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Effect of boron on seed germination, seedling vigor and wheat yield

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Abstract

Wheat is an important cereal crop in Pakistan and poor germination is an important yield limiting factor. A study was conducted to evaluate the effect of boron application on seed germination, seedling vigor and yield of wheat. Five treatments viz. recommended dose (RD) of NPK (control), RD of NPK + 0.5 kg ha^{-1} B, RD of NPK + 1.0 kg ha^{-1} B, RD of NPK + 1.5 kg ha^{-1} B and RD of NPK + 2.0 kg ha^{-1} B were used. The data regarding plant height, number of tillers per square meter, grains per spike, 1000 grain weight, grain and straw yield was collected. After harvesting the grains were tested for germination and seedling vigor. Boron had no effect on yield components, except, grain per spike and 1000 grain weight which were improved significantly with its application. Wheat leaf B content increased with B application. Maximum grain and straw yield (4.85 and 9.16 Mg ha^{-1}, respectively) was recorded with 2.0 kg B ha^{-1} along with recommended dose of NPK. Boron had no effect on seed germination; however, seedling vigor i.e. shoot and root length improved with B application.

Keywords: *Wheat, boron, grain yield, straw yield, seed germination, seedling vigor*

Introduction

Food security is one of the main issues in the modern era throughout the world. It can only be achieved by increasing crop productivity. Wheat (*Triticum aestivum* L.) is an important cereal crop as a source of staple food and thus the most important crop in food security. It contributes 10.1 percent to the value added in agriculture, 2.2 percent to GDP and was cultivated on an area of 8.693 million hectares during 2012-13 (Anonymous, 2013). In Pakistan, wheat occupies a dominant position in forming agricultural policies and leads all crops in acreage and production. Besides its tremendous significance, average yield is far below that of developed countries, although the genetic potential of local varieties is not less than any country in the region. Low yield of wheat crop in our country is attributed to poor fertility status of the soil and improper crop management practices. The unavailability of crop nutrients at the time of application is another major crop productivity constraint in the third world (Hussain *et al.,* 2005).

The demand for wheat can be met either by increasing cultivated area or by increasing its yield per unit area. . Because of competing crops and restricted supply of irrigation water, it is not possible to increase its area under cultivation. So, under the present circumstances, the best alternative for uplifting wheat production in the country is to obtain higher yield per unit area. Macronutrients as well micronutrients have a prime significance in our agriculture system but their limited availability and ignorance of our farmers about the use of micronutrients causing the deficiency of micronutrients in our soil deficiency (Tahir *et al*., 2009). Boron is one of those micronutrients which are rapidly becoming deficient in soils (Tahir *et al*., 2009). It is essential for pollen tube germination along with its elongation, cell division, elongation in meristimatic tissues, floral organs, flower male fertility, and seed/fruit formation (Marschner, 1995). Boron deficiency in soils leads to abnormal seedlings and causes reduction in leaf photosynthetic rate (Rashid and Ryan, 2004). Boron deficiency also inhibits root elongation, cell division in the growing zone of root tips and leaf expansion and reduction in photosynthesis (Dell *et al*., 1997). Keeping this in view, a study was conducted to evaluate the effect of boron application on wheat yield and its effect on seed germination and seedling vigor.

Materials and Methods

A field study was conducted at the farm area of Soil Chemistry Section, Institute of Soil Chemistry and Environmental Sciences, Ayub Agricultural Research Institute, Faisalabad for three consecutive years. The experiment was laid out in randomized complete block design having plot size of 5.0 m × 7.5 m with three replications. Basal fertilizer application to wheat comprised of 120 kg N + 90 kg P_2O_5 + 60 kg K_2O ha^{-1}. Composite soil samples taken before sowing of wheat were analysed for physical and chemical characteristics (Table 1). Soil particle distribution was measured by hydrometer method (Blake and Hartge, 1986). pH and ECe of saturated paste and extract, respectively, were measured by method of Mclean (1982). Soil organic carbon (SOC) content was

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estimated following the method described by Ryan *et al*. (2001), available phosphorus was estimated by Olsen's method and available potassium by ammonium acetate (Rowell, 1994). Soil boron was estimated by hot water method (Bingham, 1982). Macronutrients concentration in plant samples were estimated by digesting with tri-acid mixture (HNO_3 + $HClO_4$ + H_2SO_4; 5: 2: 1). Total nitrogen was determined by Kjeldhal method (Jackson, 1962). Phosphorus in plant samples was determined by using yellow color method (Chapman and Pratt, 1961). Potassium was analyzed by flame photometer (Jenway PFP-7). Boron in plant samples was measured by dry ashing and subsequent measurement by colorimetry using Azomethine-H (Bingham, 1982).

(Lindsay, 1991; Rashid, 1996). Moreover, as the crop plants (grain as well as straw in case of cereals) are removed from the field, hardly any crop residue gets recycled back to the soil resulting in decreasing nutrient pool including B. Field research in Pakistan has demonstrated yield increases due to B application in several crops, including wheat, rice, maize, groundnuts, tobacco, and potato.

Effect of boron on agronomic parameters

Plant height is a genetic characteristic, balanced nutrition is needed to attain its potential. It affects photosynthesis and shows the growth behaviour of a crop. In determining light interception plant height plays an important role. It may become a primary determinant while assessing the individual plant's success in dense plant stands, resulting in higher yields (Weiner and Fishman, 1994). The data regarding boron effect on plant height is given in Figure 1.

Table 1: Physico-chemical properties of the field soil

Year	Soil depth (cm)	pH	ECe (d Sm^{-1})	O.M (%)	Olson P (mg kg^{-1})	Amm. Ext. K (mg kg^{-1})	B (mg kg^{-1})	$CaCO_3$ %	Texture
2009-10	0-15	8.13	2.13	0.63	9.2	190	0.46	1.20	Sandy clay loam
	15-30	8.03	1.84	0.59	7.6	170	0.42	1.40	
2010-11	0-15	8.43	2.01	0.72	11.3	210	0.53	0.87	
	15-30	8.40	1.93	0.69	10.7	190	0.49	0.74	
2011-12	0-15	8.32	1.97	0.87	12.5	220	0.50	1.20	
	15-30	8.14	1.82	0.77	11.9	200	0.48	1.30	

Wheat cultivar Faisalabad-2008 was sown using seed rate of 50 kg $acre^{-1}$ and row to row distance of 22.5 cm × 22.5 cm. Five treatments viz. recommended dose (RD) of NPK (control), RD of NPK + 0.5 kg ha^{-1} B, RD of NPK + 1.0 kg ha^{-1} B, RD of NPK + 1.5 kg ha^{-1} B and RD of NPK + 2.0 kg ha^{-1} B were used. Half N and full dose of P and K was applied at sowing and remaining half N was applied with first irrigation by broadcasting. Boron as boric acid was broadcast before sowing. Overall five irrigations were applied by flooding up to crop maturity. Weeds were controlled by spraying broad and narrow leaves weedicides. Wheat leaves were collected for determination of N, P, K and B concentration. At harvest, data regarding number of spikes per square meter, number of grains per spike, 1000-grain weight (g), plant height (cm), grain and straw yield (Mg ha^{-1}) were recorded. Area of nine meters square was harvested at maturity randomly from the centre of each plot. The harvest of each plot was collected, labeled, sun-dried and threshed individually. After harvesting, wheat grain germination and seedling vigor was tested in petri dishes. After germination, shoot and root length was noted for estimating the vigor of wheat seedling.

Results and Discussion

Boron is an essential micronutrient needed by plants in smaller amount for their proper growth and development. The crops grown in soil with low organic matter, higher free carbonates and high pH mostly faced boron deficiency

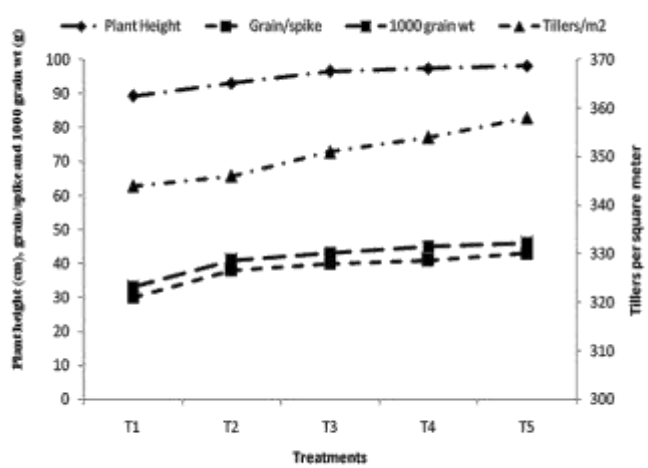

Figure 1: Effect of boron on plant height, grain/spike, 1000 grain weight (g) and tillers m^{-2}

T_1= Recommended Dose (RD) of NPK (control); T_2 =0.5 kg ha^{-1} B; T_3 = 1.0 kg ha^{-1} B; T_4 = 1.5 kg ha^{-1} B; T_5 = 2.0 kg ha^{-1} B

The maximum plant height (98 cm) was obtained in treatment where B at 2.0 kg ha^{-1} was applied while minimum plant height (89 cm) was in case of control where

Table 2: Effect of boron application on wheat grain yield (Mg ha^{-1})

Treatment B (kg ha^{-1})	2009-10	2010-11	2011-12	Pooled yield for 3 years
	Mg ha^{-1}			
0	3.92 b	4.29 b	4.87 b	4.36 c
0.5	3.97 b	4.30 b	4.99 ab	4.42 b
1.0	4.06 ab	4.70 a	5.06 ab	4.61 b
1.5	4.21 ab	4.53 ab	5.11 ab	4.62 b
2.0	4.42 a	4.83 a	5.28 a	4.85 a
LSD (p <0.05)	0.46	0.40	0.31	0.20

Table 3: Effect of boron application on wheat straw yield (Mg ha^{-1})

Treatment B (kg ha^{-1})	2009-10	2010-11	2011-12	Pooled yield for 3 years
	Mg ha^{-1}			
0	8.44 b	8.49 b	8.94 b	8.62 b
0.5	8.43 b	8.55 b	9.02 b	8.67 b
1.0	8.59 ab	8.62 b	9.22 ab	8.81 b
1.5	8.62 ab	8.85 ab	9.28 ab	8.91 ab
2.0	8.72 a	9.23 a	9.55 a	9.16 a
LSD (**p <0.05**)	0.22	0.40	0.36	0.33

boron was not applied. The results showed that plant height improved very little with B application. The results of our study are in accordance with Furlani *et al.* (2003) who found that plant height did not vary much with increasing B concentrations, but there were differences among cultivars for this trait, due to genetic variation. Tillers per square meter, is one of the most important contributor to yield of wheat. Number of tillers is controlled by environmental factors and genetic makeup of the plant. The maximum numbers of tillers per square meter (358) were counted in treatment which received 2 kg B ha^{-1} but it was statistically at par with other treatments. The minimum tillers (344) were obtained in control with no boron. Hussain *et al*. (2005) suggested that tillers per square meter, total tillers per plant and fertile tillers per plant varied non-significantly in response to boron fertilizer. They found significant improvement in number of grains per spike and 1000-grain weight when B was sprayed on wheat foliage at three growth stages i.e. at tillering, booting and milking. The number of grains per spike improved significantly by the application of boron. The highest number of grains per spike (45) were obtained in treatment where boron was applied at 2 kg ha^{-1} followed by treatment with boron at 1.5 kg ha^{-1}. Control without boron was found to have less number of grain per spike. 1000 grain weight has a direct effect on final grain yield of wheat crop. More the weight of grains, higher would be the grain yield. Boron application increased 1000 grain weight significantly. The maximum 1000 grain weight (46 g) was obtained in highest boron receiving treatment while minimum was in control. Gunnes *et al*., (2003) found that boron application at proper reproductive stage significantly increased 1000-grain weight because boron requirement is more at this stage than any other stage and ultimately the grain became healthy and gained more weight.

Effect of boron on wheat yield

Wheat grain yield is the result of combined effect of various yield contributing components. The data regarding grain and straw yield in three consecutive years is presented in Table 2 and 3. The maximum grain and straw yield (4.42 and 8.52 Mg ha^{-1}, respectively) in 2009-10 was obtained when B was applied at 2 kg ha^{-1} and it was statistically at par with treatments when B was applied at 1.5 and 1.0 kg ha^{-1}. Similar trend regarding wheat grain and straw yield was obtained in second and third year. Year wise sequence in grain and straw yield was year 1 < year 2 < year 3. The variations among years might be due to difference in fertility status of soil and environmental conditions. The maximum grain and straw yield in last year might be attributed to more organic matter, nitrogen, phosphorus and potash content in soil where crop was sown during that year. Grain yield improved significantly with boron application because pollen tube germination and grain setting at booting stage might be enhanced by boron. Rashid *et al.* (2007) reported increase of 14 to 23% in rice yield with B application in different areas of Punjab and Sindh. Similarly, Ghatak *et al.* (2006) found (7.7%) increase in wheat grain yield with B application.

Effect of boron on nutrient concentration

The data regarding nitrogen concentration (Figure 2) showed that maximum nitrogen was obtained during third

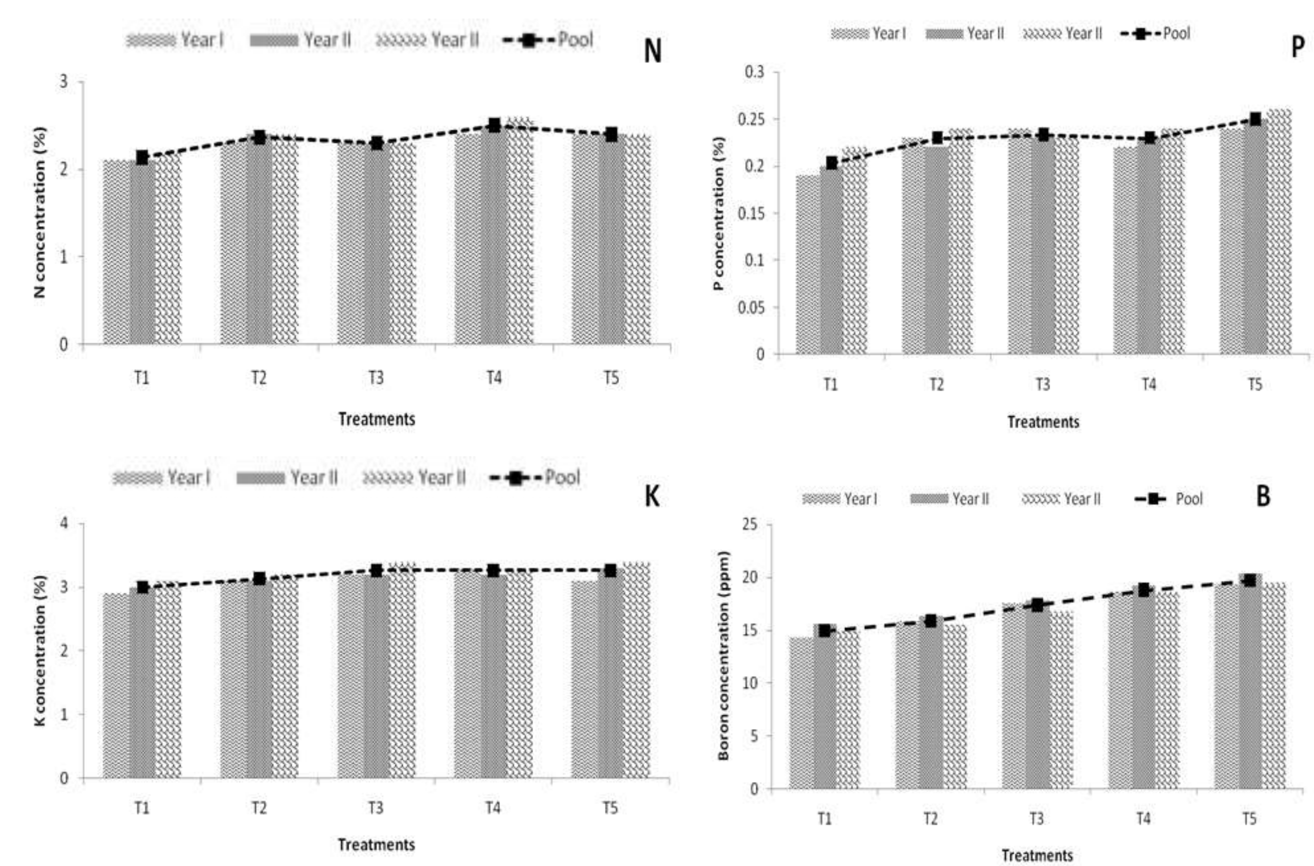

Figure 2: Effect of boron on N, P, K (%) and B (ppm) concentration in wheat leaf at booting stage
T_1= Recommended Dose (RD) of NPK (control), T_2 = 0.5 kg ha^{-1} B, T_3 = 1.0 kg ha^{-1} B, T_4 = 1.5 kg ha^{-1} B, T_5 = 2.0 kg ha^{-1} B

year in treatments with B at 0.5 and 2.0 kg ha^{-1}. It might be attributed to higher initial concentration of organic matter and total nitrogen in the soil. All treatments were statistically at par with each other regarding nitrogen concentration. However, the maximum nitrogen concentration in first year was in treatment with B at 2 kg ha^{-1} while in second and third year, nitrogen was maximum where B was applied at 1.5 kg ha^{-1}. Highest phosphorus concentration (0.26 %) was obtained in treatment where B was used at 2 kg ha^{-1} in third year followed by phosphorus concentration (0.25 %) in T_5 of second year. The phosphorus concentration varied non-significantly in all treatments. The concentration of potassium in wheat leaf remained at par in all treatments however the maximum potassium concentration (3.4 %) was recorded in T3 and T5 of last year. The ascending order of years regarding potassium concentration was year 3 > year 2 > year 1. The concentration of boron (Figure 2) improved significantly by application of boron. The maximum concentration of boron was observed where higher level of boron at 2 kg ha^{-1} was applied while the minimum concentration was in control where no boron was used. Similar trend regarding boron concentration in leaf was recorded in three years of study. Furlani *et al.* (2003) found that increasing external B concentration did not interfere with the uptake of other nutrients. They observed no interactions between B contents and other nutrients in plant dry matter of soybean cultivars grown under increasing B concentrations. However, they found that B concentrations in plant parts increased linearly with the B application. Similarly Johnson *et al.* (2005) observed that soil B fertilization increased B content of the grain of lentil (*Lens culinaris* L.) and chickpea (*Cicer arientum* L.).

Effect of boron on wheat grain germination and seedling vigor

After harvest of crop each year, grains were evaluated for effect of boron on germination and seedling vigour in the laboratory. The obtained results depicted that application of boron did not affect germination of wheat grain. After germination, shoot and root length was measured for three consecutive days in each year to assess

Table 4: Effects of boron on wheat shoot length (cm)

Treatment B (kg ha^{-1})	2009-10	2010-11	2011-12	Pooled for 3 years
			(cm)	
0 B	1.07 e	1.58 c	1.65 c	1.43 b
0.5 B	1.19 d	1.89 b	1.93 b	1.73 ab
1.0 B	1.28 c	1.94 b	2.04 b	1.75 ab
1.5 B	1.43 b	1.95 b	2.06 b	1.75 ab
2.0 B	1.62 a	2.40 a	2.45 a	2.16 a
LSD (***p***<**0.05**)	0.06	0.29	0.25	0.43

Table 5: Effect of boron on wheat root length (cm)

Treatment B (kg/ha)	2009-10	2010-11	2011-12	Pooled for 3 years
			(cm)	
0 B	1.36 e	1.97 d	1.97 c	1.76 b
0.5 B	1.62 d	2.29 c	2.31 b	2.10 b
1.0 B	1.80 c	2.45 b	2.40 b	2.25 b
1.5 B	1.96 b	2.51 b	2.50 b	2.25 b
2.0 B	2.36 a	2.93 a	2.84 a	2.71 a
LSD (***p*** **<0.05**)	0.11	0.16	0.24	0.33

the seedling vigor. The three year pool data regarding wheat seedling vigor (shoot and root length) is presented in the table 4 and 5, respectively. The results clearly indicated that boron significantly improved seedling vigor. The maximum shoot (1.62, 2.40 and 2.45 cm) and root length (2.36, 2.93, and 2.85 cm) in first, second and third year, respectively, were obtained in treatment receiving 2 kg B ha^{-1}. Iqbal *et al.* (2012) found that boron improved wheat seedling vigor by increasing shoot and root length. The increase in shoot and root length showed that boron may be involved in meristimatic growth of radicle and plumule primodia (Bohnsack and Albert, 1977).

Conclusion

Application of 2 kg B ha^{-1} along with recommended doses of chemical fertilizer gave 11% more grain yield than with the alone application of N, P and K fertilizers. However B application did not affect seed germination while seedling vigor was improved.

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