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INFLUENCE OF FOLIAR APPLICATION OF BORON ON PRODUCTIVITY OF POTATO (*Solanum tuberosum* L.) IN *INCEPTISOLS*

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ABSTRACT

A field experiment was conducted during *rabi* season of 2018 and 2019 in the alluvial soil of West Bengal (belonging to *Inceptisols* soil order) to assess the influence of the foliar application of boron on the productivity of potato (*Solanum tuberosum* L.). There were four different treatment combinations of foliar applications of 0.25 kg of B ha^{-1} in 25 and 45 days after planting and its two equal splits application in both 25 and 45 days after planting including one control. Each treatment was replicated five times. The experimental soil was neutral in pH (6.6), with low contents of organic carbon (4.65 mg kg^{-1}) and boron (0.198 mg kg^{-1}). Results revealed that foliar application of 0.25 kg of B ha^{-1} in 2 equal splits during both tuber initiation and bulking stage i.e. 25 and 45 days after planting respectively, recorded the highest plant yield (7.03 t ha^{-1}) and tuber yield (32.60 t ha^{-1}); B concentration in plant (36.8 mg kg^{-1}) and tuber (15.9 mg kg^{-1}); B uptake by plant (259.4 g kg^{-1}) and tuber (518.3 g kg^{-1}) of potato. Results also indicated that foliar application of 0.25 kg of B ha^{-1} in 2 equal splits during both tuber initiation and bulking stage significantly increased plant yield by 28.2%, tuber yield by 35.0%, total B uptake by 149.8% over control where no B was sprayed. It was again found that the single foliar spray of B (@ 0.25 kg B ha^{-1}) at 25 days after planting was found to be more effective in increasing plant and tuber yields than spraying at 45 days after planting. Results also revealed that two equal split foliar applications of the same dose of B at 25 and 45 days after planting resulted in extra plant and tuber yield advantages over the single foliar application of B.

(Key words: Boron application, foliar spray, time, potato, alluvial soil)

INTRODUCTION

Potato (*Solanum tuberosum* L.) belonging to the Solanaceae family is a very important food crop all over the world including India. Potatoes were probably brought to the Indian sub-continent hundred years ago by the Portuguese, and their cultivation expanded under British colonial rule in the 19th century (Geddes *et al.,* 1989). The potato is a heavy nutrient-demanding crop as it produces huge biomass and tubers unit area^{-1}. It consumes excess amounts of nitrogen, phosphorus, potassium, magnesium, calcium, and micronutrients (Fit and Hangan, 2010). Application of nutrients like Zn, B, S, and Mg increases the foliage at vegetative growth stages and after that increases translocation of assimilation products belowground and ultimately increases the yield of potato (Trehan and Grewal, 1981). Previous studies discovered that boron applications had a significant impact on soybean (Adkine *et al.,* 2011). According to Tariq *et al.* (2022), foliar application of B is an efficient technique for meeting the boron demands of crops due to enhanced absorption by leaves, and for maximum production of high-quality potatoes, B is suggested to be sprayed on the leaves at a rate of 0.5 kg B ha^{-1} in B-deficient alkaline soil.

To obtain optimum yield and quality of potato it is very essential to apply the optimum amount of fertilizers in the right time. Plant nutrients are essential in the intensive production systems for potatoes. Primary attention is always given to the major nutrient elements. However, the deficiencies of the essential micronutrients also have a great impact on the productivity and quality of potato tuber. Among these micronutrients, boron (B) is an important micronutrient element that is very essential for increasing the productivity of potato. Synthesis of cell wall, transportation of sugar, division, and development of cell, metabolism of auxin, pollination, setting of fruit, development of seed, amino acids synthesis, formation of nodules in legumes and regulates the metabolism of carbohydrates are some of the important functions played by boron. Boron deficiencies occur over a much wide range of soils and crops than deficiencies are found most often in light soils, low organic matter contents, and high soil pH levels (Mengel and Kirkby, 1978). Starch is translocated from leaf to potato roots due to the application of B. So inadequate amount of B application in the proper growth stages of potato reduces the yield. Numerous research works have been carried out on macro-nutrient requirements and their effect on the growth and yield of potato but information on the foliar spray of boron at different times of planting on the growth and yield

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of potato is very limited. With this background, the present study was assumed to evaluate the impact of the foliar application of boron at different growth stages on potato productivity.

MATERIALS AND METHODS

The experiment

A field experiment with potato (cv., Kufri Jyoti) was conducted in a farmer's field of the Patrasayer block of Bankura district with alluvial *Inceptisols* (Typic Haplaquepts) during *rabi* season of 2018 and 2019. The design of the experiment was randomized block design with plot size of 5 m × 4 m. The potato crop in each plot was raised with similar standard crop management practices like irrigation, weeding, application of nutrients through fertilizers (except B), controlling pests and diseases etc. The nitrogen, phosphate, and potash were applied in each of the plots maintaining the N:P:K ratio of 150:50:100 kg ha^{-1} using urea and N:P:K mixture (10:26:26). However, B was applied as a foliar spray using borax ($Na_2B_4O_7$. $10H_2O$) having B content of 10.5%.

The treatment combinations for B fertilization for the potato crop of the experiment were T_1 = control (no application of B), T_2 = 0.25 kg of B ha^{-1} as a foliar application at tuber initiation stage i.e., 25 days after planting, T_3 = 0.25 kg of B ha^{-1} as a foliar application at bulking stage i.e., 45 days after planting, T_4 = 0.25 kg of B ha^{-1} as a foliar application in 2 equal splits during both tuber initiation and bulking stage i.e., 25 and 45 days after planting respectively. Each treatment was replicated five times.

Collection of samples and recording yield data

Representative soil samples from each plot before the initiation of the experiment were collected from the 3 depths (i.e., 0-20 cm, 20-40 cm, 40-60 cm) for chemical analysis. Representative plant samples (both stalk and tuber) were collected from each of the plots for chemical analysis of B.

The plant and tuber yield of potato in each of the experimental plots was recorded after the harvest of the crop. Besides, the per cent increase in both plant and tuber yield of all treatments over control was calculated.

Chemical analysis of soil and plant samples

The initial soil samples were analyzed for pH (soil:water, 1:2.5), organic C (Walkley and Black, 1934), clay, sand, and silt (International pipette method). Available B content (hot-$CaCl_2$ extractable; Parker and Gardner, 1981) was also analyzed for the initially collected soil sample. Both the stalk and tuber of the potato plants were ashed in a muffle furnace at 550°C for 1h and subsequently extracted with 0.36 N H_2SO_4 following the method of Gaines and Mitchell (1979). Then the B content of the extract obtained was spectrophotometrically (420 nm) analyzed with azomethine-H. Boron uptake by both plant and tuber was worked out using the following equation and expressed as g ha^{-1}. Besides, the per cent increase in uptake of B by both plant and tuber of potato of all the treatments over control was calculated.

$$\text{B uptake (g ha}^{-1}) = \frac{\text{B concentration (mg kg}^{-1}) \text{ x Dry matter production (kg ha}^{-1})}{1000}$$

Statistical analysis

Duncan's multiple range test was done for comparing the different treatment effects on the biomass (stalk and tubers) yield of potato using SPSS IBM version 20 (Anonymous, 2011).

RESULTS AND DISCUSSION

Soil characteristics

The initial experimental soil (*Typic Haplaquepts*) was clay loam in texture and its pH was 6.6, 6.7 and 6.7; organic C content was 4.65, 4.25 and 4.14 mg kg^{-1}, respectively, for surface (0-20 cm), mid-surface (20-40 cm) and sub-surface (40-60 cm) respectively. Soil boron content of surface (0-20 cm), mid-surface (20-40 cm) and sub-surface (40-60 cm) was 0.198, 0.132 and 0.010 mg kg^{-1}, respectively which were at the deficiency level (Table 1).

Biomass yield

Two years pooled data revealed that treatment T_4 (foliar application of 0.25 kg of B ha^{-1} in 2 equal splits during both tuber initiation and bulking stage i.e., 25 and 45 days after planting respectively) recorded highest plant yield (7.03 t ha^{-1}) and tuber yield (32.60 t ha^{-1}) and that of T_1 (control) treatment recorded their lowest values (5.50 and 24.10 t ha^{-1}) (Table 2). However, T_2 (foliar application of 0.25 kg of B ha^{-1} at tuber initiation stage i.e., 25 days after planting,) and T_3 (foliar application of 0.25 kg of B ha^{-1} at bulking stage i.e., 45 days after planting) treatments showed statistically at par values of plant yield and tuber yield with each other.

Foliar application of boron significantly (pd"0.05) increased the yields (tuber and stalk) of potato over the control (Table 2; Fig. 1). The magnitude of such increase in yield of potato plant or stalk was 19.1%, 15.5%, and 28.2% for T_2 (foliar application of 0.25 kg of B ha^{-1} at tuber initiation stage i.e., 25 days after planting,), T_3 (foliar application of 0.25 kg of B ha^{-1} at bulking stage i.e., 45 days after planting), and T_4 (foliar application of 0.25 kg of B ha^{-1} in 2 equal splits during both tuber initiation and bulking stage i.e., 25 and 45 days after planting respectively) respectively over T_1 (control), the average increase being 20.9% over control. However, in the case of the yield of potato tuber, the magnitude of such increase was 17.9%, 15.4%, and 35.0% for treatments T_2 (foliar application of 0.25 kg of B ha^{-1} at tuber initiation stage i.e., 25 days after planting,), T_3 (foliar application of 0.25 kg of B ha^{-1} at bulking stage i.e., 45 days after planting), and T_4 (foliar application of 0.25 kg of B ha^{-1} in 2 equal splits during both tuber initiation and bulking stage i.e., 25 and 45 days after planting respectively) respectively over control (T_1), the average increase being

22.7% over control (Table 2; Fig. 1). Dwivedi and Dwivedi (1992) studied the relative effectiveness of Fe, Mn, Cu, Zn and B through soil application, foliar application and seed soaking in an acid soil (Inceptisol) and reported that single or conjoint application of Fe, Mn, Cu, Zn and B significantly improved the tuber yield over control and among all the micronutrients, B showed highest tuber productivity. However, Sarkar *et al.* (2006) while studying the performance of boronated NPK (10:26:26:0.3 B) reported that its soil application increased the tuber yield of potato by 2.4-27.2% over only recommended dose of NPK alone where no B was applied in B deficient soil. Puzina (2004) showed that using boric acid @ 8 mM in potato fertilization caused an increase in tuber size and weight by increasing of cell diameter in the tuber perimedullary zone. Likewise, B treatment might boost total leaf area due to its supportive impact on cell division, which could explain the upward trend in total dry matter (Hatwar *et al.,* 2003). Sonawane *et al.* (2010) discovered that combining 20 kg Zn + 5 kg borax + RDF resulted in a 49.94% increase in groundnut pod production when compared to RDF alone. According to El-Sherpiny *et al.* (2022), foliar spraying of B at a dose of 80.0 mg l^{-1} stimulated the transportation of the majority of sugars and carbohydrates from the plant biomass to the tubers. The favourable effect of B on tuber production is attributed to low B availability and organic carbon content in the experimental soil before planting, as well as the significant roles of B in the plant like cell division, sugar transfer, production of amino acids and proteins (Malek *et al.,* 2021).

From the experimental results, it was further observed that application of B once as a foliar spray (@ 0.25 kg ha^{-1}) was more efficient in increasing tuber yields when applied at 25 days than at 45 days after planting. Again, the two equal splits foliar application of B (i.e., at the rate of 0.125 kg ha^{-1} in each split) at 25 and 45 days after planting resulted in an extra yield advantage over the single foliar application of B at the rate of 0.25 kg ha^{-1}.

Concentration and uptake of B

Two years pooled data revealed that treatment T_4 (foliar application of 0.25 kg of B ha^{-1} in 2 equal splits during both tuber initiation and bulking stage i.e., 25 and 45 days after planting respectively) recorded highest B concentration in plant parts (36.8 mg kg^{-1}) and in tuber (15.9 mg kg^{-1}), which were, however, statistically at par with treatment T_3 (foliar application of 0.25 kg of B ha^{-1} at bulking stage i.e., 45 days after planting) which showed B concentration of 35.3 and 14.9 mg kg^{-1} for plant and tuber respectively (Table 3). It was further notified that the foliar application of boron significantly (pd"0.05) increased B concentrations both in the plant parts and economic parts over that of the control treatment. The magnitude of such increases for plant parts were 62.1%, 78.3%, and 85.9% for treatments T_2 (foliar application of 0.25 kg of B ha^{-1} at tuber initiation stage i.e., 25 days after planting,), T_3 (foliar application of 0.25 kg of B ha^{-1} at bulking stage i.e., 45 days after planting), and T_4 (foliar application of 0.25 kg of B ha^{-1} in 2 equal splits during both tuber initiation and bulking stage i.e., 25 and 45 days after planting respectively) respectively over control (T_1). However, the magnitudes of such increases for potato tuber were 7.1%, 77.4%, and 89.3% for treatments T_2 (foliar application of 0.25 kg of B ha^{-1} at tuber initiation stage i.e., 25 days after planting,), T_3 (foliar application of 0.25 kg of B ha^{-1} at bulking stage i.e., 45 days after planting), and T_4 (foliar application of 0.25 kg of B ha^{-1} in 2 equal splits during both tuber initiation and bulking stage i.e., 25 and 45 days after planting respectively) respectively over control (T_1) (Table 3). From this, it is clear that the economic parts of potato were less responsive compared to whole potato plants.

It was further observed that foliar application of B increased the B uptake by both plant (stalk) and tuber of the potato. The highest and lowest B uptake by plant (stalk) and tuber was recorded in treatment T_4 (foliar application of 0.25 kg of B ha^{-1} in 2 equal splits during both tuber initiation and bulking stage i.e., 25 and 45 days after planting respectively) and treatment T_1 (control) respectively (Table 3). The magnitude of the increase of B uptake for plant parts ranged from 93.1 to 138.2% over control (T_1) treatment. Whereas, the magnitude of increased in B uptake by potato tuber was 25.4 to 156.1% over control. So, the magnitude of total B uptake by the T_4 treatment was highest which was149.8% more over the control (Table 3; Fig. 2).

It can be inferred that foliar application of 0.25 kg of boron ha^{-1} in 2 equal splits during both tuber initiation and bulking stage of potato i.e. 25 and 45 days after planting played a significant role in having extra yield advantage of potato over the single foliar application of boron and thus it may be recommended for sustainable potato production in the alluvial soil (*Inceptisols*) of West Bengal.

Table 1. Important initial physico-chemical properties of the experimental soil

Soil depth (cm)	pH (1:2.5)	Organic C ($mg\ kg^{-1}$)	Soil separates ($g\ kg^{-1}$)			Extractable B ($mg\ kg^{-1}$)
			Sand	Silt	Clay	
0-20	6.6	4.65	45.0	25.0	30.0	0.198
20-40	6.7	4.25	43.0	22.0	35.0	0.132
40-60	6.7	4.14	41.0	20.0	39.0	0.010

Table 2. Effect of foliar application of B on plant and tuber yields of potato ($t\ ha^{-1}$)

Treatment	Plant yield ($t\ ha^{-1}$)			Tuber yield ($t\ ha^{-1}$)		
	2018	2019	Pooled	2018	2019	Pooled
T_1	5.4^c	5.6^c	5.50^c	24.0^c	24.2^c	24.10^c
T_2	6.6^b	6.5^b	6.55^b	28.3^b	28.1^b	28.20^b
T_3	6.4^b	6.3^b	6.35^b	27.7^b	27.5^b	27.60^b
T_4	7.1^a	7.0^a	7.03^a	32.4^a	32.8^a	32.60^a

Means values within the same column followed by a different letter are significantly different at pd"0.05 by Duncan's Multiple Range Test (DMRT) (where T_1 = control i.e., no application of B); T_2 = foliar application of B @ 0.25 kgha^{-1}at 25 days after planting, DAP; T_3 = foliar application of B @ 0.25 kg ha^{-1} at 45 DAP; T_4 = foliar application of B @ 0.25 kg ha^{-1}in 2 equal splitsat 25 and 45 DAP).

Table 3. Effect of foliar application of B on the concentration and uptake of B in plant and tuber of potato (pooled data of 2 years)

Treatment	Boron concentration ($mg\ kg^{-1}$)		Boron uptake ($g\ ha^{-1}$)		
	Plant	Tuber	Plant	Tuber	Total
T_1	19.8^c	8.4^b	108.9^c	202.4^d	311.3^d
T_2	32.1^b	9.0^b	210.3^b	253.8^c	464.1^c
T_3	35.3^a	14.9^a	224.2^b	411.2^b	635.4^b
T_4	36.8^a	15.9^a	259.4^a	518.3^a	777.8^a

Means values within the same column followed by a different letter are significantly different at pd"0.05 by Duncan's multiple range test (where T_1 = control i.e., no application of B); T_2 = foliar application of B @ 0.25 kg ha^{-1} at 25 days after planting, DAP; T_3 = foliar application of B @ 0.25 kg ha^{-1} at 45 DAP; T_4 = foliar application of B @ 0.25 kg ha^{-1} in 2 equal splits at 25 and 45 DAP).

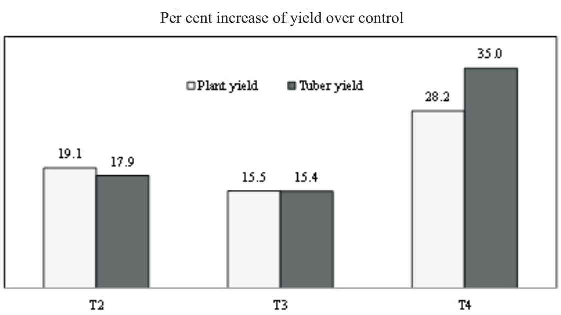

Figure 1.Per cent increase of biomass yield of potato over control treatment (pooled data of 2 years) (where T_2 = foliar application of B @ 0.25 kg ha^{-1} at 25 days after planting, DAP; T_3 = foliar application of B @ 0.25 kg ha^{-1} at 45 DAP; T_4 = foliar application of B @ 0.25 kg ha^{-1} in 2 equal splits at 25 and 45 DAP).

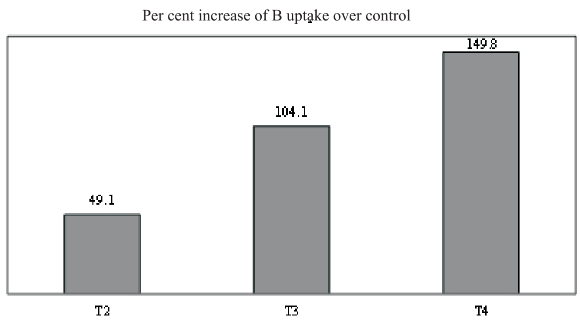

Figure 2.Per cent increase of total B uptake in different treatments over control (pooled data of 2 years) (where T_2 = foliar application of B @ 0.25 kg ha^{-1} at 25 days after planting, DAP; T_3 = foliar application of B @ 0.25 kg ha^{-1} at 45 DAP; T_4 = foliar application of B @ 0.25 kg ha^{-1} in 2 equal splits at 25 and 45 DAP).

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