (9.72 g) from T_1 (Table 2).

Table 1. Effect of variety on growth parameters of soybean at harvest

Variety	Plant height (cm)	Branches plant^{-1} (no)	Dry weight plant^{-1} (g)	Crop growth rate (g m^{-2} d^{-1})	Relative growth rate (g g^{-1} d^{-1})	Nodules plant^{-1} (no)
V_1= BARI Soybean-5	41.89 b	3.31	10.44 b	0.86	0.00217	17.94 b
V_2=BARI Soybean-6	47.13 a	3.53	11.55 a	0.84	0.00237	21.27 a
CV (%)	7.53	7.19	6.04	12.40	9.56	11.09
LSD $_{(0.05)}$	1.76	ns	0.47	ns	ns	1.63

Table 2. Effect of foliar spray urea and boron on growth parameters of soybean at harvest

Foliar spray (FS) at flower initiation stage	Plant height (cm)	Branches plant^{-1} (no)	Dry weight plant^{-1} (g)	Crop growth rate (g m^{-2} d^{-1})	Relative growth rate (g g^{-1} d^{-1})	Nodules plant^{-1} (no)
T_1=Control (RDF)	41.05 d	3.25	9.72 c	0.74	0.00220	17.63 c
T_2=FS of water + RDF	42.68 cd	3.34	10.38 c	0.83	0.00231	18.56 bc
T_3=FS of urea (2%) + RDF	46.05 ab	3.51	11.55 ab	0.70	0.00178	20.54 ab
T_4=FS of boron (1%) + RDF	43.96 bc	3.41	11.14 b	1.04	0.00275	19.56 abc
T_5=FS of Urea (2%) + Boron (1%) + RDF	48.82 a	3.59	12.18 a	0.94	0.00229	21.79 a
CV (%)	4.77	9.01	5.58	8.89	11.05	10.85
LSD $_{(0.05)}$	2.78	ns	0.75	ns	ns	2.59

Table 3. Combined effect of variety and foliar spray on growth parameters of soybean at harvest

Treatment combinations	Plant height (cm)	Branches plant^{-1} (no)	Dry weight plant^{-1} (g)	Crop growth rate (g m^{-2} d^{-1})	Relative growth rate (g g^{-1} d^{-1})	Nodules plant^{-1} (no)
V_1T_1	39.03 e	3.13	9.24 f	0.70	0.00219	16.09 e
V_1T_2	40.30 de	3.22	9.92 ef	0.92	0.00267	17.11 de
V_1T_3	43.07 cd	3.41	10.98 b-e	0.85	0.00223	18.87 b-e
V_1T_4	41.02 de	3.31	10.55 c-e	0.92	0.00253	17.82 c-e
V_1T_5	46.03 bc	3.48	11.51 b-d	0.89	0.00223	19.81 b-d
V_2T_1	43.07 cd	3.38	10.19 d-f	0.78	0.00221	19.17 b-e
V_2T_2	45.07 c	3.45	10.85 c-e	0.74	0.00196	20.02 b-d
V_2T_3	49.03 ab	3.61	12.12 ab	0.55	0.00134	22.22 ab
V_2T_4	46.90 bc	3.52	11.74 bc	1.15	0.00297	21.30 a-c
V_2T_5	51.60 a	3.71	12.86 a	0.99	0.00236	23.77 a
LSD $_{(0.05)}$	3.68	ns	1.06	ns	ns	3.68
CV (%)	4.77	9.01	5.58	14.83	15.41	10.85

Table 4. Effect of variety on yield contributing parameters of soybean

Variety	Pods plant^{-1} (no)	Pod length (cm)	Seeds pod^{-1} (no)	Wt. of 100 seeds (g)
V_1= BARI Soybean-5	49.47 b	3.52	2.54 b	12.11 b
V_2=BARI Soybean-6	57.47 a	3.74	2.87 a	13.41 a
LSD (0.05)	6.72	ns	0.28	0.86
CV (%)	9.76	6.31	9.65	7.85

Gupta *et al.* (2011) found that foliar application of 2 % urea at flowering and 10 days after flowering resulted in higher dry weight due to enhanced biological nitrogen fixation. Hemantaranjan *et al.* (2000) studied that effect of foliar application of boron at the rate of 50 and 100 ppm increase total dry matter production. Combined effect of variety and foliar spray also had significant variation for dry weight plant^{-1} (Table 3).

Crop growth rate (g m^{-2} d^{-1}) and Relative growth rate (g g^{-1} d^{-1})

The crop growth rate is defined as the gain in weight of a community of plants on a unit of land in a unit of time. Soybean varieties, urea and boron application and their combined effect had no significant variation on crop growth rate (Table 1, 2 and 3). The result contradicts with the findings of Manivannan *et al.* (2002) revealed that combined foliar application recorded markedly higher crop growth rate when compared to control. Relative growth rate expresses the dry weight increase in a time interval in relation to the initial weight. Relative growth rate is also a measure used to quantify the speed of plant growth. It is measured as the mass increase per aboveground biomass per day. Relative growth rate non-significantly varied among varieties, urea and boron application and their combined effect (Table 1, 2 and 3).

Table 5. Effect of foliar spray urea and boron on yield contributing parameters of soybean

Foliar spray (FS) at flower initiation stage	Pods plant^{-1} (no)	Pod length (cm)	Seeds pod^{-1} (no)	Wt. of 100 seeds (g)
T_1=Control (RDF)	47.50 c	3.46	2.53 b	11.98 d
T_2=FS of water + RDF	50.50 bc	3.54	2.61 ab	12.40 cd
T_3=FS of urea (2%) + RDF	56.33 ab	3.72	2.81 ab	13.15 ab
T_4=FS of boron (1%) + RDF	53.33 abc	3.63	2.69 ab	12.82 bc
T_5=FS of Urea (2%) + Boron (1%) + RDF	59.67 a	3.80	2.89 a	13.45 a
LSD (0.05)	6.38	ns	0.32	0.63
CV (%)	8.75	9.76	7.55	8.44

Table 6. Combined effect of variety and foliar spray on yield contributing parameters of soybean

Treatment combinations	Pods plant^{-1} (no)	Pod length (cm)	Seeds pod^{-1} (no)	Wt. of 100 seeds (g)
V_1T_1	43.67 e	3.34	2.37 d	11.23 f
V_1T_2	46.33 de	3.44	2.44 cd	11.67 ef
V_1T_3	52.33 b-e	3.61	2.64 a-d	12.53 c-e
V_1T_4	49.33 c-e	3.51	2.54 b-d	12.23 de
V_1T_5	55.67 a-c	3.69	2.74 a-d	12.87 b-d
V_2T_1	51.33 b-e	3.57	2.69 a-d	12.73 c-e
V_2T_2	54.67 a-d	3.65	2.78 a-d	13.13 b-d
V_2T_3	60.33 ab	3.83	2.97 ab	13.77 ab
V_2T_4	57.33 a-c	3.75	2.85 a-c	13.40 a-c
V_2T_5	63.67 a	3.91	3.05 a	14.03 a
LSD (0.05)	9.03	ns	0.45	0.89
CV (%)	9.76	6.31	9.65	4.04

Table 7. Effect of variety on yield parameters of soybean

Variety	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
V_1= BARI Soybean-5	1.81 b	2.42	4.23 b	42.84
V_2=BARI Soybean-6	2.13 a	2.72	4.85 a	43.99
LSD (0.05)	0.31	ns	0.53	ns
CV (%)	6.45	9.67	9.12	10.01

Table 8. Effect of foliar spray urea and boron on yield parameters of soybean

Foliar spray (FS) at flower initiation stage	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
T_1=Control (RDF)	1.78 c	2.41 b	4.19 c	42.47
T_2=FS of water + RDF	1.89 bc	2.49 ab	4.37 bc	43.01
T_3=FS of urea (2%) + RDF	2.07 ab	2.64 ab	4.71 ab	43.83
T_4=FS of boron (1%) + RDF	1.97 abc	2.56 ab	4.54 abc	43.44
T_5=FS of Urea (2%) + Boron (1%) + RDF	2.17 a	2.73 a	4.91 a	44.31
LSD (0.05)	0. 23	0.28	0.41	ns
CV (%)	7.15	8.46	9.34	6.45

Table 9. Combined effect of variety and foliar spray on yield parameters of soybean

Treatment combinations	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
V_1T_1	1.62 d	2.28 b	3.90 e	41.50
V_1T_2	1.72 cd	2.35 ab	4.07 de	42.23
V_1T_3	1.9 b-d	2.48 ab	4.38 b-e	43.35
V_1T_4	1.83 b-d	2.42 ab	4.24 c-e	43.08
V_1T_5	2.02 a-c	2.57 ab	4.58 a-d	44.03
V_2T_1	1.95 b-d	2.53 ab	4.48 b-e	43.44
V_2T_2	2.05 a-c	2.63 ab	4.68 a-d	43.78
V_2T_3	2.23 ab	2.81 ab	5.04 ab	44.31
V_2T_4	2.12 a-c	2.71 ab	4.83 a-c	43.79
V_2T_5	2.33 a	2.90 a	5.24 a	44.59
LSD (0.05)	0.33	0.40	0.58	ns
CV (%)	9.62	9.02	7.41	6.22

Nodules plant^{-1} (no)

Nodules plant^{-1} differed among varieties, foliar application of urea and boron (Table 1, 2 and 3). Maximum nodules (21.27) was obtained from BARI Soybean-6 and the minimum nodules (17.94) from BARI Soybean-5. Treatment T_5 was superior (21.79) in its effect on nodules plant^{-1} and the lowest (17.63) effect recorded with T_1 treatments. The results were supported by Basher *et al.* (2006) and concluded that the application of foliar boron increased the effective number of nodules. Combined effect also had positive influence on nodules plant^{-1}.

Yield contributing parameters

Pods plant^{-1}, seeds pod^{-1} and weight of 100 seeds responded positively with the cultivars of soybean except the pod length. Maximum pods plant^{-1} (57.47), seeds pod^{-1} (2.87) and weight of 100 seeds (13.41 g) was observed from BARI Soybean-6, and the minimum pods plant^{-1} (49.47), seeds pod^{-1} (2.54), and weight of 100 seeds (12.11 g) was observed from BARI Soybean-5 (Table 4). Soybean plants treated with foliar spray of urea and boron caused significant improvements in the pods plant^{-1}, seeds pod^{-1} and weight of 100 seeds (Table 5). Maximum value of the studied parameters was obtained from T_5 (RF+ Urea (2%) + Boron (1%) FS at FI) and T_1 (control) showed the minimum value of the parameters. Uikey (2012) found that foliar application of urea and boron influencing the number of seeds pod^{-1}. Manonmani and Srimathi (2009) concluded that, spraying with urea one percent recorded higher 100 seed weight. In their combinations, BARI Soybean-6 with T_5 (RF+ Urea (2%) + Boron (1%) FS at FI) treatment indicates the highest value of these parameters whereas, the BARI soybean 5 with T_1 (control) treatments indicates the lowest value (Table 6).

Yield parameters

Variety exerted significant influence on yield parameters of soybean except stover yield and harvest index (Table 7). Highest seed yield (2.13 t ha^{-1}) and biological yield (4.85 t ha^{-1}) was recorded from BARI Soybean-6. The lowest seed yield (1.81 t ha^{-1}), stover yield (2.42 t ha^{-1}) and biological yield (4.23 t ha^{-1}) obtained from BARI Soybean-5.

The result of the study revealed that seed yield, stover yield and biological yield varied significantly due to different foliar spray of urea and boron (Table 8). The highest seed yield (2.17 t ha^{-1}), stover yield (2.73 t ha^{-1}) and biological yield (4.91 t ha^{-1}) was found in treatment T_5 (RF+ Urea (2%) + Boron (1%) FS at FI). Bruns (2017) reported that soybean yield increased due to foliar boron application. Kamel *et al.* (2008) reported that seed yield increased significantly with N foliar application. El-Abady *et al.* (2008) reported that foliar applications of urea and boron significantly increase stover yield and seed yield. The results obtained from T_1 treatment showed the lowest seed yield (1.78 t ha^{-1}), stover yield (2.41 t ha^{-1}) and biological yield (4.19 t ha^{-1}). The combination of variety and level of urea and boron had also significant effect on grain yield, straw yield and biological yield except harvest index (Table 9).

Conclusion

Based on the results the following conclusions can be drawn: Among the varieties, variety V_2 (BARI Soybean-6) produced maximum growth, yield attributes and yield of soybean. Among the foliar spray, treatment T_5 [RF+ Urea (2%) + Boron (1%) FS at FI] exhibited better grain yield. BARI Soybean-6 along with foliar treatment T_5 [RF+ Urea (2%) + Boron (1%) FS at FI] would be promising and beneficial practice for the optimization of soybean growth and yield.

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