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Effect of colemanite ore as boron fertilizer on growth and yield of two wheat (*Triticum aestivum* L.) genotypes under field condition

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Abstract

Wheat (*Triticum aestivum* L.) is the most important cereal crop in the world. The deficiency of boron (B) in soil is widespread global problem and affects crop yields. Mineral colemanite is a cheap and slow release source of B. In this dual factor field experiment we evaluated the effectiveness of colemanite ore as B fertilizer by studying its effect on growth and grain yield of two wheat genotypes. Factor A comprised five B levels (0, 1.5, 2.0, 3.0 and 4.0 kg B ha^{-1}) in the shape of colemanite while factor B included two wheat genotypes TD-1 and TJ-83. The maximum plant height, number of tillers per plant, number of grains per ear head and seed index in both genotypes TJ-83 and TD-1 was observed at 4 kg B ha^{-1}. The highest grain yield (4.2 tons ha^{-1}) of the crop was also at the same B level (4 kg B ha^{-1}). The application of colemanite increased 30% grain yield in compare to control. Although B application increased the yield at all levels but difference between 3 and 4 kg B ha^{-1} was not significant in both genotypes. The B content in wheat grain also augmented and B in soil after crop harvest was also high (0.9 mg kg^{-1}) in B applied plots in compare to control plots (0.4 mg kg^{-1}). This means subsequent crop will also get positive residual effect of colemanite. The results of the study showed that colemanite can be used as a B source for wheat crop.

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Introduction

Today, wheat is grown on more land area than any other commercial crop and continues to be the most important food grain source for humans. Its production leads all crops, including rice, maize and potatoes. There is more land planted to wheat in the world than any other crop. It provides 20 percent of the world's caloric consumption, and for the world's poorest 50 percent, 20 percent of their protein consumption too. In 2014 world wheat production was 729 million metric tons and Pakistan was among the top ten wheat producing countries with 26 million tons (FAOSTAT database, 2014). This was found that the reduction of wheat crop in sense of production only due to poor and imbalanced nutritional management (Rashid and Ryan, 2004). One of the major reasons of low yield of wheat is because of insufficient supply of micronutrients and the micronutrient deficiency has become the serious because of an escalated imbalanced nutrient supply. (Alloway, 2008). Boron element is pivotal for physiological functions of plant such as metabolic and nucleic acid, protein and carbohydrates, cell wall synthesis, acetic acid, structure of cell wall, phenol metabolism, member integrity and functions (Goldbach, 2001).

The B element is a unique not only in its properties of chemical but also role in biology. It is given to plants only for healthy growth and seed flowering (Marschner, 1995). It was observed that the production of wheat could be improved with the supplements of nutrients and nutrients management. The B importance has grown rapidly and the availability of B in soil is an important cause in production of agriculture. (Tanaka and Fujiwara, 2008). Its demand and need is different within the kingdom of plant. Cruciferous and Alfalfa plant are considered as much responsive to B fertilization in comparison to other crops and dicotyledonous crops require more B than monocotyledonous crops (Tanaka and Fujiwara, 2008). The constant supply of B is required for plant growth because it is not translocate from old to new tissue. That 's why deficiency symptoms first appear on growing youngest tissues the deficiency range of B has become major in crops and soil as compared to other micronutrient element (Goldbach *et al.*, 2001).

The deficiency of Boron symptoms occur in growing organs of plant body, under deficient conditions, root elongation, leaf expansion, apical dominance, flower development, fruit and seed sets are inhibited (Huang *et al.*, 2005). Boron deficiency not only effects to decrease yield of crop but also impairs its quality as referenced by Dell and Huang, 1997.

The two kinds of B fertilizer are used to supply B to crop the first ones are refined soluble materials and can be applied in solution or as solids, and the second ones are crushed ores with inconstant chemical and physical properties (Bell, 2008). The refined B fertilizers are borax ($Na_2B_4O_7 \cdot 10H_2O$), sodium tetra borate ($Na_2B_4O_7 \cdot 5H_2O$), sodium penta-borate (Na_2B-$_{O16} \cdot 10H_2O$), boric acid (H_3BO_3) and solubor ($Na_2B_8O_{13} \cdot 4H_2O$). The crushed ores used as B source are colemanite ($Ca_2B_6O_{11}.5H_2O$), hydroboracite ($CaO.MgO.3B_2O_3.6H_2O$), datolite ($2CaO.B_2O_3.2SiO_2.H_2O$), ulexite ($Na_2O.2CaO.5B_2O_3.16H_2O$), and ascharite ($2MgO.B_2O_3.H_2O$). The first type of B fertilizers are rapidly dissolve in soils and can be leached from the soil root zone. The two crushed ores ulexite and colemanite are used for soil application (Bell, 2008). As these slowly dissolve in soil so provide season long B supply for a crop due to less leaching losses. Beside this crushed ore colemanite is a cheap source of B in compare to refined products but this one is not usually used as fertilizer. Most pot experiments had been conducted on ores to study the problems of leaching as well as toxicity rather than on their influence on crop growth (Shorrocks, 1997). Keeping in mind the importance of B for wheat and colemanite as B fertilizer a field experiment was conducted to evaluate the influence of colemanite ore on two wheat genotypes s' growth parameters and yield.

Materials and methods

To find out influence of varying levels of B in the shape of colemanite ore on the development, yield and growth of selected wheat genotypes of Sindh, a field experiment was conducted at the research field of the Foundation Seed Cell, Agriculture Research Institute Tandojam, Pakistan. The two wheat genotypes, *viz*. TD1 and TJ83 were planted. The experiment was conducted in a two factor randomized complete block design (RCBD) with 3 replications. The number of plots was 30 and the size of each plot was 16 m^2. The plots were separated from each other by a 30 cm high ridge and 1 m wide path. Factor A comprised of five B levels in the shape of colemanite ore, while factor B included two wheat genotypes TD1 and TJ83. The producer of B fertilizer colemanite was Borochemie Pvt Limited, Turkey. Colemanite was used in powder form with particle size 80 µm and contains 12% B. The five different levels of soil applied B were T1=00 kg B ha^{-1} (Control), T2= 1.5 kg B ha^{-1}, T3= 2.0 kg B ha^{-1}, T4= 3.0 kg B ha^{-1}, T5= 4.0 kg B ha^{-1}. Boron fertilizer colemanite ore were applied at the time of seed sownig. The crop also received recommended doses nitrogen at 120 kg ha $^{-1}$ in the form of urea was applied in three split doses at sowing time, at first irrigation and at flowering stage. Phosphorus (60 kg ha^{-1}) was applied as triple superphosphate (TSP) and potassium (60 kg ha^{-1}) was applied as, muriate of potash.

Soil sampling and analysis

The soil samples was collected at 0-20, and 20-40 cm depth before planting and after harvesting of wheat. These samples were analysed for physico-chemical properties and B content. The wheat was sown by drill method and the plots size was 16 m^2. All the recommended agronomic practices were followed throughout the life span of the crop. Five plants from each plot were randomly selected for analysis. The agronomic data for different parameters and yield of wheat were recorded at various growth stages of crop. The crop parameter determined include plant height, number of tillers, length of ear head, seed index, straw yield, grain yield, B content of plant straw and grain. Tillers were counted at maturity stage while, plant height and seed yield were determined at harvest. Both wheat genotypes were harvested and threshed by hand.

Boron in the soil samples was analyzed by hot water extraction method (Bingham, 1982) and in the plant tissue it was determined by the dry ashing followed by azomethine-H colorimetric method (Benton, 2001). Other physic-chemical properties were determined by following recognized laboratory analysis methods. The data was statistically analysed by using Statistix version, 8.1. The variance analysis was done by following two-factor completely randomized design. The treatment means significant differences by Tukey's test at alpha 0.05.

Results and discussion

The height of wheat varieties was positively affected by different levels of colemanite (Table 2). The results showed significant difference among B levels on both varieties and their interaction. The taller plants (89.3 cm) were measured in treatment where 4 kg B ha^{-1} was applied. The dwarf plants where found in control plot. In case of varieties TJ-83 had taller plants as compared to TD-1 the interaction effect of B levels and varieties was also found positively significant.

Table 1. Basic soil properties of experimental site.

Name of property	Soil Depth (cm)	
Texture	0-20	20-40
Sand (%)	23.00	15.00
Silt (%)	31.50	37.50
Clay (%)	45.50	47.50
Textural Class	Clay	Clay
EC (dS m^{-1}) (1:2 soil water extract)	0.43	0.42
pH (1:2 soil water extract)	7.96	8.00
Organic matter (%)	0.8	0.4
Boron (mg kg^{-1})	0.40	0.45

Boron application increased the number of tillers per plant. The maximum tillers plant^{-1} were recorded in those plots which received 3 and 4 kg B ha^{-1} no significant difference was observed within these treatments, however, statistically higher value was noted in treatment where 4 kg B ha^{-1} was applied. Minimum number of tillers plant^{-1} were counted in control plot. As for as the varietal difference against B levels are concerned, TD-1 performed better with highest number of tillers plant^{-1} as compared to the TJ-83. Interaction effect of B levels and varieties was also found significant. The length of ear head of both wheat varieties was affected at different levels of colemanite.

Table 2. The mean of plant height, number of tillers per plant, length of earhead, seed index, straw yield and grain yield (kg ha^{-1}) of two wheat genotypes as affected by B fertilizer colemanite levels.

Treatment (kg B ha^{-1})	Plant height (cm)	Number of tillers	Length of Earhead (cm)	Seed index	Straw yield (Kg ha^{-1})	Grain yield (kg ha^{-1})
Control (0.0)	46.413 E	3.2833 D	10.478 B	45.523 D	2534.8 C	2908.5 C
1.5	58.228 D	4.5833 C	11.123 AB	48.198 C	3193.2 B	3515.2 B
2.0	77.255 C	5.9167 B	11.412 A	49.655 B	3355.0 B	3491.3 B
3.0	89.207 B	7.2417 A	11.443 A	52.608 A	3486.3 B	4017.3 A
4.0	98.265 A	7.5150 A	11.770 A	52.838 A	4037.8 A	4230.0 A
SE	0.6693	0.4446	0.3345	0.6341	190.12	166.69
LSD	1.4061	0.9340	0.7029	1.3322	399.42	350.21
			Wheat Genotypes			
TD-1	67.763 B	6.7333 A	11.823 A	58.581 A	2840.3 B	4329.1 A
TJ-83	79.985 A	4.6827 B	10.668 B	40.521 B	3802.5 A	3395.8 B
SE	0.4233	0.2812	0.2116	0.4010	120.24	105.43
LSD	0.8893	0.5907	0.4445	0.8426	252.61	221.49

The values with same letter within columns are not significantly different at p=0.05.

The maximum length of ear head was noted in the plants which were fertilized with 2, 3 and 4 kg B ha^{-1}. No significant difference was observed within these treatments, however, statistically higher value was recorded in treatment where 4 kg B ha^{-1} was applied. The minimum length of ear head was noted from the plants of control plots. Among the varieties, TD-1 had lengthy ear head than TJ-83. Rahmatullah *et al.* (2011) reported that B application on wheat crop significantly increased its number of tillers and spikelets, size and weight of panicle, leaf and grain B concentration most probably because of B role in cell wall synthesis and structure. It is involved in the plant seed formation and have positive correlation between B in the plant and number of flowers (Gupta 1993).

The results presented in Table 2 showed that colemanite as source of B has significant effect on the weight of 1000 grains. The highest seed index were recorded in the treatments where 3 and 4 kg B ha^{-1} were applied. No significant difference was observed within these treatments. However, the minimum seed index was found in control plot. Similarly TD1 wheat variety had heavier seeds than those in TJ-83. The interaction effect of boron levels and varieties was also found significant. The results are substantial because B requirement at plant reproductive phase is of more than other growth stages and eventually the grain was healthy and weightier. These results are in harmony with those reported by Gunnes *et al.* (2003) they reported that B application significantly increased the number and weight of grains per spike and further defined that B plays a vital role in grain setting of wheat., its supply at this stage helps in grain filling and reduction in sterility so the number and weight of grains per spike increased. Subedi *et al.* (2000) observed that the grain of wheat became failure owing to the deficiency of B. colemanite application increased the wheat straw yield of both genotypes in compare to control.

The maximum straw yield was recorded from the plots which received 4 kg B ha^{-1}. The plants from control plots had minimum straw yield. In terms of varietal performance, straw yield obtained from TJ-83 was more than TD1. Colemanite application significantly affected B concentration in wheat straw and grain (Table 4). Laboratory analysis of plant samples showed that the highest B concentration was found in the 4 kg B ha^{-1} plots compared to the other treatments. This same trend of plant B content was observed in both genotypes.

Table 3. Boron in soil and plant after harvest.

Treatment (kg B ha^{-1})	Soil Depth 0-20 cm	Soil Depth 20-40 cm	B content of Straw (mg kg^{-1})	B content of Grain (mg kg^{-1})
Control (0.0)	0.462 E	0.3052 E	5.0 C	3.0 B
1.5	0.5400 D	0.3318 C	5.5 C	3.96 B
2.0	0.8070 C	0.5352 B	6.6 B	4.66 AB
3.0	0.9113 B	0.7352 A	7.8 A	5.66 A
4.0	0.962 A	0.767 A	8.5 A	5.0 A
SE	0.0400	0.0219	0.5321	0.4342
LSD	0.0840	0.0460	0.8532	0.8340
Wheat Genotypes				
TD1	0.8013 A	0.5445 B	7.2	5.5
TJ83	0.7510 A	0.6091 A	6.9	4.7
SE	0.0253	0.0138	0.4932	0.4432
LSD	0.0531	0.0291	0.8124	0.7853

The values with same letter within columns are not significantly different at p=0.05.

As the B improved all growth parameters of the wheat crop so ultimately the grain yield also significantly increased at all B levels in compare to control (Table 2). The mean data showed significant differences among B levels in varieties and their interaction. The maximum per hectare grain yield (4017.3 and 4230.0 kg ha^{-1}) was recorded from the plots which were fertilized with 3 and 4 kg B ha^{-1}, respectively. Increasing B levels from 1.5 to 4.0 kg ha^{-1} increased grain yield gradually minimum yield of grain was recorded in control plots. Although both genotypes gave positive response to B application but when these were compared them than TD-1 had performed better than TJ-83. The results of our field experiment have shown that colemanite application upto 4.0 kg ha^{-1} had increased 30% grain yield over the control. Rehman (2012) reported that B application was main contributor of total grains mass by improving the spike length and number of grains, number of spikelets, 1000-grain weight and grain yield.

Tahir *et al.* (2009) observed the response of wheat yield to application of B at various growing stages. They observed that grains number per spike, thousand grain weight and grain yield was significantly enhanced where the application of B was applied. Wrobel (2009) studied impacts of the foliar B application to grown wheat of spring on sandy soil. The availability of B enhanced the grain mass, straw yield and enhancing the yield. Wheat production increased significantly may be due to the reason that the application of B enhances the pollen tube germination and grain setting at booting stage and the availability of B through colemanite at this stage in the anthers for successful fertilization was met so the grain yield boosted. These inferences are in accordance with the Alam *et al.* (2000) who reported that grain yield of wheat increased due to the application of B at different growth stages.

The data collected from all the agronomic observations is showing that colemanite was effective source of B when it was applied in higher quantity and this was due to slow release of B from it. As crop needs continuous supply of B through its growth cycle so under these conditions colemanite is good option. Beside this residue B level in soil after harvest was high in colemanite applied plots and this residual B will be beneficial for subsequent crop cycle. Results of our experiment are supported by the findings of Saleem *et al.* (2010 and 2013) they comparatively evaluated the effectiveness of colemanite ore and borax as sources of B for rice crop under field conditions in acidic soils and pot experiment in calcareous soil. They reported that powder colemanite application significantly increased plant growth parameters including B concentration in grain and colemanite with smaller particle size was an effective B source.

Conclusion

The results of the present study revealed that colemanite ore application of boron increased the plant height, number of tillers, length of ear head, seed index, grains and straw yield of both wheat varieties. However, TD-1 variety has significantly more values of studied traits than TJ-83. The application of colemanite ore as B at 3 kg ha^{-1} enhanced and found quite economical. It is concluded that the application of 3.0 kg Colemanite ore B ha^{-1} along with recommended dose of NKP (120-60-60 kg ha^{-1}) was found best combination for higher growth and grain yield of wheat variety TD-1. Further research on colemanite is suggested to its residual effect on subsequent crop.

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