ISSN 0258-7122 (Print), 2408-8293 (Online)
Bangladesh J. Agril. Res. 45(2): 125-135, June 2020

EFFECT OF FOLIAR APPLICATION OF BORON ON THE YIELD AND QUALITY OF POTATO

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Abstract

Foliar application of boron on the yield and storability of potato was evaluated at Breeder Seed Production Centre, Debiganj during two consecutive years 2013-14 and 2014-15. Six different concentration of boron such as: 0 ppm B (T_1), 70 ppm B (T_2), 140 ppm B (T_3), 210 ppm B (T_4), 280 ppm B (T_5) and 350 ppm B (T_6) were tested. The maximum yield 35.9 and 35.3 t ha^{-1} in 2013-14 and 2014-15, respectively was found when plants treated with 210 ppm B as foliar application (T_4). The highest dry matter content of tuber was obtained from T_4. T_4 (210 ppm B) also showed the minimum rottage loss of tuber. The highest gross margin and marginal benefit cost ratio were recorded in the same treatment. Foliar application of 210 ppm B can be recommended for economically potato production in Tista Meander Floodplain Soil.

Keywords: Boron, foliar application, dry matter, potato yield, storage.

Introduction

Potato is one of the most important vegetables in Bangladesh. It can meet up vegetable demand and provide necessary nutrients for the people of the low income group. The national average yield of potato in Bangladesh is 20.4 ton per hectare and it is very low as compared to that of the major potato growing countries (BBS, 2017). The causes of lower yield might be due to the application of imbalanced fertilizers (AGPRO, 2013). Boron is one of the micronutrients necessary for plant growth and development (Banerjee *et al*., 2016). Boron deficiencies occur over a wide range of soil, low organic matter contents and high soil pH levels (Mengel and Kirkby, 1978). Generally foliar application is very fast method for providing required elements in plants (Hashemy *et al*., 1998). However, no data is available regarding foliar application of boron for potato in Bangladesh. So, the present experiment was initiated to assess the effect of boron through foliar application on the yield and storability of potato.

Materials and Methods

Experimental site and soil characteristics

The experiment was conducted at the Breeder Seed Production Centre (BSPC), Debiganj, Panchagarh during the *rabi* season of 2013-14 and 2014-15. The

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geographical distribution of experimental plot is located at N-26° 12´ and E-88° 76´. The texture of soil was sandy loam, acidic in nature where iron (Fe) was found higher than the critical limit but other nutrients such as total nitrogen (N) (0.06%), exchangeable potassium (K) (0.18 meq/100g), sulphur (S), calcium (Ca), Zinc (Zn), magnesium (Mg) and boron (B) were lower than the critical level.

Experimental design, treatment, fertilizer application and intercultural operation

The experiment was laid out in a randomized complete block design (RCBD) with three replications. There were six treatments comprising different levels of boron: 0 ppm B (T_1), 70 ppm B (T_2), 140 ppm B (T_3), 210 ppm B (T4), 280 ppm B (T_5) and 350 ppm B (T_6) . Fertilizers were applied on the basis of soil test value except boron (B). Urea, TSP, MoP, gypsum, magnesium sulphate, zinc sulphate and boric acid were used as a source of N, P, K, S, Mg, Zn and B, respectively. It is worthwhile to mention that, boric acid contains 17% boron. All the fertilizers and half of urea were applied at the time of final land preparation and incorporated in soil. Earthing up and side dressing were done at 30 DAP (days after planting). Boric acid (H_3BO_3) solution was applied at three stages of plant growth (stolonization, tuberization and bulking) followed by three foliar sprays. At first, 1000 ppm boron stock solution was prepared taking 88.5g H_3BO_3 powder lab grade in 15 liter water (5.9g H_3BO_3 powder/ L water). From the stock solution, different concentration of boron solution was prepared according to treatment in the following way: T_1 = 0 ppm B, T_2 = 70 ppm B (700ml stock solution was added in 10 liter water), T_3 = 140 ppm B (1400 ml stock solution was added in 10 liter water), T_4 = 210 ppm B (2100 ml stock solution was added in 10 liter water), T_5 = 280 ppm B (2800 ml stock solution was added in 10 liter water) and T_6 = 350 ppm B (3500 ml stock solution was added in 10 liter water). The rest two growth stages, the solution was prepared in same way and the same amount of boric acid was also required. Weeding and mulching were performed as per requirement. Four irrigations were applied during the growing period. For proper germination, a light irrigation was applied at 5 DAP and second irrigation was done after earthing up and side dressing. Rest two irrigations were done according to the demand of crops which was at 48 and 63 DAP. Late blight disease was managed by spraying of Dithen M 45 at the rate of $2gL^{-1}$.

Potato Tuber Planting and harvesting

Potato variety *BARI Alu-25* (Asterix) was used as test crop. In 3 m × 3 m unit plot, the potato tuber was planted on 15 and 17 November of 2013 and 2014, respectively maintaining 60 cm × 25 cm spacing. After maturity, the potato was harvested on 25 February 2014 and 28 February 2015.

Plant and soil sampling and chemical analysis

The collected soil samples were analyzed following the standard laboratory method (Page *et al*., 1989). Bulk density was determined by core sampler Method. Soil pH was determined by using glass electrode pH meter and organic carbon by wet oxidation method. Total N content of soil determined by Kjeldahl method (Jackson, 1973), available P by ascorbic acid and blue color method, exchangeable K by flame photometer and available S by turbidimetric method.

Data collection

Data were recorded on plant height, foliage coverage, stems / hill, tubers / hill, wt. of tubers / hill, tuber yield and tuber dry matter of potato, tuber size and number were recorded. At 60 DAP, Green method (Groves *et al*., 2005) was followed to assess the foliage coverage, stem/ hill and height of plant. Furthermore, yield data and dry weight were collected at harvest and seven days after harvesting, respectively.

Storage data

The fresh weight of potato tubers was recorded at the time of harvest. Weighing of tubers was continued at a regular interval of 15 days started from 30 days after storage (DASt) to 150 DASt. Rotted tubers were discarded after weighing.

Benefit cost analysis

Considering normal market price, the inputs and outputs (potato tuber) were assessed. Calculating the price of inputs and value of the crop/ yield, the gross return, net return and return/ dollar in different treatments were also measured. With the help of partial budgeting followed by marginal benefit cost ratio (MBCR), the economic analysis was done (Perrin *et al*., 1979).

Statistical analysis

For different crop parameters and dry matter, the analysis of variance (ANOVA) was done following F test and means were separated by DMRT (Steel and Torii, 1960) test. The SAS software (version 9.3) was used to analyze the data.

Results and Discussion

Yield and yield contributing characters

The plant height, foliage coverage, stem per hill and number of tuber per hill were positively influenced by the foliar application of different doses of boron but its effects were not significant (Table 1). The weight of tuber per hill was significantly variable among different doses of foliar application of boron (Table 1). In 2013-14, the highest weight of tubers per hill (0.60 kg hill^{-1}) was found in T_4 (210 ppm B), which was statistically identical to T_5 (280 ppm B) and T_6 (350 ppm B). The lowest weight of tubers/ hill (0.49 kg hill^{-1}) was recorded in the control (0 ppm B). The similar trend was found in the following year (2014-15).

Table 1. Effect of foliar application of boron on the yield contributing characters of potato

Treat	Plant height (cm)		Foliage coverage (%)		Stem per hill (no.)		Tuber per hill (no.)		Weight of tubers/ hill (kg)	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
T_1	66.53	60.60	93.66	91.33	7.00	7.66	9.46	11.13	0.49 c	0.46d
T_2	66.33	60.66	94.00	92.33	6.60	8.33	9.93	12.26	0.53 bc	0.50cd
T_3	65.93	59.66	95.33	92.33	7.20	8.13	10.46	13.53	0.55 a-c	0.52b-d
T_4	65.93	61.46	96.00	93.33	7.86	8.13	10.13	11.26	0.60 a	0.59a
T_5	67.80	56.66	95.33	93.66	7.40	8.26	10.93	11.86	0.59 ab	0.57ab
T_6	67.53	57.13	94.66	94.33	6.80	8.53	11.66	14.00	0.58 ab	0.53a-c
CV (%)	3.86	5.40	1.48	1.88	13.32	12.92	16.46	15.27	4.58	3.36

Notes: T_1 = 0 ppm B, T_2 = 70 ppm B, T_3 = 140 ppm B, T_4 = 210 ppm B, T_5 = 280 ppm B and T_6 = 350 ppm B.

Figure (s) in column having common letter (s) and without letter (s) do not differ significantly at 5% level.

Table 2. Effect of foliar application of boron on the tuber yield and dry matter of potato

Treatments	Tuber yield (t/ha)			Dry mater (%)
	2013-14	2014-15	2013-14	2014-15
T_1	29.20 d	27.10e	19.37 c	19.11d
T_2	31.63 c	29.89d	20.95 b	19.98cd
T_3	33.12 bc	32.46c	21.28 b	20.71abc
T_4	35.90 a	35.33a	22.07 a	21.68a
T_5	35.21 ab	34.20ab	22.05 a	21.10ab
T_6	34.85 ab	33.67bc	20.79 b	20.52bc
CV (%)	3.97	2.52	1.64	2.56

Notes: T_1 = 0 ppm B, T_2 = 70 ppm B, T_3 = 140 ppm B, T_4 = 210 ppm B, T_5 = 280 ppm B and T_6 = 350 ppm B. Figure (s) in column having common letter (s) and without letter (s) do not differ significantly at 5% level.

Yield and dry matter content of tuber

The highest tuber yield of potato (35.90 t ha^{-1}) was obtained in T_4 (210 ppm B), which was statistically identical to T_5 and T_6 in 2013-14. The lowest tuber yield (29.20 t ha^{-1}) was recorded in the control. The similar trend was followed in 2014-15. Increase in yield and yield attributes due to boron application may be attributed to enhanced photosynthetic activity and increased production and accumulation of photosynthesis, carbohydrates and favorable effect on vegetative growth which increased tubers yield per plant. It also plays important roles in cell wall synthesis, sugar transport, cell division, cell development, auxin metabolism, and seed development, synthesis of amino acids and proteins and carbohydrate metabolism, all this influenced growth and development of plant and contributed to higher yield and dry matter content (El-Dissoky and Abdel-Kadar, 2013).

In 2013-14, the highest dry matter content (22.07 %) of potato tuber was recorded in T_4 (210 ppm B), which was statistically identical to T_5 (280 ppm). The lowest dry matter content in potato tuber (19.37%) was noted in the control. The similar trend was followed in 2014-15. It was found that tuber and dry matter yield of potato increased with the increase of boron content up to 210 ppm. This may be due to increase in the amount of chlorophyll in leaves and photosynthetic area which in turn leads to enhanced photosynthetic rate and ultimately accumulation of nutrients in tuber which improves protein, sugars and starch content of tubers. Foliar spray of boron improves photosynthetic activity, enhances activity of enzymes and plays significant role in protein and nucleic acid metabolism. Boron seems to protect plasma membrane against peroxidase damage and helps in maintenance of structural integrity (Ewais *et al*., 2020). However, high dose doses of boron might cause toxic effect and restricted plant growth (Ayvaz *et al*., 2013).

Number and size of tubers

In 2013-14, the highest medium (76.77%) and large (3.05%) size tuber was found in T_4 (210 ppm B) followed by T_5 (280 ppm). The lowest medium (73.35%) and large (0.20%) size tuber was noted in the control (Table 3). The similar trend was recorded in the following year (2014-15). Puzina (2004) showed that using boric acid in potato fertilization increased in tuber size and weight by increasing of cell diameter in the tuber perimedullary zone.

Table 3. Effect of foliar application of boron on number and size of tubers

Treat	Grading by No (%)					
	2013-14			2014-15		
	<28 mm	28-55 mm	>55 mm	<28 mm	28-55 mm	>55 mm
T_1	26.45	73.35	0.20	29.43	70.11	0.45
T_2	25.89	73.69	0.42	27.03	71.83	1.12
T_3	25.00	74.59	0.41	24.41	74.72	0.87
T_4	20.18	76.77	3.05	19.41	78.42	2.15
T_5	22.63	76.62	0.75	21.94	76.38	1.67
T_6	24.19	75.32	0.49	24.76	74.10	1.14

Economic analysis

In 2013-14 the maximum gross margin (US$. 4258.13 ha^{-1}) was found in T_4 (210 ppm B) followed by T_5 (US$. 4173.65 ha^{-1}) (Table 4). The lowest gross margin (US$. 3504.14 ha^{-1}) was recorded in the control. The MBCR (marginal benefit cost ratio) ranged from 5.24 to 15.06. The highest MBCR (15.06) was recorded in T_4 followed by T_5. The lowest MBCR (5.24) was noted in T_2 (70 ppm B). The similar trend was followed in the next year (2014-15) It was observed that MBCR was increased with the increase of boron concentration up to 210 ppm, after that it was decreased (Table 4).

Storage behavior of potato tuber

Weight loss

At 150 DASt, the minimum weight loss (58.3 %) was found in T_4 followed by T_5 (65.8 %) and the maximum value was recorded in the control (72.9 %). This result might be due to higher content of protein, sugar and starch during tuber formation (Bari *et al*., 2001). The 30 DASt showed the minimum weight loss. It was observed that weight loss increased with the increase of days after storing. Similar results were also observed by Kanbi and Bhatnagar (2005), where potato cultivar Kufri Badshah evaluated under integrated nutrient management and the highest weight loss was found in 105 DASt. Weight loss during storage was mainly due to evaporation and contribution of respiratory carbon loss to total weight loss (Mehta and Ezekiel, 2010).

Rottage loss due to* Fusarium *dry rot

At 150 DASt, total rottage loss was maximum in the control (3.75 %) followed by T_2 (3.25 %) and the minimum loss (2.10 %) was noted in T_4. Based on storage period, the maximum rottage loss was recorded at 150 DASt followed by 120 DASt. The minimum rottage loss was recorded at 30 DASt (Table 6). Akhter *et al*. (2014) reported that the maximum rottage loss was noted at 120 DASt followed by 90 DASt, which are in agreement with the present findings of our study.

Table 4. Cost and benefit analysis of foliar application of boron on potato

Treat	Tuber yield (t/ha)		Gross Return (US$/ha)		TVC (US$/ha))		Gross margin (US$/ha)		Marginal gross margin (US$/ha)		MBCR	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
T_1	29.20	27.10	3504.14	3252.13	0	0	3504.14	3252.13	-	-	-	-
T_2	31.63	29.89	3795.75	3586.94	46.68	46.68	3749.07	3540.26	244.93	288.13	5.24	6.17
T_3	33.12	32.46	3974.55	3895.35	48.36	48.36	3926.19	3846.99	422.05	594.86	8.72	12.30
T_4	35.90	35.33	4308.17	4239.76	50.04	50.04	4258.13	4189.72	753.99	937.59	15.06	18.73
T_5	35.21	34.20	4225.37	4104.16	51.72	51.72	4173.65	4052.44	669.51	800.31	12.94	15.47
T_6	34.85	33.67	4182.17	4040.56	53.40	53.40	4128.77	3987.16	624.63	735.03	11.70	13.76

Note: T_1=0 ppm B, T_2=70 ppm B, T_3=140 ppm B, T_4=210 ppm B, T_5=280 ppm B, T_6=350 ppm B

TVC = Total Variable Cost, MBCR= Marginal Benefit Cost Ratio

Input prices: Boric acid = US$ 3.36/kg.

Output prices: Potato = US$ 0.12/kg.

Table 5. Weight loss of potato at different days after storing influenced by levels of boron

Treat	Cumulative weight loss (%) at different DASt					
	Initial (0)	30 days	60 days	90 days	120 days	150 days
T_1		3.57 a	7.87 a	23.57 a	44.36 a	72.85 a
T_2		2.55 b	5.61 cd	22.47 b	40.01 c	68.52 b
T_3		1.89 d	5.69 c	21.40 c	41.33 b	66.23 c
T_4		2.27 c	5.73 c	19.91 e	32.95 e	58.28 d
T_5		2.00 d	5.30 d	14.88 f	34.60 d	65.75 c
T_6		3.65 a	6.67 b	20.33 d	42.32 b	68.49 b
CV (%)		4.21	2.99	0.96	1.39	0.74

Notes: T_1 = 0 ppm B, T_2 = 70 ppm B, T_3 = 140 ppm B, T_4 = 210 ppm B, T_5 = 280 ppm B and T_6 = 350 ppm B. Figure (s) in column having common letter (s) do not differ significantly at 5% level.

Table 6. Rottage loss due to *Fusarium* dry rot (FDR) of potato at different DASt

Treat	Rottage loss FDR (%) at different DASt					
	Initial (0)	30 days	60 days	90 days	120 days	150 days
T_1		1.22 a	1.42 a	2.14 a	3.11 a	3.75 a
T_2		1.22 a	0.71 b	1.95 b	2.76 b	3.25 b
T_3		0.71 b	0.71 b	0.71 e	2.06 e	2.98 c
T_4		0.71 b	0.71 b	1.24 d	1.64 f	2.10 f
T_5		0.71 b	1.34 a	1.71 c	2.31d	2.57 e
T_6		1.15 a	0.71 b	0.71 e	2.50 c	2.73 d
CV (%)		7.82	11.92	4.78	2.46	2.64

Figure (s) in column having common letter (s) do not differ significantly at 5% level.

Table 7. Rottage loss due to bacterial soft rot (BSR) of potato at different DASt

Treat	Rottage loss BSR (%) at different DASt					
	Initial (0)	30 days	60 days	90 days	120 days	150 days
T_1		0.71 b	0.94 e	3.38 a	4.63 a	6.15 a
T_2		0.71 b	1.15 d	2.07 d	3.75 c	5.68 b
T_3		0.71 b	1.31 bc	3.30 a	4.47 a	5.64 b
T_4		0.71 b	1.17 cd	2.96 b	3.39 d	5.13 c
T_5		1.18 a	1.42 b	2.78 c	4.20 b	5.57 b
T_6		1.07 a	1.57 a	3.11 b	4.25 b	5.79 b
CV (%)		7.05	5.95	2.85	2.64	2.59

Figure (s) in column having common letter (s) do not differ significantly at 5% level.

Rottage loss due to bacterial soft rot

At 150 DASt, the maximum bacterial rottage loss (6.15%) was found in control followed by T_2 (5.68 %) and the minimum loss (5.13 %) was noted in T_4. Based on storing period, the maximum bacterial rottage loss was also recorded at 150 DASt followed by 120 DASt while the minimum rottage loss was observed at 30 DASt (Table 7).

Conclusion

Dry matter content and storability are very important for long term and commercial use of potato. The findings of the present study indicate that the tuber yield of potato was significantly influenced by the foliar application of boron. The highest tuber yield of potato (35.90 and 35.33 t ha^{-1} for 2013-14 and 2014-15, respectively) was found in 210 ppm B application. The highest dry matter of potato tuber was found in this treatment. The highest gross margin and marginal benefit cost ratio were also recorded in the same treatment. The storage performance of potato tuber under T_4 (210 ppm B) treatment was also found to be encouraging having the minimum rottage loss. Therefore, foliar application of 210 ppm B can be recommended for economically potato production at Tista Meander Floodplain Soil.

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