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Effect of soil and foliar application of boron on wheat productivity in north east alluvial plain of eastern India

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Abstract
On-farm trials were conducted during *rabi* season of 2013 in a randomized block design with six treatments on boron deficits soil at farmer's field by KVK Purnea (Bihar) to validate, refine and popularize the technology developed at Bihar Agricultural University Sabour, Bhagalpur (Bihar) for enhancing the productivity of wheat {*Triticum aestivum* (L.) emend. Fiori & Paol.}. Results revealed that all B application *i.e.* 1.0 & 2.0 Kg/ha B application as basal, 0.2% foliar application of B at 2-5% spike initiation, 1.0 & 2.0 Kg/ha B application as basal + 0.2% foliar application of B at 2-5% spike initiation were increased plant height, spikes/m^2, spike length, grains/spike and 1,000-grain weight, grain yield, straw yield and nutrient uptake over farmer's practice (No B). 2.0 Kg/ha B application as basal + 0.2% foliar application of B at 2-5% spike initiation produced 15.1% higher grain yield as compared to farmer's practice (No boron). 2.0 Kg/ha B application as basal + 0.2% foliar application of B at 2-5 spike initiation was most economical. This boron application on wheat crop recorded ₹23.51 ×10^3 /ha net returns along with 1.20% benefit: cost ratio.

Keywords: Boron, economics, nutrient uptake, wheat and yield

Introduction
Wheat is the second important food crop of India. It is grown in 29.31 m ha with the production of 85.76 million tonnes and productivity of 2.27 t/ha and contributes about 40% in the total food grain production in the country (MOF, 2011) [8]. It is also grown in 21.54 lakh ha with the production of 35.70 lakh tonnes and productivity16.57 q/ha in the Bihar, while 39.7 thousands ha wheat area covered by Purnea district with the productivity of only 6.03 q/ha during 2014-15 (*Directorate of Statistical and Evaluation, Bihar* 2014-15). Wheat is predominately grown in rice-wheat cropping system, and this system is considered backbone of food security in India (Yadav and Kumar, 2009) [10]. This system exhausts of the soil nutrients limiting crop production, especially for the high yielding varieties. Intensive cropping also renders deficiency of micro-nutrients in addition to major nutrients in the soil. The farmer's perception of nutrient management until now has mostly been the use of major nutrients like N, P and K. The imbalance use of inorganic fertilizer, in the absence of organic sources of nutrients, has lead to the micronutrient deficiency especially in rice and wheat restricting upward growth of productivity. Boron (B) deficiency has been realized as the second most important micronutrient constraints in crop productivity after that of zinc on global scale as well as in Indian agriculture. The deficiency symptom of B in wheat leads to thinner stems, shorter and fewer tillers, and failure to produce viable seeds. Boron has been found to play a key role in pollen germination and pollen tube growth, stimulate the plasma membrane, anther development, floret fertility and seed development. Boron deficient stems and leaves are brittle, whereas, B sufficient stems and leaves are flaccid. The soils of eastern states of India namely Assam, Bihar, Meghalaya, West Bengal, Jharkhand and Orissa are deficit in boron. In India, boron deficiency was initially reported 2% in the year 1980, which has now increased to 68% in red soils of Bihar, with mean of 52% for the whole country. Rice and wheat, the two most important crops in Purnea district of Bihar are sensitive to B deficiency, however, substantial yield reduction has been observed under B deficiency., Due to continuous growing of boron exhaustive crops, high pH and calcium compounds in soils, leaching and without B application to the crops and high humidity in atmosphere most of the soils are B deficient in that area. To cope with B deficiency, it can be delivered as soil and

foliar application. Foliar applied B plants retain significant phloem mobility to flowering parts from senescing leaves. Therefore, foliar sprays of B not only provide a means to apply B at a particular growth stage, but also remove B deficiency.

Keeping in view the importance of boron in increasing crop yield, the present study was conducted to investigate the effects of soil and foliar application of boron on wheat yield in north eastern plain zone of India.

Materials and Method

On-farm trial (OFT) was conducted during the *rabi* season of 2013 on boron deficits soil at two location of five farmer's field after participatory rural appraisal (PRA) and identified causes of low yield of wheat and high cost of production in late sown condition. It was found that boron deficiency in upland situation, which pose a serious constraint in Koshi region of Bihar. Purnea district lies in the Gangatic Alluvial plain with $25^0 13^I 80^{II}$ to $27^0 7^I 59^{II}$ N latitude, $86^0 59^I 6^{II}$ to $87^0 52^I 35^{II}$ E longitude and 52.3 m above mean sea level with annual rainfall 1412 mm. The cold season commences in November when both day and night temperature drop rapidly and lasts till February with humid climate. January is the coldest month, with mean daily minimum temperature in the range of 5-10^{0}C and mean daily maximum in the range of 20-25^{0}C. Humidity is generally above 70% except in the first half of the summer season.

Soil sample of all selected sites (at five farmer's field) were collected and analyzed. The soil of experiment sites were sandy loam to loamy having alluvial properties, with pH 6.2, organic carbon 0.39%, available N 246.7 kg/ha, P_2O_5 42.2 kg/ha, K_2O 180.3 kg/ha and available boron 7.0 ppm. The experiment comprised six treatments viz. T_1- Farmer's practice (No application of boron), T_2- 1.0 Kg/ha B application as basal, T_3- 2.0 Kg/ha B application as basal, T_4- 0.2% foliar application of B at 2-5% spike initiation, T_5- 1.0 Kg/ha B application as basal + 0.2% foliar application of B at 2-5% spike initiation and T_6- 2.0 Kg/ha B application as basal + 0.2% foliar application of B at 2-5% spike initiation. Treatments were arranged in randomized block design (RBD) with five replications in which one farmer was treated as one replication. The area of each experimental site was 0.40 ha. Wheat variety HI 1563 was sown after the harvesting of rice in the first week of December during at the spacing of 18 cm apart at the depth of 3-4 cm with the seed rate of 150 kg/ha. A uniform application of recommended dose of fertilizers 80:40:20 kg/ha N, P_2O_5 and K_2O were applied through urea, di-ammonium phosphate and muriate of potash. Half dose of nitrogen and full dose of phosphorus and potash were drilled as basally at the time of sowing; remaining dose of nitrogen was applied in two equal splits as top dressing at 25 and 50 days after sowing. Full dose of Boron those applying in soil as per treatments (*i.e.* 1.0 and 2.0 kg/ha) was applied at the time of first ploughing as broadcasting and 0.2% foliar application at 2-5% spike initiation stage through borax (11% B). Crop was manually harvested in the first fortnight of April. The grain yield data were recorded and adjusted to 13% of the moisture content. The harvest index (%) was calculated according to the following formula.

Harvest index (%) = Grain yield / Biological yield (grain yield + straw yield) ×100

Crop was raised using recommended cultural practices. After harvest, treatment wise grain and straw samples were collected for N, P and K nutrient analysis/nutrient uptake. Total nutrient uptake (grain + straw) in wheat was determined by multiplying the N, P and K concentration with corresponding grain and straw yields, respectively and expressed in kg/ha or g/ha. Economics was computed using prevailing costs of inputs and labour and returns were computed. B: C ratio was calculated net return to cost of cultivation. The statistical analysis of the data was carried out by using standard statistical methods of analysis of variance (Panse and Sukhatme, 1985).

Results and Discussion

Yield attributes

Yield-attributing characters viz. plant height, spikes/m^2, spike length, grains/spike and 1,000-grain weight were positively affected by boron (B) application as soil/foliar. Crop yield mainly depends upon many yield attributing characters. Among them number of fertile tillers (spikes/m^2) are very important because higher the number of fertile tillers/m^2 higher will be the final yield of the crop. Application of 2.0 Kg/ha B as basal followed by 0.2% foliar application of B at 2-5% spike initiation gave the highest values of yield attributes of wheat. Application of boron as soil/foliar or both have shown significant improvement in yield attributes as compared to farmer's practice (*i.e.* without boron application). Application of 1.0 Kg/ha B as basal followed by 0.2% foliar application of B at 2-5% spike initiation was statistically non significant with the application of 2.0 Kg/ha B as basal alone. Grain yield was positively and significantly correlated with growth and yield attributes, namely plant height ($R^2 = 0.800$), spikes/m^2 ($R^2 = 0.887$), spike length ($R^2 = 0.778$), grains/spike ($R^2 = 0.841$) and 1,000-grain weight ($R^2 = 0.872$). This may be due to the reason that boron plays a vital role in grain setting of wheat. So, the supply of Boron at this stage helps in grain filling and ultimately sterility is reduced and number of grains per spike increased. The similar results and observations were also reported by Mitra and Jana (1991) [7], Tahir *et al.* (2009) [9] and Debnath and Ghosh (2011) [2].

Grain and straw yield

Grain and straw yield of wheat was positively affected by boron application as soil or foliar or both methods. Grain yield production was significantly increased due to boron application. The maximum grain yield (3.58 t/ha) was observed in treatment where boron was applied 2.0 Kg/ha as basal followed by 0.2% foliar application at 2-5% spike initiation which was statistically at par with the treatment where boron was applied 2.0 Kg/ha as basal (T_3) and 1.0 Kg/ha as basal followed by 0.2% foliar application at 2-5% spike initiation (T_5). However, minimum grain yield (3.11 t/ha) was observed in farmer's practice *i.e.* without boron application which was statistically at par with 1.0 kg/ha boron application as basal (T_2) and 0.2% foliar application at 2-5% spike initiation alone. Grain yield of wheat crop is the result of combined effect of various yield-attributing characters. Grain yield increased significantly due to the application of boron by which enhanced pollen tube germination and grain setting. As the boron requirement of male reproductive organ, the anthers was also greater than carpel, since the boron requirement in the anthers for successful fertilization was met by of boron application as basal and foliar at spike initiation stage so the grain yield was higher than control. Mishra *et al.* (1989) [6], Tahir *et al.* (2009) [9], Ganie *et al.* (2014) [3] and Layek (2014) [5] also reported similar results.

The ability of wheat crop plant to convert the dry matter into grain yield of wheat is indicated harvest index. Higher the harvest index, greater will be the physiological potential for converting dry matter into grain. Harvest index (H.I.) was significantly affected by the application of Boron. The maximum H.I. (40.11%) was observed in case where Boron was applied at anthesis which is statistically at par with all other treatments where Boron was applied followed by control. These results are supported by the findings of Alam *et al*. (2000) [1].

Nutrient uptake

Total (Grain and straw) nutrient uptake by wheat crop plant at harvest stage was positively affected by boron application as soil or foliar or both methods. Nutrient uptake was significantly increased due to boron application. Maximum total nutrients uptake (total N, P and K) was analysed with the application of 2.0 Kg/ha B as basal followed by 0.2% foliar application of B at 2-5% spike initiation, which was statistically at par with application of 2.0 Kg/ha B as basal and 1.0 Kg/ha B as basal followed by 0.2% B foliar application at 2-5% spike initiation. However, minimum total nutrient uptake was observed in farmer's practice *i.e.* without boron application. Nutrient uptake is a product of its content in plant and dry matter accumulation, hence, it follows the same pattern as for growth particularly grain and straw yields. It might be attributed to the vigorous growth of plants due to better absorption of nutrients from the plots supplied with balanced nutrients. The results are in conformity with those of Kapoor *et al.* (2016) [4].

Economics

The variations in the cost of cultivation under different treatments were recorded due to variable doses of boron. The cost of cultivation was recorded to be highest (₹19.45 x10^3/ha) with the application of 2.0 Kg/ha B as basal followed by 0.2% foliar application of B at 2-5% spike initiation. Highest net return (₹23.51 x10^3/ha) and benefit cost ratio (1.20) were also calculated in 2.0 Kg/ha B as basal followed by 0.2% foliar application of B at 2-5% spike initiation. The minimum cost of cultivation, net return and benefit cost ratio was observed with farmers practice (Table 2). Application of 2.0 Kg/ha B as basal followed by 0.2% foliar application of B at 2-5% spike initiation gave ₹4.45 x10^3/ha higher net return over farmer's practice (without boron application). Tahir *et al.* (2009) [9] also reported similar results.

It may be concluded that application of 2.0 Kg/ha B as basal + 0.2% foliar B at 2-5% spike initiation in wheat was more productive and most profitability as compared to farmers practice (No boron).

Table 1: Effect of boron application on yield attributes, yield and economics of wheat

	Treatment	Plant height (cm)	Spikes/ m²	Spike length (cm)	Grains/ Spike	1000 grain weight (g)	Grain Yield (t/ha)	Straw yield (t/ha)	HI (%)	Cot of cultivation (₹×10³ /ha)	Gross Return (₹×10³ /ha)	Net Returns (₹×10³ /ha)	B:C Ratio
T_1	Farmer's practice (No B application)	93.6	256	9.4	31.7	33.6	3.11	4.28	42.1	18.26	37.32	19.06	1.04
T_2	1.0 Kg/ha B as basal	97.1	271	9.8	38.4	38.9	3.26 (4.8)	4.30	43.1	18.50	39.12	20.62	1.11
T_3	2.0 Kg/ha B as basal	99.0	292	10.4	42.0	41.5	3.55 (14.1)	4.39	44.7	18.73	40.20	21.47	1.15
T_4	0.2% foliar application of B at 2-5% spike initiation	96.8	253	10.2	38.2	38.0	3.20 (2.9)	4.24	43.0	18.30	38.40	20.10	1.09
T_5	1.0 Kg/ha B as basal + 0.2% foliar application of B at 2-5% spike initiation	97.3	276	10.4	41.1	40.7	3.47 (11.6)	4.41	43.2	19.10	41.64	22.54	1.18
T_6	2.0 Kg/ha B as basal + 0.2% foliar application of B at 2-5% spike initiation	99.8	300	10.8	43.2	42.6	3.58 (15.1)	4.52	44.2	19.45	42.96	23.51	1.20
	SEm±	0.66	7.1	0.22	0.80	0.74	0.093	0.119					
	CD (P=0.05)	1.9	16.4	0.62	2.31	2.15	0.28	0.33					

Note: Figures in parentheses are percent increase in grain yield relative to farmer's practice (without boron application)

Table 2: Nutrients uptake by grain, straw and total as influenced by different dose and application method of boron in wheat

Treatment	Nitrogen (kg/ha)			P (kg/ha)			K (kg/ha)		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
Farmer's practice (No B application)	53.18	20.80	73.98	10.92	3.06	13.98	10.23	53.86	64.09
1.0 Kg/ha B as basal	56.72	22.79	79.51	11.08	3.35	14.43	11.08	59.77	70.85
2.0 Kg/ha B as basal	62.13	26.34	88.47	14.56	3.93	18.49	13.14	67.54	80.68
0.2% foliar application of B at 2-5% spike initiation	54.72	22.89	77.61	10.88	3.39	14.27	10.88	57.66	68.54
1.0 Kg/ha B as basal + 0.2% foliar application of B at 2-5% spike initiation	60.38	24.79	85.17	13.53	3.76	17.29	12.15	64.26	76.41
2.0 Kg/ha B as basal + 0.2% foliar application of B at 2-5% spike initiation	63.37	27.01	90.38	15.04	4.08	19.12	13.60	71.20	84.8
SEm±	2.03	1.38	3.26	0.99	0.21	1.29	0.72	3.60	4.15
CD (P=0.05)	5.88	3.94	9.36	2.87	0.61	3.74	2.11	10.47	11.9

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