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Original Research Article

Effect of B Application on Grain Yield Production and Its Movement in Soil at Different Growth Stages in Rice

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Rice, Boron, Foliar Application, Grain Yield and soil boron content

A B S T R A C T

To evaluate the effect of B application on grain yield production and its movement in soil at different growth stages in rice, the present experiment was conducted at Birsa Agricultural University, Ranchi during *kharif* seasons of 2012 and 2013. Treatments included four levels of B (T1: 0 kg ha^{-1}, T2: 1 kg ha^{-1} and T3: 1.5 kg ha^{-1} B added to the soil and T4: 1kg B ha^{-1} as soil alongwith two foliar sprays at tillaring and pre flowering) in a randomized block design. The results of this study showed that each incremental levels of B application contributed towards significantly higher yield. Soil and soil plus foliar application of B seem to have brought about almost similar impact on the grain yield. Boron application has been found to increase the B content of soil. The B application level @ 1.0 kg B ha^{-1} along with foliar application could not bring the soil B content well above the critical level.

Introduction

Boron (B) is an essential micronutrient required for normal growth and development of plants. It plays an important roles in plant growth development include sugar transport, cell wall synthesis, lignification, cell wall structure integrity, carbohydrate metabolism, ribose nucleic acid (RNA) metabolism, indole acetic acid (IAA) metabolism, phenol metabolism, and as part of the cell membranes.

Among the elements required by plants that are taken up from the soil, B is the only element that is taken up by plants not as an ion, but as an uncharged molecule (Marschner, 1995; Miwa and Fujiwara, 2010). Soils may contain of available B, but this represents only a small part of the total since only 0.5−2.5% of the total B in the soil is available to plants. There is also a very narrow range between B deficiency and toxicity as more than 5 mg kg^{-1} available B can be toxic to many agronomic crops (Kelling, 2010).

The factors affecting B concentration and its bioavailability in soils are parent material, texture, nature of clay minerals, pH, liming, organic matter content, sources of irrigation, interrelationship with other elements, and environmental conditions like moderate to heavy rainfall, dry weather and high light intensity (Havlin *et al.*, 2007). Under low rainfall conditions boron cannot be sufficiently leached and therefore may reach levels that become toxic to plant growth (Reid, 2007) whereas in heavy rainfall areas B may loss by leaching and runoff.

In Jharkhand, B deficiency is a nutritional disorder in many plants grown on coarse textured soil with heavy rain fall. Similarly, soil texture is an important factor that affects B availability in soil. Many investigators (Takkar *et al.*, 1989; Goldberg, 1997) have found that increasing coarse textured soil with heavy rainfall reduces B concentration in soil. Since B is significantly involved in reproduction process and their deficiency may occur simultaneously in soils of Jharkhand; this field experiment was carried out to investigate the effect of B application on grain yield production and its movement in soil at different growth stages.

Materials and Methods

A field experiment was conducted at Ranchi Experimental field of the Department of Soil Science and Agricultural Chemistry, Birsa Agriculture University, India on the rice (*Oryza sativa* L.), cultivar "Shahbhagi" during 2012 and 2013. The experimental site located on latitude 23°17′N and longitude 85° 19′E and an altitude of 625 meters above mean sea level.

Composite surface soil samples were collected from surface horizon (0− 15 cm) of the soil before the experiment was initiated, air-dried, passed through a 2- mm sieve and analyzed for the following properties. Selected soil chemical and physical characteristics for the soil are presented in Table 1.

This experiment consisted of four levels B (0, 1, and 1.5 kg ha^{-1} B added to the soil, and 1 kg B added to soil alongwith two foliar sprays at 0.2 percent of boron at tillaring and pre flowering stage). The design was completely randomized block design.

Nitrogen, P and K used at 80, 40 and 30 kg ha^{-1} according to the recommendation, from sources of urea DAP and MOP, were added to all treatments. Half of the N was used when planting and the remainder two times: At 25 days after transplanting and 50 days after transplanting. Potassium and P used before planting.

Soil samples were collected at tillering, before flowering, panicle initiation and post harvest stage at maturity period. Soil samples were collected randomly from four different places from each plot and then made a composite sample. Grain and straw yield of crop was observed at physiological maturity.

Results and Discussion

Boron content in soil at tillering stage

Boron content in soil was found significantly higher in all the treatment as compared to the control plot (T_0). Available B content of soil under different levels of B application, ranged from 0.388 to 0.512 mg kg^{-1} and from 0.401 to 0.534 mg kg^{-1} during 2012 and 2013 respectively at tillering stage. Pooled analysis revealed that soil B content increased with increasing levels of B application. At tillering stage compared to the B content of control plot (0.394 mg kg^{-1}), higher soil B contents were observed under its application levels T_1 (0.475 mg kg^{-1}), T_2 (0.516 mg kg^{-1}) and T_3 (0.520 mg kg^{-1}), all the 3 levels of B application were statistically at par with each other (Table 2 and Fig 1).

However, all the levels of B application were found significantly superior over the control. In spite of the added boron applications there was only marginal increase in available B content in the soil, till tillering stage remaining at and below the critical limit of 0.5 mg kg^{-1} as laid down by B. Kumar *et al.*, (1994). Considering 0.5 mg kg^{-1} as the critical limit of B in majority of soil samples of Jharkhand state were found low in available B. Kumar *et. al*., (1994) reported that hot water soluble B in soils of Chhotanagpur region varied from traces to 2.8 mg kg^{-1} with an average value of 0.7 mg kg^{-1}. Hence, under the present investigation it has been found that application of B increased the B built up of the soil. However, the marginal enhancement in the levels of B application within a narrow range of 1-1.5 kg B ha^{-1} (T_1 and T_2) or even the level T_3 (1.0 kg B ha^{-1} + 2 foliar application of 0.2% Borax) could bring only the marginal increase in available soil B content. As reported by Cooke (1982) the deficiency of soil Boron could be avoided only when the hot water soluble B in soil is maintained well above 0.5 mg kg^{-1}, preferably at around 1.0 mg kg^{-1} but not more than 3.0 mg kg^{-1} as it could cause B toxicity.

Boron content in soil at pre flowering stage

At pre flowering stage, the soil B content (Table 2) remained more or less same as the tillering stage. However, there was slight increase in soil B content under the B application level T_3. At this stage the soil B content ranged from 0.409 mg kg^{-1} (T_0) to 0.583 mg kg^{-1} (T_3) in 2012 whereas it ranged from 0.418 mg kg^{-1} (T_0) to 0.568 mg kg^{-1} (T_3) in 2013. The improvement in soil B content under T_3 was from 0.512 mg kg^{-1} to 0.614 mg kg^{-1} in 2012 and from 0.529 mg kg^{-1} to 0.618 mg kg^{-1} in 2013. The pooled data of 2012 and 2013 (Table 2 and Fig 1) revealed that the soil B content at pre-flowering stage was maintained in an order of $T_0 < T_1 < T_2 < T_3$ with the corresponding values of 0.415, 0.451, 0.520 and 0.578 mg kg^{-1}. As reported by Rerkasem *et. al.* (1997) the B requirement of plants is higher during reproductive stages than vegetative stages. Under the present investigation the lesser B requirement of crop plants during the active vegetative stage of crop (tillering-pre flowering) seems to have been fulfilled by the foliar sprays done at tillering as well as pre flowering stages. Hence, there was not much depletion in the soil B contents, particularly under the B application levels T_0 (Control), T_1 and T_2. However, the soil B content increased from 0.520 mg kg^{-1} (Tillering stage) to 0.578 mg kg^{-1} (Pre flowering stage) in T_3.

Boron content in soil at panicle initiation stage

At panicle initiation stage, the pooled data revealed that the B contents in soil showed little different trend (Table 2) as it improved under all the levels of B applications (including control). Compared to the previous stage of crop (pre flowering) the soil B content increased from 0.415 to 0.419 mg kg^{-1} (control T_0), 0.451 to 0.493 mg kg^{-1} (T_1), 0.520 to 0.539 mg kg^{-1} (T_2) and from 0.578 to 0.596 mg kg^{-1} under the B application level T_3. The level T_3 comprising of two components of B application viz., 1.0 kg ha^{-1} B application in soil + 2 foliar applications of 0.2% B at tillering and pre flowering stages could be considered here same as the level T_1 obviously due to the fact that the foliar application might have been utilized by the aerial part of the plant of which no portion would be expected to go into the soil. However, the foliar application might have enhanced the B utilization efficiency of plants. The higher soil B content under T_3 (compared to T_1 and other levels) may be attributed to the fact that the plants did not exhaust the soil B as it fulfilled its requirement from the foliar applications itself. Whereas under other levels of B application the plants might have extracted some amount of B from soil which was reflected into decreased soil B contents.

Boron content in soil at maturity

Soil B contents recorded under different levels of B application in 2013 was more or less similar to that recorded in 2012 (Table 2) In both the years all the levels of B application were found significantly superior over the control and this significance was also notice among the levels. Soil B content at maturity varied from 0.386 mg kg^{-1} (T_0) to a maximum of 0.614 mg kg^{-1} (T_3) in 2012 while it varied from 0.405 mg kg^{-1} (T_0) to 0.618 (T_3) in 2013. The pooled data also revealed the same pattern of increase in soil B build up with each incremental levels of B application. The level T_3 having 1.0 kg ha^{-1} soil B application (similar to T_1) along with two foliar application of 0.2% B at tillering and pre flowering stage prove to be significantly superior over the control as well as the rest level of B applications. This level of B application (T_3) maintained superiority at all the stages right from tillering to maturity. However, the highest soil B content under this treatment was recorded at maturity (0.616 mg kg^{-1}) followed by panicle initiation stage (0.596 mg kg^{-1}), pre flowering (0.578 mg kg^{-1}) and least was recorded at tillering stage (0.520 mg kg^{-1}). Asad and Rafique (2000) also reported increase in soil B concentration with enhanced levels of B application.

Table.1 Soil physical and chemical analysis

Property	Value
Physical properties	
Textural analysis	
Sand (%)	50.07
Silt (%)	32.49
Clay (%)	18.08
Textural class	Sandy loam
Chemical properties	
pH (1:2.5 soil water suspension)	4.68
Electrical conductivity (dSm^{-1})	0.395
Organic carbon (%)	0.41
Available nitrogen (kg N ha^{-1})	330
Available phosphorus (kg P ha^{-1})	30.63
Available potassium (kg K ha^{-1})	142.5
Available zinc (mg kg^{-1})	1.08
Available iron (mg kg^{-1})	15.27
Available manganese (mg kg^{-1})	6.91
Available copper (mg kg^{-1})	1.02
Available boron (mg kg^{-1})	0.31

Table.2 B content (mg kg^{-1}) in soil at different growth stages of rice

Level of B application	Tillering stage			Pre flowering stage			Panicle initiation stage			Maturity stage		
	2012	2013	pooled	2012	2013	Pooled	2012	2013	pooled	2012	2013	pooled
T_0	0.388	0.401	0.394	0.409	0.418	0.415	0.409	0.428	0.419	0.386	0.405	0.395
T_1	0.484	0.466	0.475	0.444	0.458	0.451	0.503	0.483	0.493	0.476	0.480	0.478
T_2	0.498	0.534	0.516	0.531	0.508	0.520	0.548	0.530	0.539	0.548	0.544	0.546
T_3	0.512	0.529	0.520	0.583	0.568	0.578	0.581	0.612	0.596	0.614	0.618	0.616
CD at 5 %	0.06	0.05	0.04	0.06	0.05	0.03	0.05	0.05	0.04	0.05	0.05	0.04
CV %	14.8	12.2	10.9	12.6	11.3	6.60	11.2	11.6	9.77	11.1	11.1	10.4

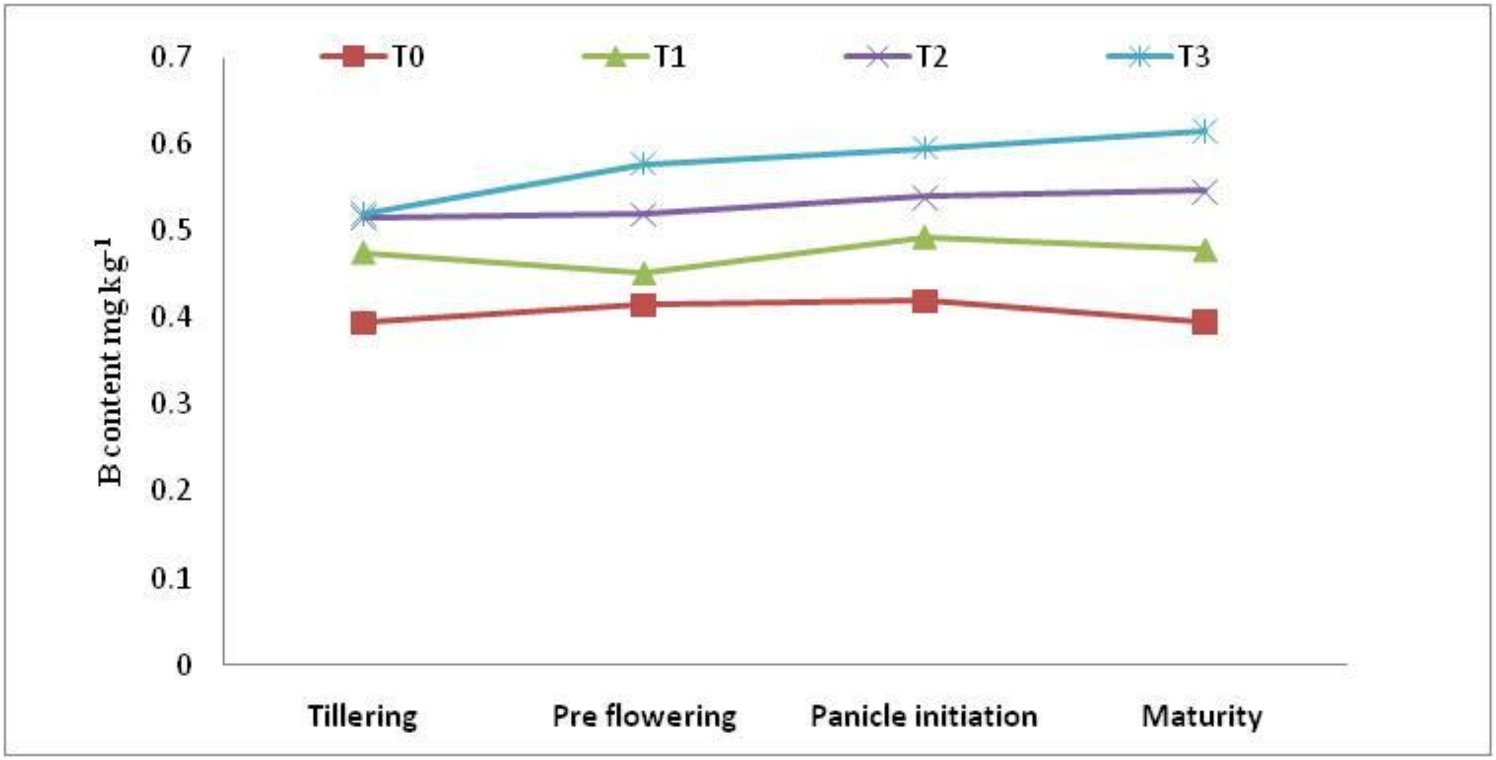
❖ T_0 - Control, T_1 - 1.0 kg B ha^{-1}, T_2 - 1.5 kg B ha^{-1}, T_3 – 1.0 kg B ha^{-1} with two foliar applications

Table.3 Crop response to different levels of B application on yield of rice

Level of B application	2012			2013			Pooled		
	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
T_0	3.78	8.75	30.1	3.54	8.58	29.3	3.66	8.66	2.96
T_1	4.33	9.12	32.1	4.06	8.91	31.2	4.18	9.00	3.17
T_2	4.63	9.80	32.4	4.37	9.47	31.7	4.50	9.63	3.21
T_3	4.66	10.27	31.4	4.43	10.11	30.6	4.55	10.2	3.11
CD at 5 %	4.12	5.97	NS	5.26	5.68	NS	3.39	7.44	NS
CV %	11.3	7.56	10.1	15.3	7.35	12.1	9.64	4.76	8.42

❖ T_0 - Control, T_1 - 1.0 kg B ha^{-1}, T_2 - 1.5 kg B ha^{-1}, T_3 – 1.0 kg B ha^{-1} with two foliar applications

Fig.1 Soil boron content (mg kg^{-1}) at differnet stages in rice



The soil B content during the crop growth period ranged from 0.394 to 0.419 mg kg^{-1} under control (T_0), from 0.451 to 0.493 mg kg^{-1} under T_1, from 0.516 to 0.546 mg kg^{-1} under T_2 and from 0.520 to 0.616 mg kg^{-1} under T_3. Hence, it can be inferred that increased application of B into the soil did improve soil B built up but could not improve to the extent of bringing the soil well above the critical limit of 0.5 mg kg^{-1} under the levels of T_1 and T_2. However, under the level T_3 the soil B content was improved considerably above the critical limit at pre flowering, panicle initiation and maturity stages. It is also realized that the levels of B application adopted under the present investigation seems to be insufficient, may be due to leaching of applied B under heavy rainfall conditions. This level T_3 might have been sufficient in low and less intense rainfall zones. Under the rainfall conditions of Jharkhand it would be advisable to go for even higher level of B application to maintain the soil B content well above the critical level. In neutral or slightly acid soils boron occurs mainly as undissociated form of boric acid, and readily absorbed by plant roots (Hu and Brown 1997; Power and Woods, 1997) which is mobile and easily lost by leaching under high rainfall conditions leading to boron deficiency in plants that grow there. On the contrary, under low rainfall conditions boron cannot be sufficiently leached and therefore may reach levels that become toxic to plant growth (Reid, 2007).

Grain and straw yield

Enhancement in the level B application significantly increased the Straw and grain yield of rice as compared to control. Enhancement in soil application of B from zero to 1.5 kg ha^{-1} and soil plus foliar B application as compared to control increased grain yield by 22.9 and 24.3% and straw yield by 11.2 and 17.8 % respectively (Table 3). However, harvest index were found non significant.

Here, with respect to the crop performance (in terms of grain yield), the level T_2 (1.5 kg ha^{-1} B application in soil) and level T_3 (1.0 kg ha^{-1} + two foliar application) seem to have brought about almost similar impact on the grain yield. To overcome micronutrient deficiency in soil, foliar spray of B has been reported to be equally or even more effective than soil application (Ali *et al.*, 2009) However, soil as well as foliar application of boron has been reported to the increase the yield (Dunn and Jones, 2001).

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