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Effect of Boron Supplement on Yield of Wheat Grown in Calcareous Soils of Different Textural Classes under Arid Conditions

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Abstract

Boron sufficiency supply to plant in calcareous soils of arid regions is severely reduced under arid climatic conditions. Therefore, this study was conducted to determine the effect of Boron (B) fertilization on yield of Wheat grown in calcareous soils of arid regions. Boron was added at two rates namely 0 and 0.5 mg B kg^{-1} soil to three most common textured class's soils. Straw and grain yield was determined on oven dried basis. B content of plants was determined as well. Straw and grain yield of wheat was significantly increased by (67.0 and 87.1%), (24.5 and 82%) and (64.5 and 48%) under the addition of 0.5 mg B Kg^{-1} soil over that of no B addition to clay, loam and sandy loam soil, respectively. Results also showed that wheat grown on the coarse-textured soil had the least B uptake per pot compared to loam and clay textured soils. B content in straw and grain was increased by (77.4 and 121%), (81.2 and 157%) and (184 and 96.9%) under B addition compared to those of zero B addition to clay soil, loam soil and sandy loamy soil, respectively. Response to B addition, significantly, increased in all soils due to increase of available B content in soils which may suggest the importance of adding adequate rate of B application under cropping system of arid regions.

Keywords: Boron uptake, dry mater, nutrients, response to boron

1. Introduction

Boron (B) is a necessary element for plants growth and development (Muntean, 2009). Its deficiency has been realized as the second most important micronutrient constraint in crops after that of zinc (Zn) on global scale (Ahmed et al., 2009). It is required by plants in many metabolic processes, including plasma membrane stability, cell wall strength, nucleic acid metabolism, cell division, plant hormone synthesis, fruit and seed development, sugar synthesis, and transport (Brown et al., 2002; Bassil & Brown, 2004; De Oliveira et al., 2006).

The factors affecting B uptake include soil texture, pH, lime content, soil moisture content (Gupta & Hitesh, 2013). Boron deficiency and toxicity symptoms in plants is in the range of 0.028 to 0.093 mmol/L for sensitive crops and 0.37 to 1.39 mmol/L for tolerant crops (Goldberg, 1997).

Boron is relatively immobile in plant, and thus its availability is essential at all stages of growth, especially during maturity development. The deficiency of B has been reported to result in considerable yield reduction in various crops, like cereals (rice, corn, wheat), legume, oilseed and fruit trees (Sinha et al., 1991; Borkakati & Takkar, 2000; Niaz et al., 2007; Rashid et al., 2005; Johnson et al., 2005; Zia et al., 2006). Rashid 2006, on the other hand, found that B fertilizer increased the yield of B-deficient crops.

Boron bioavailability decreases under drought condition because of reduced mobility of B from soil by mass flow to roots (Diana, 2006; Chang, 1993; Barber, 1995). Boron can move relatively long distances by mass flow and diffusion to roots. Soil drying reduces B diffusion by reducing the mobility of soil solution and increasing the diffusion path length (Hajiboland & Farhanghi, 2011).

Raza et al. (2002) and Malhi et al. (2003) reported that coarse-textured soils contain less available B than fine-textured soils. Furthermore, surface area of soil clay minerals, calcium carbonate, aluminum and iron oxides and organic matter, are the primary B adsorbing surfaces in soils (Goldberg, 1997). The level of native B is also closely related to the clay content of the soil (Elrashidi & O'Connor, 1982; Raza et al., 2002).

The level of B adsorbed by the soil thus largely depends on soil texture in addition to pH of soil solution. It increases with an increase in clay content (Elrashidi & O'Connor, 1982).

Shortages of B in wheat cultivated soils have been observed in various arid and semi-arid regions. Therefore, this study was conducted to assess Wheat response to B fertilization in calcareous soils of arid region in Iraq.

2. Materials and Methods

Three alluvial soils (Typic Torrifluvents) (Soil Taxonomy, 1975) of Caly, Loam and Sandy loam textured were selected for this study. Soil samples were obtained from Ap surface horizon at 0-30 cm depth. Samples were air dried and grounded to pass 2.0 mm sieve. Physical and chemical properties of the soil were determined (Table 1).

Table 1. Characteristics of soils used

Character	soils		
	Clay	Loam	Sandy loam
Sand (gm kg^{-1})	162.63	428.7	755.53
Silt (gm kg^{-1})	378.03	368.7	80.16
Clay (gm kg^{-1})	459.33	202.6	164.33
Texture	Clay	Loam	Sandy loam
EC 1:1 (dSm^{-1})	0.72	0. 74	0.16
pH 1:1	7.50	6.82	7.69
Calcium carbonite (g kg^{-1} soil)	238.3	250.0	256.0
Organic mater (g kg^{-1} soil)	20.0	19.8	10.0
NH4- N (mg N Kg^{-1} soil)	40.88	30.92	12.32
NO3- N (mg N Kg^{-1} soil)	14.7	10.42	7.7
Available-P (mg Kg^{-1} soil)	18.21	23.51	13.29
Available-Ca (C mole +kg^{-1} soil)	74.49	81.425	46.52
Available-Mg (C mole +kg^{-1} soil)	5.48	5.95	2.80
Available-K (C mole +kg^{-1} soil)	7.58	9.83	2.16
Available-Na (C mole +kg^{-1} soil)	867.78	863.98	71.65
Boron (H.W) mg Kg^{-1} soil	3.050	1.268	0.147

Pot experiment was conducted as Randomized Complete Block Design in a three replicates. Boron was added in two rate of application namely, 0.0 mg B Kg^{-1} soil and 0.5 mg B Kg^{-1} soil. Therefore, the experiment includes total of six treatments. The treatments were arranged in three replicates. In order to achieve the objective. Plastic pots of 7000 gm were used for growing wheat under greenhouse conditions. Three hundred gram of washed fine gravel were placed at the bottom of each pot and covered with 200 g of pure sand washed previously with 0.01M hydrochloric acid and distilled water. Weights of 5000 g of each soil were transferred to the pots. Boron fertilizer was added in a Liquid form at a layer of 2 cm depth of the soil. Pots were then seeded to 12 seeds of wheat. The seedlings were then thinned to 7 seedlings per pot after 3 days of emergency. Soil moisture in all pots was maintained at 75% of field capacity. Macro nutrients of N, P and K were added to pots at a level of 100, 50 and 63 mg kg^{-1}, respectively.

At maturity (after 150 days of planting) plants were harvested. Grain and straw yield of wheat of each pot was dried at 65 °C in an oven until weight is stable. Grain and straw was determined as well as the weight of 100 seed. The dried grains were grilled and ash drying digested according to Page et al. (1982). B was measured with ICP (Inductivity Couple Plasma Atomic Emission Spectrometer model ICPE-9000 SHIMADZU).

3. Results and Discussion

3.1 Dry Mater Yield

3.1.1 Straw Yield

Results (Table 2) showed that straw yield of wheat, upon addition of B at a level of 0.5 mg per Kg soil, increased by 67.0%, 24.5% and 64.5% over that of no Boron addition to clay, loam and sandy loam soil, respectively (Huang et al., 2000). High response to B addition in clay textured soil may be attributed to adequate levels of plant essential nutrients (Table 1) in this soil and the possibility that B is the main constrain for plant growth in heavy textured soil, which is in agreement with the report of (Shorrocks, 1997). Weight of yield of straw per pot with and without B addition was significantly the highest under the clay textured soil and was the significantly least under the sandy loam textured soil which is in agreement with plant essential nutrient of the two soils. This may clearly indicate that other plant growth limiting factor other than B is prevailing in such soils (Niaz et al., 2002; Niaz et al., 2007).

Table 2. Effect of B application on straw yield

Application level	Clay soil	Loam soil	Sandy loamy soil	Mean (X¯)
	Straw yield gm pots^{-1}			
0.0	21.03	19.33	14.03	18.13
0.5	35.13	24.07	23.13	27.44
Mean (X¯)	28.08	21.7	18.58	22.787

Variable	Least Significant Difference LSD
	Straw yield gm pot^{-1}
Application level	1.498
Soil	1.834
Interaction	2.594

3.1.2 Grain Yield and Weight of 100 Grain

Results (Table 3) showed that grain yield of wheat, upon addition of B at a level of 0.5 mg per Kg soil, increased by 87.1%, 82% and 48% over that of no Boron addition to clay, loam and sandy loam soil, respectively. High response to B addition in clay textured soil may be attributed to adequate levels of plant essential nutrients (Table 1) and the possibility that B is the main constrain for plant growth in such soil, which is in agreement with the report of (Shorrocks, 1997). Least response in grain yield was observed in sandy loam soil which may be explained on the basis that this soil is of low level of plant essential nutrients (Table 1). This may be coincided with previous reports that low level of other essential nutrients are main constrain for plant growth in light textured soils (Niaz et al., 2007; Rashid et al., 2005; Johnson et al., 2005; Zia et al., 2006). Weight of 100 grain per pot as an important growth bio indicator (Shafig, 2008) showed that weight of 100 grain per pot with and without B addition was significantly the highest under the clay textured soil and was the significantly least under the loam textured soil which is in agreement with plant essential nutrient of the two soils. This may clearly indicate that other plant growth limiting factor other than B is prevailing in such soils (Niaz et al., 2002; Niaz et al., 2007).

Table 3. Effect of B application on grain yield and on the weight of 100 grain

Boron Application level mg kg^{-1} soil	Clay soil		Loam soil		Sandy loamy soil		Mean (X¯)	
	Grin yield gm pot^{-1}	Wight 100 grain gm	Grin yield gm pots^{-1}	Wight 100 grain gm	Grin yield gm pots^{-1}	Wight 100 grain gm	Grin yield gm pots^{-1}	Wight 100 grain gm
0.0	7.50	5.08	5.17	3.80	4.57	3.43	5.75	4.10
0.5	14.03	5.40	9.40	5.09	6.78	4.13	10.10	4.87
Mean (X¯)	10.77	5.24	7.28	4.44	5.68	3.78	7.92	4.48

Variable	Least Significant Difference LSD	
	Green yield gm pot^{-1}	Wight 100 grain gm
Application level	0.827	0.491
Soil	1.013	0.601
Interaction	0.85	1.432

3.2 B Concentration and Uptake in Straw and Grain

Application of B to soils at 0.5 mg B per kg soil showed (Table 4) a significant increase of B concentration in straw. It was increased by 31.5% over that without B addition as an average over the three soils used. The increase of B content in straw with addition of B confirm the positive wheat response to added B which may be supported by the finding of Singh and Singh (1984) which were confirmed by a number of researchers (Furlani et al., 2003; Johnson et al., 2005; Tsadilas et al., 2005; Shafig, 2008), also, addition of B to soils increased B uptake by straw by 77%, 81% and 184% compared to those of zero B addition to clay soil, loam soil and sandy loam soil, respectively. These results were in agreement with those of Shafig (2008).

Table 4. Effect of B on its concentration and uptake in straw

B Application level mg Kg^{-1}	Clay soil		Loam soil		Sandy loam soil		Mean (X^{-})	
	B concentration mg Kg^{-1}	B uptake µg pot^{-1}	B concentration mg Kg^{-1}	B uptake µg pot^{-1}	B concentration mg Kg^{-1}	B uptake µg pot^{-1}	B concentration mg Kg^{-1}	B uptake µg pot^{-1}
0.0	18.000	378.0	18.817	364.13	15.117	213.08	17.311	318.403
0.5	19.087	670.526	27.417	659.93	26.267	605.48	24.257	645.312
Mean (X^{-})	18.544	524.263	23.117	512.03	20.692	409.28	20.784	481.858

Variable	Least Significant Difference LSD	
	B concentration mg Kg^{-1}	B uptake µg pot^{-1}
Application level	1.6027	48.262
Soil	1.9629	59.109
Interaction	2.776	83.593

Application of B to soils at 0.5 mg B per kg soil showed (Table 5) a significant increase of B concentration in wheat grains. It was increased by 40% over that without B addition as an average over the three soils used. The increase of B content in grain with addition of B confirm the positive wheat response to add B which may be supported by the finding of V. Singh and S. P. Singh (1984) which were confirmed by a number of researchers (Furlani et al., 2003; Johnson et al., 2005; Tsadilas et al., 2005; Shafig, 2008).

Furthermore, Addition of B to soils increased B uptake by wheat by 121%, 157% and 96.9% compared to those of zero B addition to clay soil, loam soil and sandy loamy soil, respectively. These results were in agreement with those of Shafig (2008).

Table 5. Effect of B on its concentration and uptake in grain

B Application level mg Kg^{-1}	Clay soil		Loam soil		Sandy loam soil		Mean (X-)	
	B concentration mg Kg^{-1}	B uptake µg pot^{-1}	B concentration mg Kg^{-1}	B uptake µg pot^{-1}	B concentration mg Kg^{-1}	B uptake µg pot^{-1}	B concentration mg Kg^{-1}	B uptake µg pot^{-1}
0.0	12.8	96.0	15.2	78.6	0.284	1.30	9.43	58.6
0.5	15.2	212	21.5	202	0.377	2.56	12.4	139
Mean (X-)	14.0	154	18.4	140	0.331	1.93	10.9	98.9

Variable	Least Significant Difference LSD	
	B concentration mg Kg^{-1}	B uptake µg pot^{-1}
Application level	0.973	12.1
Soil	1.192	14.9
Interaction	1.686	21.0

The results of this study also showed that the interaction between B application and soil type had a significant effect at the level of $P \leq 0.05$ on B uptake by plant (Tables 4 and 5). B uptake as an average over three soils received B addition 102.7 and 137% higher than that of zero B addition in straw and grain respectively. It is noted that response to B fertilizer increased significantly in all soils due to increase of available B content in soils upon B addition.

4. Conclusion

Boron (B) is non-metal essential microelement for plants and it is needed for normal plant growth and development. Boron deficiency under arid condition is very common especially under intensive cropping system. B application at an adequate level to soils of arid regions need to be adapted as a part of successful fertilizer recommendation. Further studies to determine the major crops response curve to B addition is very much essential to develop effective package of B application for obtaining expected yield.

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