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RESPONSE OF WHEAT (*TRITICUM AESTIVUM* L.) TO SOIL APPLIED BORON AND ZINC FERTILIZERS UNDER IRRIGATED CONDITIONS

M. A. Ali[1], N. H. Tariq, N. Ahmed, M. Abid and A. Rahim

[1]Department of Soil Science, Faculty of Agricultural Sciences and Technology, Bahauddin Zakariya University, Multan, Pakistan

ABSTRACT

A field study was conducted to evaluate the effect of boron (B) and zinc (Zn) fertilizer alone and in combination on yield, yield components and nutrient concentration in various plant parts. The treatments consisted of (a) untreated control (b) three levels of B (0, 1, 2 kg B ha^{-1}) and (c) three levels of Zn (0, 5, 10 kg Zn ha^{-1}). The basal dose of NPK at the rate of 150, 110, 60 kg ha^{-1}, respectively, was applied to all treatments except control. The treatments were arranged in randomized complete block design with four replications. Results showed that combined addition of 2.0 kg B and 5 kg Zn ha^{-1} produced significant impact on the grain yield and its components i.e., number of tillers m^{-2}, spike length, number of grains $spike^{-1}$and 1000-grain weight. The improvement in dry matter production and grain yield was 14.5% and 9.4%, over control, respectively, by the combined application of 2.0 kg B ha^{-1} and 5.0 kg Zn ha^{-1}. There was substantial increase in B concentration in grains i.e., 129.6% and 47.6% by individual addition of 2.0 kg B and 5.0 kg Zn ha^{-1} over control, respectively. The level of Zn content was raised from 15.2 to 37.4 mg kg^{-1} by application of 10.0 kg Zn ha^{-1}. Thus, substantial improvement in wheat productivity could be harvested with simultaneous increased concentration of Zn nutrient in grain for alleviation of syndrome caused due to Zn deficiency across rural and peri-urban communities.

Keywords: Boron, growth, *Triticum aestivum* L. Zinc.

INTRODUCTION

In Pakistan, wheat is grown on an area of 9.0 million hectares with annual production of over 24.0 million tons. The average yield is 2.9 and 1.3 tons ha^{-1} under irrigated and rainfed areas, respectively. The yield level is far below than other wheat growing countries. The productivity could be enhanced through integrated management. In consonance with increasing population, current per capita consumption of wheat is 126 kg per annum, which is highlighted in the

Corresponding author: arif1056@bzu.edu.pk

world. Despite, its high uptake, the prevalence of Zn malnutrition is 47.6 and 39.2% in women and children, respectively.

Fertilizers are mandatory for enhancing productivity in crops especially in wheat. Apart from macronutrients (N, P, K), micronutrients play a pivital role in balanced nutrients management for better yield and quality of crops. The responses of fertilizer to crops differ greatly due to soil and climatic conditions. The soils of Pakistan are generally light to medium texture, high in pH and calcareous in nature.

Deficiency of micronutrients in alkaline calcareous soils is wide spread (Rashid and Ahmad, 1994; Anonymous, 1998). Particularly, deficiencies of B and Zn are emerged because of intensive cropping, use of high analysis fertilizer and adoption of high yielding varieties (Rashid and Fox, 1992; Rafique *et al*., 2006). Boron is involved in many biochemical and physiochemical processes for optimal plant growth, its requirement vary markedly with crop plants (Gupta, 1993; Shelp, 1993). The gap between sufficiency and toxicity level is very narrow, especially in the arid and semi-arid regions (Sillanpaa, 1982). The productivity of crops is significantly influenced due to various rates of boron fertilizer. Mandal and Das (1988) reported protein response to number of grains, wheat grain yield and 1000-grain weight by addition of 2.0 kg B ha^{-1}. Rashid (1989) recorded 11% increase in wheat yield by the addition of 102 kg B ha^{-1} in a deficient soil combining 0.3 mg B ha^{-1}. A significant increase in grain yield of wheat is observed by the addition of 1.0 kg B ha^{-1} with concurrent increase in boron content (Asad and Rafique, 2000). There was significant improvement in number of tillers per unit, leaf area, spike length, number of grain per spike, 1000-grain weight and with simultaneous increase of boron concentration in flag leaves and grain. Halder *et al.* (2007) recorded 66% increase in wheat grain yield by the addition of 2.0 kg B ha^{-1} over control. The productivity was enhanced by greater assimilation of boron and resulting positive effects on components contributing to yield. Zinc is involved in several enzymatic and metabolic processes (Marschner, 1995). The deficiency of zinc is well documented in flooded rice soils (Yoshida and Tanaka, 1969). Various researches (Rashid *et al.,* 1979; Tahir, 1981; Rashid, 1993) recorded increase in yield of maize, rice, wheat, cotton, vegetable and fruit trees by the application of Zn fertilizer. The productivity of wheat crop was improved by 10 % by the addition of 2.5 kg Zn ha^{-1} over control. Makhdum et al. (1988) also found positive response of 10 kg Zn ha^{-1} on wheat grain yield. Yilmaz *et al*. (1997) reported 100 % increases in wheat grain yield by foliar spray of Zn fertilizer. The concentration of zinc was raised from 10 mg ha^{-1} to 18 mg^{-1} kg^{-1} in shoot and grain parts of the plant. Khan *et al.* (2007, 2009) also found an increase of 31.6% in wheat grain yield over control by the addition of 5 kg Zn ha^{-1}. Similarly, the yield parameters like number of spike per plant, spike length, plant height, biological yield and 1000-grain weight were increased over control. Alam *et al.* (2000) found an increase of 24% in wheat grain yield by combined application of B and Zn at the rate of 2.0 kg B and 10.0 kg Zn ha^{-1}. Ali *et al*. (2009) also recorded significant increase in wheat grain yield and its components by combined application of B and Zn fertilizers.

The integrated plant nutrient management requires exact quantity of boron and zinc fertilizers to avoid any negative effects on productivity of wheat and succeeding crops. Moreover, the increased concentration of Zn in grain results in reducing Zn deficiency syndrome among vulnerable communities. Therefore, a field study was undertaken to quantify the different response of B and Zn to wheat crop.

MATERIALS AND METHODS

Experiment was conducted at Research Experimental Farm, University College of Agriculture, Bahauddin Zakariya University, Multan. The farm is located in arid and semiarid climatic conditions. The treatments consisted of (a) control; (b) three levels of B (0.0, 1.0, 2.0 kg B $ha^{-1,}$ and (c) three levels of Zn (0.0, 5.0, 10.0 kg Zn ha^{-1}). The basal dose of N, P, K at the rate of 150, 110, 60 kg ha^{-1} in the form of urea, di-ammonium phosphate and potassium sulphate was applied to all treatments, expect control. The layout of the experiment was randomized complete block design with four replications. Wheat crop (Cv. Sehr) was used as test crop. The application of boron and zinc fertilizers was done three week after sowing as side-dressing in the form of borax and zinc sulphate, respectively and incorporated in the soil.

Soil samples were collected randomly from the experimental site before imposition of treatments. The samples were analyzed for their physical and chemical characteristics i.e., pH, organic matter content, calcium carbonates (Hussain and Jabbar,1985), electrical conductivity, hot water soluble boron (Page *et al*., 1982); DTPA- extractable Zn (Lindsay and Norvell, 1978); and mechanical analysis (Klute, 1986). The soil texture was silt loam with low soil fertility status. The contents of B and Zn were below the critical limits (Table 1).The plant samples collected at heading stage were analysed for zinc and boron concentration on dry weight basis according to methods of Ryan *et al,* (2001) and Gains and Mitchell (1979), respectively. Data for grain yield and its parameters were recorded at harvesting of crop. Data were statistically analysed to determine the significance among the treatments (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Growth and development

Plant height was significantly affected by the application of B and Zn fertilizers alone or in combination. Addition of 2.0 kg B ha^{-1} and 5.0 kg Zn ha^{-1} caused an increase in plant height 18.7% and 8.8% over control (Table 2). The combined effects of 2.0 kg B ha^{-1} and 5.0 kg Zn ha^{-1} enhanced the plant height by 30.6% over NPK alone. The increase in plant height resulted due to balanced micro and macro nutrients which improve photosynthetic and metabolic activity in the plant system. Shelp *et al.* (1993) reported enhanced translocation of photosynthates from leaves to other plant parts in presence to a sufficient quantity of boron nutrition. Khan *et al.* (2006) found 4.6 and 6.9% increase in wheat plant height by adding 1.0 and 2.0 kg B ha^{-1}, respectively. Various researchers (Ranjbar and

Bahamian, 2007; Khan *et al.,* 2009) reported 5.8% increase in plant height of wheat treated with 10.0 kg Zn ha^{-1} over an untreated control.

Data for total dry matter yield of wheat crop increased significantly, individually or in combination with the addition of different rates of boron and zinc fertilizers. The addition of 2.0 kg B ha^{-1} and 5.0 kg Zn ha^{-1} caused an increase in dry matter production by 8.6% and 10.0%, respectively, over NPK alone. The conjunctive addition of 2.0 kg B ha^{-1} and 5.0 kg Zn ha^{-1} resulted in an increase of 14.5% dry matter over untreated check. The increase in dry matter production occurred due to better growth and development of wheat crop with integrated nutrient management. The various researchers (Shelp, 1993; Ruiz *et al.,* 1998; Qiong *et al.,* 2002; Panhwar *et al.,* 2001) reported substantial increase in dry matter production of various crops with balanced nutrient management. Webb and Loneragan (1990) reported positive correlation between leaf zinc concentration and biomass production of wheat crop.

Grain yield and components

Data for number of tillers per unit area differ significantly due to addition of B and Zn fertilizer alone and in combination in the presence of NPK fertilizers. The application of 2.0 kg B ha^{-1} and 5.0 kg Zn ha^{-1} caused an increase in number of tillers up to 28.6% and 18.2% over NPK alone, respectively.

However, their combined effects resulted in an increase of 41.1% over control treatment. The addition of micro and macronutrients improved the fertility level, resulting high uptake of nutrients and photosynthetic activities in the plant system (Dewal and Pareek, 2004).The results of the study correlates with those of Rajindar and Rathore (2004) and Khan *et al.* (2006) who reported 5.4% increase in number of tillers per unit area by application of 2.0 kg B ha^{-1}.

Table 1. Physical and chemical characteristics of the experimental site.

Characteristics	Value
pH	8.3
Organic matter (%)	0.76
EC_e (dS m^{-1})	1.7
$CaCO_3$ (%)	5.4
NO_3-N (mg kg^{-1})	6.8
$NaHCO_3$-P (mg kg^{-1})	7.4
NH_4OAc-K (mg kg^{-1})	198
DTPA-Extractable Zn (mg kg^{-1})	0.45
Hot water Soluble-B (mg kg^{-1})	0.35
Texture Class	Silt loam (sand, 29%; silt, 53%; clay, 18%)

Table 2. Effect of B and Zn fertilizer application on growth and development of wheat crop.

Fertilizer treatments (kg ha^{-1})			Plant height (cm)	Total dry matter yield (gm^{-2})
NPK	B	Zn		
0	0	0	88.6g	641.8f
+	0	0	90.7fg	663.5e
+	0	5	98.7ef	692.6d
+	0	10	100.4cd	703.0cd
+	1	0	102.3de	706.0cd
+	1	5	109.7cde	722.0bc
+	1	10	113.3bed	728.7bc
+	2	0	107.7abc	720.3b
+	2	5	118.6ab	760.1a
+	2	10	121.1a	766.5a
LSD (p≤0.05)			9.51	21.51

+ = NPK 150, 110, 60 kg ha^{-1}

Table 3. Effect of B and Zn fertilizer application on grain yield and its components of wheat crop.

Fertilizer treatments (kg ha^{-1})			No of tillers (m^{-2})	Spike length (cm)	No of grains/ spike	1000-grain weight (g)	Grain yield (kg ha^{-1})
NPK	B	Zn					
0	0	0	252e	7.39cd	40.3c	32.1e	3581d
+	0	0	280e	7.65cd	42.0c	33.1de	3609cd
+	0	5	231c	8.72bc	45.0b	34.5cde	3790b
+	0	10	340c	8.95bc	45.0b	34.8cd	3725bcd
+	1	0	312d	9.30abc	46.5b	35.0bcd	3740bc
+	1	5	340b	10.05ab	47.3ab	35.8abc	3840ab
+	1	10	360c	10.30ab	47.5ab	36.0abc	3840ab
+	2	0	360b	9.90ab	46.5b	35.6abc	3840ab
+	2	5	395a	11.13a	49.5a	37.4ab	3850ab
+	2	10	400a	11.30a	49.5a	37.8a	3970a
LSD (p≤0.05)			17.24	2.02	2.93	2.44	152.2

+ = NPK 150, 110, 60 kg ha^{-1}

Data for spike length differed significantly due to either individual application of boron and zinc fertilizer or in combination. The addition of 2.0 kg B ha^{-1}and 5.0 kg Zn ha^{-1} caused an increase of 29.4% and 14.7% over control, respectively. Thereby, the combined application of these nutrients resulted to enhance 45.5% spike length over NPK alone. The increase in spike length may be associated with the balanced nutrients availability in the rhizosphere and their potential impact on better uptake and assimilation by the plant (Blevins and Lukaszewki, 1998). Various researchers (Abbas *et al*., 2009; Khan *et al.,* 2009) reported 11.8% increase in spike length by the addition of 10 kg Zn ha^{-1}.

Table 4. Effect of B and Zn fertilizer application on B concentration in flag leaf and grain of wheat crop.

Ferrilizer treatments (kg ha^{-1})			Boron concentration (mg kg^{-1})	
NPK	B	Zn	Flag leaf	Wheat grain
0	0	0	3.90i	1.10f
+	0	0	4.12i	1.18f
+	0	5	4.72h	1.30de
+	0	10	5.17g	1.38d
+	1	0	11.14f	2.11c
+	1	5	13.22d	2.79b
+	1	10	14.64c	2.81b
+	2	0	12.42e	2.71b
+	2	5	15.68b	3.11a
+	2	10	16.59a	3.15a
LSD ($p \leq 0.05$)			0.352	0.152

+ = NPK 150, 110, 60 kg ha^{-1}

Table 5. Effect of B and Zn fertilizer application on Zn concentration in flag leaf and grain of wheat crop.

Fertilizer treatments (kg ha^{-1})			Zinc concentration (mg kg^{-1})	
NPK	B	Zn	Flag leaf	Wheat grain
0	0	0	14.00j	15.25j
+	0	0	15.15i	16.55i
+	0	5	39.26f	31.44f
+	0	10	45.50e	37.44d
+	1	0	16.42h	17.42h
+	1	5	48.13g	34.69e
+	1	10	55.00d	40.42c
+	2	0	17.67c	19.65g
+	2	5	58.25b	46.38b
+	2	10	60.00a	47.25a
LSD ($p \leq 0.05$)			0.991	0.70

+ = NPK 150, 110, 60 kg ha^{-1}

Data for number of grains per spike were impacted significantly with alone and combined application of B and Zn fertilizers. The addition of 2.0 kg B ha^{-1} and 5.0 kg Zn ha^{-1} enhanced number of grains by 11.3% and 67.8% over control. Whereas, 17.9% increase in number of grains was recorded by combined application of 2.0 kg B ha^{-1} and 5.0 kg Zn ha^{-1} over control. The results agree with those of Bhatta *et al.* (2005) that number of grains per spike increase significantly due addition of B fertilizer.

Data for 1000 grains weight differed significantly due to single or combined application of boron and zinc fertilizers. The addition of 2.0 kg B ha^{-1} and 5.0 kg Zn ha^{-1} caused an increase of 7.49% and 7.6% over untreated check. While combined effect of both nutrients witnessed an increase of 16.5% over NPK alone treatment. The similar results have been reported by (Butt *et al.,* 1995; Mete *et al.,* 2005; Khan *et al*., 2009) that substantial increase in 1000-grain weight by addition of B and Zn fertilizers was recorded.

Data for grain yield reported significantly different due to addition of B and Zn fertilizers alone or in combination. The application of 2.0 kg B ha^{-1} and 5.0 kg Zn ha^{-1} resulted in an increase in grain yield by 7.2% and 5.8% over untreated check. The improvement in grain yield by 7.52% over control was obtained by combined application of 2.0 kg B $ha^{-1}$and 5.0 kg Zn ha^{-1}. The boron nutrient is essential element for better utilization of macro-nutrients by plants and thereby greater translocation of photo-assimilates from source to sink during growth period. Similar results have been reported by Soylu *et al*. (2004) and Jana *et al.* (2005) who recorded substantial improvement in wheat grain yield. The increase in yield was combined effects of greater number of tillers per unit area, and number of grains per spike, 1000-grains weight and enhanced growth and development of crop. Rafique *et al.* (2006) reported 12% increase over control by the application of 4.0 kg Zn ha^{-1} under an arid environment. Similarly, Kalayci *et al.* (1999) observed 30% increase in grain yield of wheat crop grown in Zn deficit calcareous soils. Butt *et al.* (1995) observed significant increase in wheat grain yields by combined application of B and Zn fertilizers.

Boron concentration

Boron concentration in flag leaves differed significantly due to addition of B and Zn fertilizers. The B concentration in diagnostic tissue increased from 3.9 mg kg^{-1} to 12.4 mg kg^{-1} by the addition of 2 kg B ha^{-1}. But by the addition of 5.0 kg Zn ha^{-1}, the increase in B concentration was 3.9 to 4.72 mg kg^{-1}. Different researchers (Subedi *et al*., 1999; Asad and Rafique 2002; Furlani *et al.,* 2003) reported substantial improvement of B-concentration in flag leaf of wheat crop by addition of B fertilizer. The results of the study agreed with that of Takker *et al.* (1975); Kauser *et al.* (1988); Khan *et al.* (2009) that boron concentration increased in flag leaf with Zn fertilization on calcareous soils.

Data for B concentration in grain was significantly influenced by the application of B and Zn fertilizer alone or in combination. The addition of 2 kg B ha^{-1} and 5 kg Zn ha^{-1} resulted in an increase of 129.6 % and 10.16% in B concentration in wheat grains. Moreover, the combined effect of 2.0 kg B ha^{-1} and 5.0 kg Zn ha^{-1} caused an increase of 166.9% over control. The threshold level of B concentration in the ear and flag leaf is 2.0-4.0 and 3.0-7.0 mg B kg^{-1} DW (Cakmak *et al.,* 1989). Butt *et al.* (1995) reported combined application of B and Zn enhanced B concentration in wheat plants.

Zinc concentration

Concentration of Zn in flag leaf was significantly affected due to sole or combined application of B and Zn fertilizers. Addition of 2.0 kg B ha^{-1} and 5.0 kg Zn ha^{-1}caused an increase in Zn concentration in diagnostic tissues was 17.6 mg kg^{-1} and 39.2 mg kg^{-1}over untreated check (14.0 mg kg^{-1}), respectively. Zinc concentration in wheat leaves was significantly increased by Zn application in rainfed conditions (Butt *et al*., 1995). Various researchers (Rafique *et al.,* 2006; Khan *et al*., 2009) also reported that addition of 5.0 kg Zn ha^{-1} caused an increase up to 34.0 mg kg^{-1} in wheat flag leaf.

Zinc concentration in wheat grain was also significantly affected by various levels of zinc fertilizer. The addition of 2.0 kg B ha^{-1} and 5.0 kg Zn ha^{-1} resulted in increase of 18.6 % and 47.6% over untreated check, respectively. The combined application of B and Zn fertilizer (2.0 kg B and 10.0 kg Zn ha^{-1}) caused an increase in Zn concentration i.e., 47.25 mg kg^{-1} in grain over control (15.2 mg kg^{-1}). Butt *et al.* (1995) and Ali *et al.* (1983) reported that zinc concentration was significantly increased by the application of zinc fertilizer. The zinc concentration in wheat grain ranges from 20.4 to 36.4 mg kg^{-1}, and this level could be improved substantially by addition of 10.0 kg Zn ha^{-1} fertilizer. These results agree with those of Rashid and Fox (1992).

CONCLUSION

It can be concluded from this study that the substantial improvement in wheat productivity could be harvested with simultaneous increased concentration of Zn nutrient in grain for alleviation of syndrome caused due to Zn deficiency across rural and peri-urban communities.

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