Research Article

Exogenous Supply of Boron at Various Growth Stages Improved Wheat Yield

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Abstract | Boron (B) affects plant growth and development by influencing vital processes like cell division, cell wall formation, water relations, meristematic tissue growth, carbohydrate metabolism, and pollen tube growth which suggests plausible effects on all these activities due to its deficiency. Therefore, a field trial was set up to assess the efficacy of different levels (control, 0.01 M and 0.05 M) of foliar applied B at booting, anthesis, and grain filling growth stages of wheat crop respectively. Results revealed that B application at the rate of 0.05 M solution substantially increased plant height, productive tillers, 1000 grain-weight and final grain yield. It was observed that 0.05 M B applications at delayed growth stages after booting is less effective in improvement of yield attributes of wheat crop as compared to booting stage. Economic analysis revealed that 0.05 M B application gave highest net income and benefit-cost ratio. Thus foliar application of 0.05 M B application (foliar) at booting stage can improve wheat productivity possibly by optimizing post-vegetative plant metabolic activities during grain filling, in contrast to late application rate.

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Introduction

Wheat (*Triticum aestivum* L.) is stable food grain of Pakistan as well as many other nations of the world. With tremendous rise in population, wheat demand has increased by many folds in Pakistan. But the average grain yield of Pakistan is far less than that of the developed countries (Khan et al., 2000). Several biotic and abiotic factors responsible for low grain yield in wheat including, various plant diseases drought stress, temperature extremes, salinity and insufficient nutrient availability. However, imbalanced crop nutrition is of more significance at scientist's end, which is controllable (Ali et al., 2008). Micronutrients deficiencies are prevalent worldwide, and are reported to exist on more than 50% of soils under cereals cultivation (Cakmak, 2006). A major chunk of Pakistani soil is deficient in micronutrients including boron (B) which is due to alkaline-calcareous nature of soil, reduced organic matter, intensive cropping pattern and poor nutrient management (Rashid, 2006; Shah et al., 2017). Boron plays several important functions in plants such as, sugar transport, carbohydrates metabolism, nitrogen metabolism, cell wall synthesis, ribose nucleic acid (RNA) metabolism, respiration, indole acetic acid (IAA) metabolism, phenol metabolism, pollen tube formation and membrane integrity (Nielsen, 2008; Ahmad et al., 2009; Tahir et al., 2009; Marschner, 2011; Rehman et al., 2012). Three methods are commonly employed for micronutrient application in crops, i.e. seed treatment, foliar spray and soil application and each method has its own importance (Johnson et al., 2005). Because B is immobile in plants, B deficiency in crops growing in soils with marginal B levels can occur during peak growing periods (vegetative, flowering, and seed development stages), so a steady supply of B throughout the growing season is essential for optimum growth and seed yield. Foliar fertilization appears to be an effective way to supply B to plants, especially when root activity is restricted during later growth stages of plants (Shah et al., 2016). Foliar application of B at reproductive stage is found more promising for healthy grains. Among various reproductive stages exogenous B supply at booting stage resulted in better wheat yield and quality (Tahir et al., 2009). Therefore, present study was aimed to identify appropriate wheat growth stage for B application for optimum yield, standardize dose of foliar applied B and to evaluate the impact of B application on yield attributes of wheat.

Materials and Methods

A field experiment was conducted at Agronomic Research Area, Department of Agronomy, University of Agriculture, Faisalabad Pakistan on November 25th, 2014. Wheat cultivar Galaxy-2013 was acquired from Punjab Seed Corporation, Faisalabad and sown at seed rate of 125 kg ha^{-1} in 22.5 cm spaced rows. The experimental soil was deficient in B. Detailed physic-chemical properties of soil are given in (Table 1). Meterological data collected during the crop growth period are presented (Table 2). Randomized complete block design, with factorial arrangement of treatment and four replications, was employed as an experimental design. Net plot size was maintained 1.80 m × 6.0 m. The treatments were factorial combinations of three B doses (control as no B application, 0.01 M and 0.05 M) and three growth stages of crop (booting, anthesis and grain filling stage). Boron was applied through foliar application method using borax salt (11.3% B). Soil physical and chemical properties were given in (Table 1). Fertilizers were applied at NPK 150-110-65 kg ha^{-1}. Whole of the P, K and one third of the N was applied as basal dose. Remaining N was applied with 1st and 2nd irrigation in equal splits. Four irrigations (3-acre inch each) were applied from sowing to harvesting. All the agronomic parameters were recorded as described by (Khan et al., 2010). Crop was harvested on 15th of April, 2015. Net benefits were calculated by subtracting the total variable cost from the total benefits of each treatment combination. Input and output cost for each treatment combination was converted into Rs. ha^{-1}. Statistical procedures were carried out with SAS version 8.0 for Windows. For each variable measured at the B level or growth stage, the data were analyzed by one-way analysis of variance (ANOVA) and treatment means were separated by Fisher's least significant differences (LSD) method at 5% probability level. Two-way ANOVA was used to determine statistical differences by B level and growth stages.

Table 1: *Physico-chemical analysis of experimental soil.*

Characteristics	Value
Texture	**Sandy loam**
pH	8.20
EC	0.33 dS m^{-1}
Exchangeable Na	0.20 mmolc100 g^{1}
Organic matter	0.92 %
Nitrogen	0.06 %
Phosphorus	5.00 ppm
Potassium	166.0 ppm
Zinc	0.80 ppm
Boron	0.56 ppm
Iron	6.75 ppm

Results and Discussion

Number of tillers (m^{-2})

Total number of tillers remained unchanged to B application at various developmental stages as shown in (Figure 1, Table 3). This might be due to no application of B at tillering stage. Same findings were obtained by (Khan et al., 2010) and Hussain et al. (2005).

Number of productive tillers (m^{-2})

The observations recorded showed significant results for number of productive tillers (m^{-2}) presented in (Figure 2, Table 3). Maximum number of productive tillers was recorded when 0.05 M solution of B was applied at booting stage followed by anthesis and grain filling, respectively. Boron application significantly in-

Table 2: *Weather data during crop growth period 2014-15.*

Months	Max Temp. (°C)	Min Temp. (°C)	Mean R.H. (%)	Total Rain Fall (mm)	Mean Sunshine (Hours)	Mean ET_o (mm)	Mean Wind Speed (km h^{-1})
Nov-14	26.3	11.5	61.7	10.0	07.6	01.5	03.1
Dec-14	18.5	5.9	75.0	0.0	04.7	01.3	02.0
Jan-15	16.6	6.9	75.3	12.2	05.0	00.7	03.6
Feb-15	21.4	9.3	66.0	20.5	05.6	01.8	05.3
Mar-15	24.5	13.6	64.0	67.9	04.9	02.8	05.6
Apr-15	33.2	20.7	43.9	32.8	09.1	03.7	06.2

Max: *maximum;* **Min:** *minimum;* **ET_o:** *Evapo-transpiration.*

Table 3: *F and P values derived from two ways ANOVA analysis of crop growth, biological, yield traits of maize crop.*

Parameters	Dose		Stage		Dose × Stage	
	F	P	F	P	F	P
Number of tillers	0.91	0.3051	0.67	0.40365	2.46	0.3504
Productive tillers	23.10**	0.0074	17.44**	0.0083	1.48	0.0720
Plant height	69.02**	0.0055	49.77**	0.0097	1.82	0.0666
Spike length	147**	0.0015	55.3**	0.0063	8.64	0.0804
1000 grain weight	176.5**	<0.0001	17.1**	0.0001	2.5	0.5304
Grain yield	195.43**	<0.0001	16.15**	0.0046	4.34**	0.0094
Biological yield	8.3**	0.0018	13.4**	0.0061	2.06	0.0852

creased number of productive tillers count over control and is might be due to involvement of B in flower fertilization, hormone production, photosynthesis, nitrogen and phosphorus metabolism (Ahmad and Irshad, 2011). Similarly, Arif et al. (2006) and Uddin et al. (2008) also stated that B addition positively influenced fertile tillers.

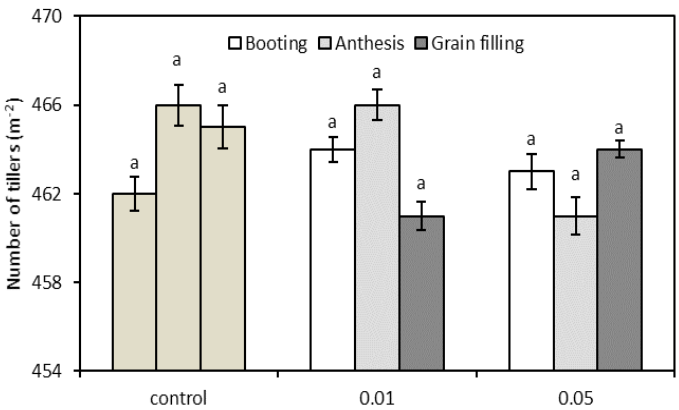

Figure 1: *Influence of boron (B) application at different growth stages on number of tillers (m^{-2}).*

Plant height (cm)

Results revealed that B application produced significant effects on plant height of wheat as shown in Figure 3, Table 3. Maximum plant height was observed when 0.05 M B was applied at booting stage followed by anthesis and grain filling stages, respectively. Whereas lowest plant height was recorded from control. Boron positively influences plant growth because it has imperative role in cell wall integration (Loomis and Durst, 1992), sugar transport (Miwa et al., 2008) and auxins metabolism (Shelp, 1993).

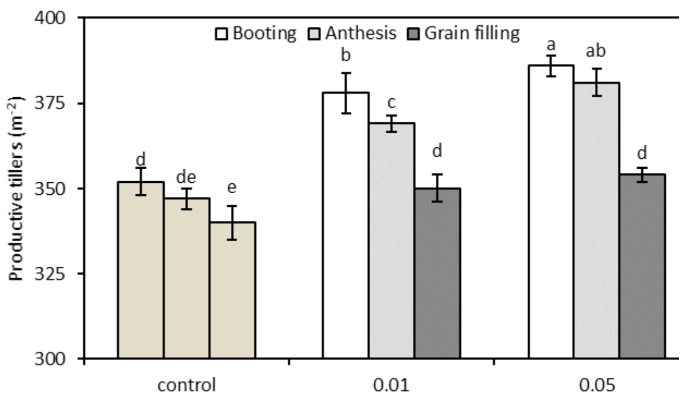

Figure 2: *Influence of boron (B) application at different growth stages on productive tillers (m^{-2}).*

Spike length (cm)

Perusal of data depicted that B application significantly influenced spike length (Figure 4, Table 3). Significantly higher spike length was obtained when 0.05 M B was applied at booting stage and minimum spike length was recorded when there was no application of B. Increased spike length due to B application might be due to fact that B is associated to various physiological process like enzyme activation and chlorophyll synthesis (Hussain et al., 2005). Similarly, Rehman et al. (2012) and Uddin et al. (2008) found B addition resulted in enhanced spike length over control.

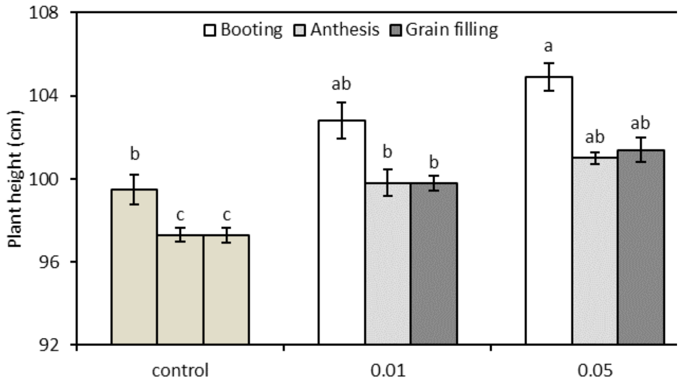

Figure 3: *Influence of boron (B) application at different growth stages on plant height (cm).*

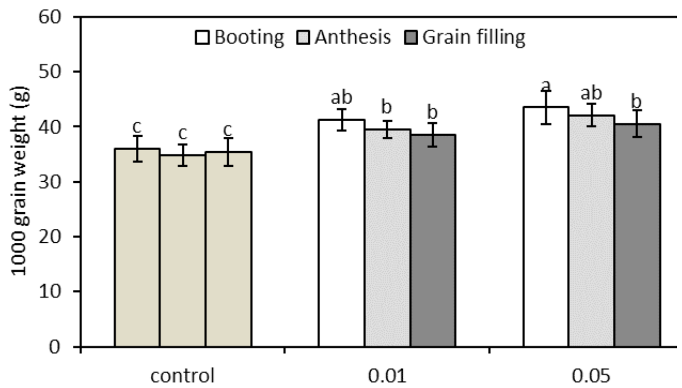

Figure 4: *Influence of boron (B) application at different growth stages on spike length (cm).*

1000-grain weight (g)

Results depicted that B application has significant effect on 1000-grain weight as shown in Figure 5, Table 3. Highest 1000-grain weight was achieved at booting stage followed by anthesis and grain filling under 0.05 M B application, while lowest 1000-grain weight was recorded from control plots. Higher grain weight due to 0.05 M B application at booting stage is attributed to association of B in pollen viability and pollen tube synthesis, resulting in better seed set (Jamjod and Rerkasem, 1999). Pronounced growth of reproductive parts indicates constructive job of B towards dry matter partitioning. (Hussain and Yasin, 2004). Dell and Huang (1997) concluded that deficiency of B during vegetative stages have less influence to grain yield but marked changes could be observed when B is deficient during reproductive stages.

Grain yield (t ha^{-1})

Data revealed that B application produced statistically significant effects on grain yield (Figure 6, Table 3). Maximum grain yield was recorded when 0.05 M B was foliar applied at booting followed by anthesis and grain filling, respectively. Control plots revealed lower grain yield. Boron is responsible for reducing the spikelet sterility, thereby improving the grain yield of wheat (Anantawiroon et al., 1997). Boron produced positive effects on grain yield of wheat crop which might be attributed to peculiar behavior of B in dry matter portioning (Hussain and Yasin, 2004). Insufficient B availability is responsible for grain sterility which has ultimately drastic effect on the grain yield (Subedi et al., 2000).

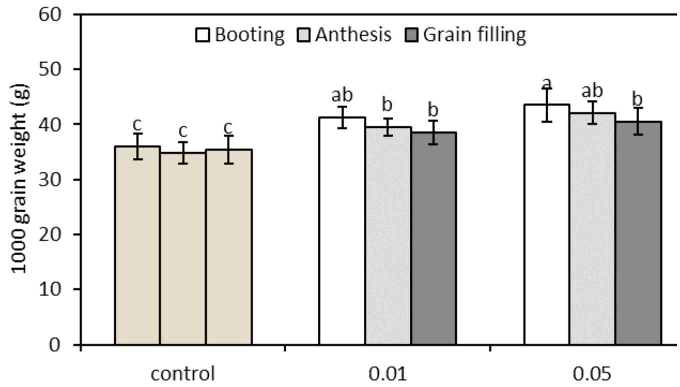

Figure 5: *Influence of boron (B) application at different growth stages on 1000 grain weight (g).*

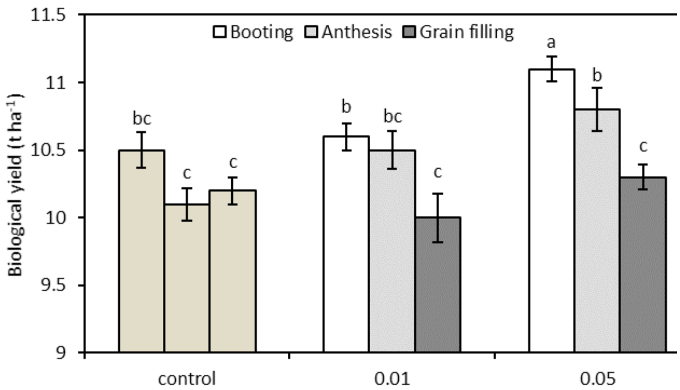

Figure 6: *Influence of boron (B) application at different growth stages on grain yield (t ha^{-1}).*

Biological yield (t ha^{-1})

Biological yield (above ground biomass) of wheat was significantly affected by B application (Figure 7, Table 3). Highest biological yield was recorded when 0.05 M B was applied at booting stage followed by anthesis and grain filling. Control had lowest biological yield. It was concluded that the biological yield increased significantly by B application and its deficiency has detrimental effect on biological yield of wheat crop. The positive contribution of B for biological yield might be due to fact that B is associated with various cell functioning like, cell division, meristematic tissues elongation, enzyme activation, leaf expansion, IAA and carbohydrates metabolism (Gupta and Solanki, 2013; Da Rocha Pinho et al., 2015).

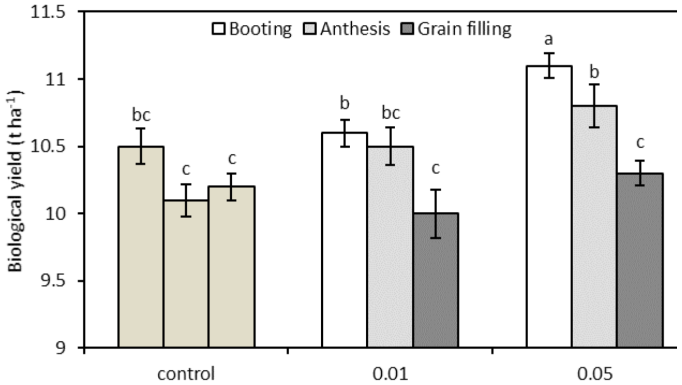

Figure 7: *Influence of boron (B) application at different growth stages on biological yield (t ha⁻¹).*

Table 4: *Economic analysis.*

Treatments	Total Cost (Rs. ha^{-1})	Gross Income (Rs.ha^{-1})	Net Income (Rs. ha^{-1})	Benefit Cost Ratio
Booting				
Control	70042	168182	98140	1.40
0.01 M	70292	176586	106229	1.51
0.05 M	71042	193573	122531	1.72
Anthesis				
Control	70042	164633	94591	1.35
0.01 M	70292	174856	104564	1.49
0.05 M	71042	183704	112662	1.59
Grain filling				
Control	70042	163131	93089	1.33
0.01 M	70292	168320	98028	1.39
0.05 M	71042	178059	107017	1.51

Economic analysis

The practical applicability and adoptability of some techniques involved in any production system is ultimately determined by its relative profitability and economic feasibility. It is evident from economic analysis that maximum gross income (Rs. 193573 ha^{-1}), net income (Rs. 122531 ha^{-1}), and benefit-cost ratio (1.72) were obtained when we applied 0.05 M solution of B at booting stage (Table 4). The minimum benefit cost ratio (1.33) and net income (Rs. 93089 ha^{-1}) were recorded in control treatment of grain filling stage. It means by applying B we can increase yield which also results in the increase net income. However, in modern days of economics, one is more interested in more net income and benefit cost ratio (BCR). It is apparent that growing of wheat with application of B with 0.05 M solution at booting will be helpful to improve wheat yield and to obtain maximum income.

Conclusions and Recommendations

From above results it can be concluded that 0.05 M B application at booting stage substantially improved number of productive tillers, plant height, spike length, 1000 grain weight, grain yield and biological yield. So 0.05 M B at booting stage is effective approach to increase wheat crop yield.

Author's Contribution

Shakeel Ahmad Anjum and Mohsin Raza: conceived the idea, Sami Ullah wrote result and discussion and technical input at every step, Muhammad Mohsin Raza: overall management of article, Mohsin Raza: did SAS analysis, Muhammad Abbas: wrote abstract, Ijaz Ahmad: data collection, Malik Muhammad Yousaf: Methodology, Muhammad Zeshan: Data entry in SAS, Adeel Abbas: wrote Introduction, Mehmood Ali Noor: Conclusion and Mohsin Nawaz: References.

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