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EFFECT OF FOLIAR APPLICATION OF BORON ON FRUIT SET AND YIELD OF BARI *BT* BEGUN

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Abstract

A field experiment on *Bt* brinjal (var. BARI *Bt* Begun-2) was carried out to investigate the effect of boron on its flowering, fruit setts and yield at the Soil Science Division, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur during 2018. The experiment was laid out in a Randomized Complete Block Design with three replications. The experimental treatment comprised four doses of boron (B), viz. 0.0 (control), 50, 100 and 150 ppm B. Boron in the form of boric acid (H_3BO_3) was applied at full bloom stage and then the other two sprays were given at an interval of 10 days. Results revealed that the yield and yield contributing characters of *Bt* begun were significantly influenced by foliar application of boron. Plant height (70.4 cm), number of fruits/plant (30.4), length of fruit (13.4 cm), individual fruit weight (79.0 g), fruit yield/9.0 m^2 (2433 g) were found to be maximum with spraying of B @ 100 ppm compared to the other treatments. Spraying of 100 ppm B recorded the highest fruit yield (24.30 t/ha) which was significantly higher than 150 ppm B and control treatment. According to regression equation, the optimum dose of boron concentration was 85 ppm. Quality attributes, viz. TSS (6.23 °Brix), Vitamin C (22.7 mg/100g and b carotene (25.2 ug/100 g) were also found highest at 100 ppm B. The maximum boron uptake both by fruits (0.07 kg/ha) and plants (0.06 kg/ha) was recorded at 100 ppm B. Therefore, it is concluded that 85 ppm boron (500 ppm boric acid) as foliar application along with other soil applied fertilizers @ 116-32-70-13-2 kg/ha of N-P-K-S-Zn can be recommended for higher yield and quality of *Bt* begun production.

Keywords: Boron, Yield, *Bt* eggplant, Vitamin-C, β- carotene, Transgenic brinjal

Introduction

Brinjal or eggplant (*Solanum melongena* L.), a member of Solanaceae family, is a very important vegetable in Bangladesh. It is popularly known as ‘begun’ grown throughout the country. It is low in calories (24 kcal/100g) but high in folate, calcium, vitamin B & C, fiber and water content. It is also used in ayervedic medicine for curing diabetics, hypertension and obesity. Brinjal is the second most important vegetable crop in Bangladesh in terms of production area as well as yield and it is cultivated all over the country in *rabi* and *kharif seasons*. In 2018-19, it is cultivated in 19114.5 hectares of land with an annual production of 170189 metric tons in *kharif* and 33281.8 hectares of land with an annual production of 360421 metric tons in *rabi* season. (Anon., 2020). However, the average brinjal yield in

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Bangladesh is relatively low compared to other advanced countries of the world. The low yield of brinjal in Bangladesh is primarily due to the lack of high yielding varieties, inadequate, imbalanced use of manure and fertilizers lacking in micronutrients especially boron.

Brinjal suffers regular and heavy losses from a very destructive insect-pest called the fruit and shoot borer which cannot be controlled effectively by conventional insecticides. *Bt* begun is the genetically modified (transgenic) version of regular brinjal. In common brinjal variety Cryl-AC gene isolated from the soil bacterium, *Bacillus thuringiensis* (*Bt*) is inserted to develop *Bt* brinjal. The special gene, Cryl-AC makes the brinjal poisonous to the pest brinjal fruit and shoot borer by the synthesis of insecticidal proteins, which are effective against pest but do not cause any harm to other organisms. Micronutrients such as boron had a great influence on plant growth and development. The essential physiological activities of boron linked to strength of cell wall and development, RNA metabolism, sugar transport, hormones development, respiration, cell division, Indole acetic acid (IAA) metabolism and as part of the cell membranes (Marchner, 1995). Boron deficiency causes delay in pollen germination and pollen tube development and ultimately it halts flowering and fruit setting (Halfacre, and Barden, 1979). Further, macronutrients are quickly absorbed and utilized by the tissues of the plants by the catalyzing effect of micronutrients (Phillips, 2004).

Foliar spray of micronutrients is the common practice to overcome the deficiencies in order to improve the quality of fruit. Nutrients are generally quickly available to the plants by the foliar application than the soil application (Phillips *et al*., 2004 and Silberbush, 2002). Boron also plays an important role in flowering and fruit formation (Nonnecke, 1989). Several studies have been conducted on effect of boron on flowering and fruit setting in tomato, chilli and potato which belong to the same family Solanaceae (Ali *et al*., 2015; Basavarajeswari *et al*., 2008; Lenka and Das, 2019; Mondal *et al*., 2023). In Bangladesh foliar application of boron on brinjal has not yet been reported. Therefore, the present study was conducted to investigate the effect of boron on flowering, fruit setting and yield of *Bt* brinjal and find out the optimum dose of boron for maximizing the yield of *Bt* brinjal.

Materials and Methods

A field experiment was conducted at the Soil Science Division, Bangladesh Agricultural Research Institute (BARI), Gazipur on 03 December, 2018 to study the effect of boron on flowering, fruit set and yield of *Bt* brinjal (transgenic brinjal) (var. BARI *Bt* Begun-2). The experiment was laid out in a randomized block design with three replications. The unit plot size was 3 m × 3 m. Fertilizers were applied @ 116-32-70-13-2 kg/ha of N-P-K-S-Zn in the form of urea, triple super phosphate, muriate of potash, gypsum and zinc sulphate respectively. Equal size healthy 35 day-old seedlings of brinjal were transplanted on 03 December, 2018 with a spacing of 100 cm from row to row and 75 cm from plant to plant. Non-*Bt* begun seedlings were planted as resistant varieties. Intercultural operations were done as and when necessary.

Methods of chemical analysis of soil

Initial soil samples collected from 0-15 cm depth prior to fertilizer application, were analyzed for all important soil parameters using standard procedures (Table 1). Soil pH was measured by a combined glass calomel electrode (Jackson, 1958). Organic carbon was determined by the wet oxidation method (Walkley and Black, 1934). Total N was determined by a modified Kjeldahl method. Calcium (Ca), magnesium (Mg) and K were determined by NH_4OAc extractable method, copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn) were determined by DTPA extraction followed by AAS reading. Boron (B) was determined by $CaCl_2$ extraction method. Available P was determined by the Bray and Kurtz method while S was determined using the turbidimetric method with $BaCl_2$.

Table 1. Initial properties of the soil samples of experimental field

Soil Properties	Texture	pH	OM (%)	Ca	Mg	K	Total N (%)	P	S	B	Cu	Fe	Zn
				meq 100g^{-1}				µg g^{-1}					
Result	Clay loam	5.77	0.97	5.33	1.83	0.18	0.051	8.5	13.2	0.19	2.1	66	0.96
Critical level	-	Acidic	Low	2.0	0.5	0.12	Very low	7.0	10	0.2	0.2	4.0	0.6

Foliar application

Boric acid (H_3BO_3) having 18% boron were applied at different concentrations as per imposed treatments. Sprays were done three times at full bloom stage and the other two sprays were given at an interval of 10 days. The treatment combinations of foliar spray of boron were 0.0 (control), 50, 100 and 150 ppm B. Foliar sprays were applied using a hand sprayer. All treatments were applied as a foliar spray on plants using hand operated compressed air sprayer at the rate of 9 liter/plot. Boron @ 100 ppm (100 mg/L) solution was prepared by dissolving 0.572 g boric acid (H_3BO_3) in 1000 mL of deionized water. Similarly, 50 and 150 ppm were prepared with 0.286 and 0.858 g of boric acid dissolving in 1000 mL deionized water, respectively. The time of foliar spray was 8:00 A.M. Young fruits were harvested time to time at edible stage. Five plants were randomly selected from each and every treatment for recording necessary yield data such as plant height (cm), fruit length (cm), number of fruits per plant, fruit weight (g) and yield (t ha-^{1}). Fruit quality data were total soluble solid (TSS) and vitamin C. The ANOVA was prepared on yield attributes, quality and yield data. When F was significant at the $p<0.05$ level, the means were compared by Tukey's W test using Excel version 4.0 (Esumi Co. Ltd., Tokyo, Japan).

Total soluble solid, ascorbic acid content and carotenoids:

Brinjal fruit from each treatment were cut into small slices and pooled. Samples were homogenized in a blender and portion of the homogenate were taken to determine the fruit quality. Total soluble solids content (TSS) was determined at 20^0C with a refractometer and reported as ^{0}Brix. Ascorbic acid content (vitamin C) was measured by classical titration method using 2, 6-dichlorophenol indophenols solution and express as mg 100 $g^{-1}$of fresh weight (Miller, 1998). Total carotenoid (μg 100 g^{-1}) was measured by spectrophotometer (T-40, PG Instrument Ltd.UK) at 451ɳm (Alasalvar *et al.,* 2005).

Results and Discussion

Yield and yield contributing parameters of *Bt* begun were significantly influenced by foliar spray of boron (Table-2). The highest plant height (70.5 cm) was recorded in 150 ppm B, which was statistically identical to 50 ppm B and 100 ppm B but higher than the control. The lowest (67.8 cm) plant height was recorded in the control. In general, the vegetative growth of brinjal responded positively to foliar application of boric acid. Boron is vital to plant health, due to its role in forming and strengthening cell walls (Broadly *et al*., 2012). The highest number of fruits per plant (30.4) was recorded at 100 ppm B which was was identical with 50 ppm B but significantly higher than 150 ppm B and control treatments. This attributed to the accessibility of boron by foliar feeding and the key role of boron on cell integrity, sugar transport, RNA metabolism and enhancing respiration rate, increasing uptake of certain nutrients and metabolic activities. Ali *et al*. (2013) reported that boron increased the number of fruits in tomato (30 fruits at 5x 10^6 ppm). Similar results were also observed by Shnain *et al.* (2014) where 1250 ppm boron was applied as foliar spray in tomato. The maximum length of fruit (13.4 cm) was found in T_2 which was significantly higher than the other treatments. The lowest fruit length (10.7cm) was noticed in the control.

Individual fruit weight was significantly variable among the treatments (Table 3). The maximum individual fruit weight (79.0 g) was obtained from the plants receiving 100 ppm boron which was significantly higher than the other treatments and the minimum fruit weight was obtained from the control treatment. Foliar application of boron (100 ppm) increased weight of fruits that may be due to greater photosynthetic activity, resulting the increased production and accumulation of carbohydrates and favorable effect on vegetative growth and retention of flowers and fruits, which might have increased number and weight of fruits. The results agree with the findings of Davis *et al*. (2003); Bhatt *et al*. (2004); Naga *et al*. (2013) and Basavarajeswari *et al.* (2008).

The fruit yield per plot and per hectare was significantly influenced by the different levels of boron (Table 2). The maximum fruit yield/plot (9.0 m^2) was obtained from the spray of 100 ppm B (2433 g) closely followed by 50 ppm B spray (2166 g) and its minimum value was obtained from the control. The highest yield (24.3 t/ha) was noted at 100 ppm boron spray which was statistically similar to 50 ppm B spray (21.6 t/ha) and significantly higher than the 150 ppm B and control. This resulted due to production of fertile flowers and better pollen germination which is an essential phenomenon of reproduction process. The productive flowers are directly linked with the content of phenolic compounds. B has also an important role in phenol metabolism (Gupta *et al*., 2012). Meena *et al*. (2015) showed that foliar application of boron and zinc either solely or in combination is quite beneficial for vegetative growth, flowering and fruiting as well as quality improvement of tomato fruits.

Table 2. Effect of boron on yield and yield contributing character of *Bt* brinjal

Treatment (Born conc. in ppm)	Plant height (cm)	Number of fruits/plants	Length of fruit (cm)	Individual fruit weight (g)	Fruit weight/plot (g)	Yield (t/ha)
50	69.5a	26.3ab	12.1b	73.4b	2166ab	21.6ab
100	70.5a	30.4a	13.4a	79.0a	2433a	24.3a
150	68.1a	22.3b	11.2c	71.3b	1966b	19.6b
0 (Control)	67.8b	16.4c	10.7d	63.6c	1766b	17.6b
CV (%)	6.48	1.65	7.07	2.46	7.71	7.70

Plot area: 3 m x 3 m (9.0 m^2)

It was observed that the fruit yield was increased with the increase in boron concentration up to 100 ppm beyond that yield decreased. The percent increase in fruit yield over control was 22.7, 38.1 and 11.4% for 50, 100 and 150 ppm B, respectively (Table 3). As a micronutrient B requirement is very low (concentration) for plant growth and development (Abd El-Gawad *et al*, 2014). There is a very thin margin between the level of B deficiency and toxicity. An optimum concentration of B for a plant can be toxic for another plant. Plant growth can be affected very badly due to the higher concentration of B (Miwa *et al.*, 2007).

Economic performance

The economic performance of different treatments is presented in Table 3. The highest gross return (972000 Tk/ha) and maximum marginal benefit-cost ratio (MBCR) (28) were found from 100 ppm B spray. The lowest MBCR (8) with 784000 Tk/ha was obtained from 150 ppm B spray.

Table 3. Yield comparison between different levels of foliar application of B and their economics

Treatment (Born conc. in ppm)	Fruit yield (t ha^{-1})	Yield increased (%) Over control	Variable cost[§] (Tk ha^{-1})	Gross return (Tk ha^{-1})	MBCR over control
50	21.6	22.7	32308	864000	17
100	24.3	38.1	32357	972000	28
150	19.6	11.4	32407	784000	8
0 (Control)	17.6	–	22808	704000	–

[§] Variable cost considering only fertilizer, wage rate, seed and land preparation only.

Input prices (Tk kg^{-1}): Urea: 16; TSP: 25; MoP: 15; Gypsum: 15; Zinc sulphate: 140; Boric acid: 240. Wage rate: 450 Tk., Seed: 500 kg^{-1}, Land preparation: 9880 Tk ha^{-1}.

Response function between boron and yield

A positive but quadratic relationship was observed between yield of *Bt* brinjal and B application (Fig. 1). To build a response function, boron levels were plotted in X axis and yield levels were plotted in Y axis. The obtained regression equation was y = 17295 + 147.9 B – 0.87 B^2 and the coefficient of determination (R^2) was 0.9243. The R^2 value 0.9243 indicates that 92.43% yield was due to B application and the rest 7.57% yield was due to other factors. Thereby the optimum dose of B was 85 ppm and estimated maximum yield was 23.5 t/ha.

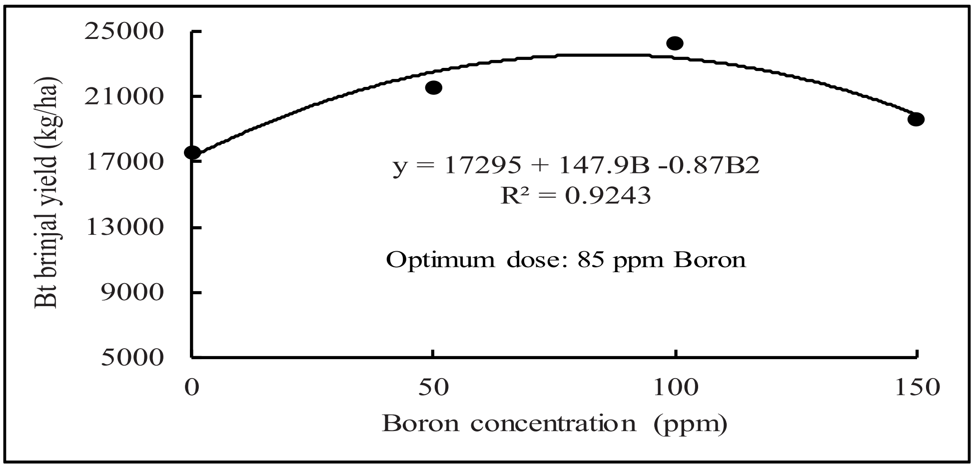

Fig. 1. Response of *Bt* brinjal yield to boron application.

Boron concentration and uptake of *Bt* brinjal

Boron concentration and uptake by Bt brinjal fruit and plants are presented in Tables 4 and 5. The maximum boron concentration and uptake were found in 100 ppm foliar spray of B followed by 50 ppm B and 150 ppm B. It was observed that boron uptake increased with increase in boron concentration. Similar result was also reported by Haribhushan *et al.* (2008) where B availability increased in soil after application of optimum dose of borax.

Table 4. Boron concentration and uptake of *Bt* brinjal fruit in different treatments

Treatment (Born conc. in ppm)	B content (ppm)	B conc. (%)	B uptake by *Bt* brinjal fruits (kg/ha)
50	27	0.0027	0.06
100	29	0.0029	0.07
150	25	0.0025	0.05
0 (Control)	21	0.0021	0.04

Table 5. Boron concentration and uptake of Bt brinjal plant in different treatments

Treatment (Born conc. in ppm)	B content (ppm)	B conc. (%)	B uptake by *Bt* brinjal plants (kg/ha)
50	22	0.0022	0.05
100	24	0.0024	0.06
150	20	0.0020	0.04
0 (Control)	19	0.0019	0.03

TSS, Vitamin C content and β- carotene content in *Bt* brinjal fruit

TSS and vitamin C content are presented in Table 6. Higher TSS (6.23^{0}Brix) was found in 100 ppm and the lowest value (5.40^{0}Brix) was noted in the control. The increase in TSS might be due to the more nutrients were available by foliar sprays which may enhance the synthesis of carbohydrate and other quality characters. These results are in conformity with findings of Fagaria *et al*. (2009). The maximum vitamin C (22.7 mg 100g^{-1}) was found in 100 ppm foliar spray of B and minimum value (17.7 mg 100 g^{-1}) was in the control. Similarly, the highest β-carotene (25.2µg 100 g^{-1}) was found in 100 ppm B followed 50 ppm B and 150 ppm B.

Table 6. Quality characters of *Bt* brinjal as affected by foliar application of boron

Treatment (Born conc. in ppm)	TSS (^{0}Brix)	Vitamin-C (mg/100 g)	β- carotene (µg/100 g)
50	5.70	21.1	23.4
100	6.23	22.7	25.2
150	5.56	20.3	20.4
0 (Control)	5.40	17.7	18.8

Conclusion

Foliar application of boron enhanced number of fruits/plants, individual fruit weight and fruit yield of *Bt* brinjal. The highest fruit yield, Vit-C and β-carotene content were recorded in 100 ppm boron treatment. From the quadratic response function, the optimum dose of B was recorded as 85 ppm boron. Therefore, it may be concluded that 85 ppm boron (500 ppm boric acid) as foliar application along with other soil applied fertilizers @ 116-32-70-13-2 kg/ha of N-P-K-S-Zn may be recommended for producing good quality of *Bt* brinjal in Grey Terrace Soil of Joydebpur.

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