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Influence of potassium, zinc and boron on productivity of wheat in an acid Alfisol

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Abstract

To evaluate the effect of potassium, zinc and boron on wheat productivity, the present investigation was undertaken at the experimental farm of Department of Soil Science, College of Agriculture, CSK HPKV, Palampur. The experiment comprised of sixteen treatments with four levels of K (0, 50,100 and150% of recommended dose), two levels of Zn (0 and 10 kg ha^{-1}) and two levels of B (0 and 1 kg ha^{-1}) in factorial randomized block design. Application of K @ 50, 100 and 150 % of recommended dose increased plant height, dry matter accumulation, total and effective tillers per metre row length, grains per ear and test weight significantly. Application of Zn (10 kg ha^{-1}) and B (1 kg ha^{-1}) influenced the growth and yield attributes of wheat significantly. Highest grain (42.52q ha^{-1}) and straw (66.80q ha^{-1}) yield of wheat was recorded under 150 % of recommended dose of potassium. Application of 150 % of recommended dose of K increased grain and straw yield by 44 and 47 % over no K, respectively. Application of Zn (10 kg ha^{-1}) increased grain and straw yield by 11 and 10 % over no Zn, respectively. The increase in grain and straw yield with the application of B (1 kg ha^{-1}) was 5.6 and 6.3 %, respectively.

Key words: Potassium, zinc, boron, growth, yield attributes, wheat yield, Alfisol.

It is well recognized that fertilisers have played a key role in the green revolution and are the best hope for meeting the food challenges in future also. Efficient nutrient management is one of the most important options for sustaining high production level of intensive cropping systems and arresting declining responses to fertilisers. Continuous imbalanced nutrient use disturbs the nutrient balance and leads to depletion of other nutrients as well as the under-utilisation of nutrients supplied through fertilizers. The evidences have suggested that repeated applications of N and P fertilizers can lead to deficiencies of other nutrients. Potassium is second only to nitrogen in the quantity required by plants for healthy growth but Indian agriculture has traditionally relied on the soil resource of potassium. Increasing incidences of potassium deficiencies demonstrate that we need a better understanding of potassium fertilization. However, with increasing cost of potassic fertilizers, farmers are often inclined not to use K or to replace K with nitrogenous or phosphatic fertilizers. Consequently, mining of native soil potassium is increasing at an alarming rate.

Accelerated depletion of micronutrients from soil due to enhanced food grain production has accentuated the micronutrients deficiencies in many parts of India, which has brought sharp reduction in the macronutrient (NPK) use efficiencies (Shukla *et al.* 2009). Deficiencies of micronutrients in crop plants are widespread all over the world because of increased micro nutrient demands from intensive cropping and adoption of high-yielding cultivars having higher micro nutrient demand. Moreover, enhanced production of crops on marginal soils, increased use of high analysis fertilizers, decreased use of organic manures, use of soils that are inherently low in micro nutrient reserves add to the cause (Fageria *et al.* 2002; Singh 2009).

The extent of deficiency of Zn, B, Mo, Fe, Mn and Cu in Indian soils was to the order of 48.8, 33, 13, 11.9, 4.4 and 3 percent, respectively (Singh 2009). Incidences of B deficiency have been reported from many of the world's wheat growing countries. Wheat is more prone to B deficiency than rice and maize, and some dicotyledons including soybean and mungbean and its deficiency depresses wheat yield primarily through grain set failure caused by male sterility. In one of the studies on nutrient mining in Himachal Pradesh, it has been reported that crop lands in the state are getting depleted in respect of nitrogen, potassium, secondary and micronutrients from the soil system at an alarming rate (Sharma *et al.* 2001; Chander *et al.*, 2014). The decline in soil health, if not managed timely will pose a serious threat to our farming systems in future.

Although micro nutrients are needed in much smaller amount as compared to macro nutrients but without their adequate supply, it is impossible to get optimum production levels with the addition of only NPK fertilizers using high yielding varieties. Response to applied zinc and boron has been obtained across the soils in different agro ecological regions of country. In view of imparting sustainability to the crops and cropping systems, incorporation of these products into major NPK fertilizers is necessary. Keeping in view the above facts, the present study was conducted to evaluate the effect of potassium, zinc and boron on productivity of wheat.

Materials and Methods

The present investigation was undertaken with sixteen treatment combinations of four levels of potassium (0, 50,100 and 150 % of recommended dose of K), two levels of zinc (0 and 10 kg ha^{-1}) and two levels of boron (0 and 1kg ha^{-1}) in factorial randomized block design. The treatments were replicated three times. The field experiment was conducted on wheat crop (HPW155) under irrigated conditions at experimental farm of Department of Soil Science, College of Agriculture, CSK HPKV, Palampur during *rabi* 2010-11. The experimental farm is situated at $32^0 6$ N latitude and $76^0 3$ E longitude at an altitude of about 1290 m above mean sea level and is characterized as zone 2.2 under mid hill sub-humid zone of Himachal Pradesh and lies in the Palam Valley of Kangra district at the foothills of Dhauladhar ranges. The area is characterized by wet temperate climate having severe winters and mild summers with mean annual temperature ranging from around 10 ^{0}C in January to 30^{0}C during May and June. The average annual rainfall ranges between 1500 to 3000 mm, out of which about 80 per cent is received during monsoon period (June to September). The mean relative humidity in the region varies from about 29 to 84 %, the minimum being in April and maximum in July and August.

The soil of experimental site was acidic with pH value of 5.3 and was classified as "*Typic Hapludalf*". The experimental soil was silty clay loam in texture, medium in organic carbon, available N, P and K. The contents of DTPA extractable Fe, Mn and Cu were adequate whereas DTPA extractable Zn and hot water soluble B were marginal and the respective contents were 29.03, 20.79, 0.57, 0.63 and 0.38ppm.

Recommended dose of N, P_2O_5, K_2O for wheat is 120, 60, 30 kg ha^{-1}, respectively. Half dose of N and full dose of P and different doses of K, B and Zn were applied as per treatments at the time of sowing of the crop. The remaining half N was top dressed at 30 DAS. The sources of N, P, K, Zn and B were urea, single superphosphate, muriate of potash, zinc oxide and borax, respectively. The crop was sown on 29th November, 2010 and harvested on 30th May, 2011. The crop was grown with recommended package of practices under irrigated conditions.

The observations on growth (plant height and dry matter accumulation) and yield attributes (total and effective tillers per metre row length, grains per ear and test weight) of wheat were recorded. The plot size was 11 m^2. The plant height was measured at 60, 105 and 150 days after sowing (DAS). For recording data on different growth parameters and yield attributes, five plants were randomly selected from each plot and observations were recorded. Crop dry matter was recorded at flowering and at harvest. The yield attributes and yield were recorded at harvest.

Results and Discussion

Crop growth

Plant height

The data presented in Table 1 revealed that application of K @ 50, 100 and 150 % of recommended dose of K increased plant height significantly over no K application at all the stages (60, 105 and 150 DAS). Maximum plant height was recorded at 150 % of the recommended dose of K. The values being 14.6, 63.7 and 88.0 cm at 60, 105 and 150 DAS, respectively. The positive effect of potassium on plant height may be attributed to its significant role in meristematic growth through its effect on synthesis of phyto-hormones (Beringer 1983). Application of Zn increased plant height significantly at all the stages. Its application @ 10 kg ha^{-1} recorded plant height of 13.8, 61.2 and 84.9 cm at 60, 105 and 150 DAS, respectively. The important role of Zn in bio-synthesis of indole acetic acid (IAA) might have resulted in increased plant height (Dewal and Pareek 2004). Similar to K and Zn, application of B resulted in significant increase in plant height at all the stages. Application of B @ 1 kg ha^{-1} recorded plant height of 13.6, 60.2 and 84.1 cm at 60, 105 and 150 DAS, respectively. The increase in plant height due to the application of boron may be attributed to its role in auxin metabolism and protein synthesis.

Dry matter accumulation

Application of K increased dry matter accumulation at maximum tillering and harvesting significantly (Table 1). Highest value of dry matter accumulation of 44.1 and 109.3 q ha^{-1} at maximum tillering and harvesting, respectively, were recorded at 150 % of the recommended dose of K. The increase in dry matter accumulation due to application of potassium may be attributed to its role in photosynthesis and synthesis of starch, fat and proteins (Rattan and Goswami 2002). In case of Zn application, dry matter accumulation at maximum tillering and harvesting increased in a significant manner. Its application @ 10 kg ha^{-1} recorded dry matter accumulation of 41.3 and 96.8 q ha^{-1} at maximum tillering and harvesting, respectively. It may be due to the involvement of zinc in auxin metabolism which results in improvement in overall biomass. These results are in consonance with the findings of Ozkutlu *et al.* (2006). Similar to K and Zn, addition of B also resulted in significant increase in dry matter accumulation at both the stages. Application of B recorded 40.4 and 95.0 q ha^{-1} dry matter accumulation at maximum tillering and harvesting, respectively. It may be due to the significant role of boron in translocation of sugar and

Table 1 Effect of potassium, zinc and boron on plant height (cm) and dry matter accumulation (q ha^{-1})

Treatment	Plant height			Dry matter accumulation	
	60 DAS	105 DAS	150 DAS	Maximum tillering	Harvesting
K level (% of recommended)					
K_0	11.7	52.5	73.4	34.19	75.07
K_{50}	12.7	60.2	84.7	37.42	85.16
K_{100}	13.7	60.6	87.8	41.15	99.52
K_{150}	14.6	63.7	88.0	44.16	109.32
CD (P=0.05)	0.6	1.6	1.8	2.91	5.21
Zn level (kg ha^{-1})					
Zn_0	12.6	57.3	82.1	37.16	87.77
Zn_{10}	13.8	61.2	84.9	41.31	96.76
CD (P=0.05)	0.4	1.1	1.3	2.06	3.68
B level (kg ha^{-1})					
B_0	12.77	58.37	82.8	38.12	89.58
B_1	13.58	60.15	84.1	40.35	94.95
CD (P=0.05)	0.4	1.12	1.3	2.06	3.68

starch, synthesis of amino acids and proteins (Das 2011).

Yield attributes

Total tillers and effective tillers per metre row length

The data (Table 2) indicated that total tillers and effective tillers per metre row length increased significantly with increasing K levels upto 150 % of the recommended dose. Application of K @ 150 % of recommended dose recorded highest total tillers (84.0) and effective tillers (79.1). Since potassium helps in synthesis of phyto-hormone like cytokinin which might have led to the positive influence of potassium on these parameters. These results corroborate the findings documented by Raghav *et al.* (2011). Like K, use of Zn increased total tillers and effective tillers significantly. Mean number of total tillers and effective tillers per metre row length at 10 kg Zn ha^{-1} were 80.6 and 73.4, respectively. The important role of Zn in initiation of primordia for reproductive parts and bio-synthesis of IAA might have resulted in better development of these yield contributing characters (Dewal and Pareek 2004). Similar positive effect of zinc application on tillers number has also been reported by Khan *et al.* (2008). In case of B, significantly higher values of total tillers (79.7) and effective tillers (73.0) were recorded compared to no B application. The beneficial effect of B on plant growth may be ascribed to involvement of B in the development of new cells in meristematic tissues, cell wall formation and stabilization, lignification and xylem differentiation (Dewal and Pareek 2004; Das 2011).

Grains per ear

The data reported in Table 2 revealed that number of grains per ear was influenced positively and significantly with the application of K. Application of K @ 150 % of recommended dose of K recorded highest grains per ear (50.4). The increase in number of grains per ear due to the application of potassium might be due to positive impact of its application on physiological processes of plant. These results are in accordance with the findings of Raghav *et al.* (2011). Application of Zn @ 10 kg ha^{-1} exhibited significant influence on grains per ear. Number of grains per ear at 10 kg Zn ha^{-1} was 47.6. It

Table 2. Effect of potassium, zinc and boron on yield attributes of wheat

Treatment	Tillers per m row length	Effective tillers per m row length	Grains per ear	Test weight (g)
K level (% of recommended)				
K_0	69.3	60.4	42.4	52.8
K_{50}	76.2	70.3	45.3	54.9
K_{100}	83.8	77.3	47.9	57.5
K_{150}	84.0	79.1	50.4	59.4
CD (P=0.05)	2.6	3.2	0.8	0.6
Zn level (kg ha^{-1})				
Zn_0	76.0	70.2	45.4	55.6
Zn_{10}	80.6	73.4	47.6	56.7
CD (P=0.05)	1.8	2.3	0.6	0.4
B level (kg ha^{-1})				
B_0	77.0	70.6	44.9	55.1
B_1	79.7	73.0	48.0	57.2
CD (P=0.05)	1.8	2.29	0.6	0.4

might be due to the reason that zinc plays important role in bio-synthesis of indole acetic acid (IAA) and initiation of primordia for reproductive parts (Dewal and Pareek 2004). Sharma *et al.* (2016) also noted similar positive effect. Application of B @ 1 kg ha^{-1} recorded 48 grains per ear in comparison to 45 at no B application. Boron had a remarkable contribution in grain setting. It might be due to the role of boron in translocation of food material in plants, therefore, it plays vital role in grain setting as well as higher number of grains per ear in wheat (Nadim, 2011). The results corroborate the findings of Hossain *et al.* (2002).

Test weight

Like grains per ear, test weight increased significantly with the application of upto 150% K (Table 2). Maximum test weight (59.4 g) was recorded under highest level of K application (150 % of recommended dose). Higher test weight due to potassium application may be the result of enhanced photosynthetic activity followed by efficient transfer of metabolites and subsequent accumulation of metabolites in the seed. Yadav *et al.* (2012) have also recorded similar observations in the soils of southern Haryana.

A significant increase in test weight was recorded when Zn was applied @ 10 kg ha^{-1}. Test weight under Zn_{10} was 56.7g. Remarkable effect of zinc application might be on account of balanced nutritional environment. Similar findings on the effect of zinc application on test weight have been reported from elsewhere by Sharma *et al.* (2000). Likewise, the increase in test weight due to the application of boron may be attributed to its physiological roles like carbohydrate metabolism, translocation of sugar and starches etc.

Grain and straw yield

It is evident from the results (Table 3) that graded levels of K increased grain and straw yield significantly over no K application. The increase in grain and straw yield was significant upto 150 % of recommended dose. Compared to 29.59 under no K, application of 50, 100 and 150 % of recommended dose of K recorded 34.91, 39.57 and 42.52 q ha^{-1} grain yield, respectively. A marked increase was registered with the application of K. Application of K at the rate of 50, 100 and 150 % of recommended dose increased grain yield by 18, 33.7 and 43.7 % over no K application, respectively. The corresponding values in straw yield were 10.5, 31.8 and 46.9 %. The increased yield might be due to increased availability, absorption and translocation of K (Yadav *et al.* 2012). Moreover, there was significant effect of K application on growth and yield attributes of wheat as discussed earlier, the significant increase in grain and straw yield of wheat is obvious. Singh and Singh (2000), Mishra (2003), Yadav and Yadav (2004) and Raghav *et al.*(2011) also recorded the significant effect of K application on crop yield at different locations.

Application of Zn @ 10 kg ha^{-1} recorded

Table 3. Effect of potassium, zinc and boron on grain and straw yield (q ha^{-1})

Treatment	Grain	Straw
K level (% of recommended)		
K_0	29.59	45.47
K_{50}	34.91	50.25
K_{100}	39.57	59.95
K_{150}	42.52	66.80
CD (P=0.05)	2.51	3.04
Zn level (kg ha^{-1})		
Zn_0	34.75	53.03
Zn_{10}	38.55	58.21
CD (P=0.05)	1.78	2.15
B level (kg ha^{-1})		
B_0	35.64	53.93
B_1	37.65	57.31
CD (P=0.05)	1.78	2.15

grain yield of 38.55 q ha^{-1} compared to 34.75 q ha^{-1} under no Zn treatment. Application of Zn registered 10.9 and 10 per cent increase in grain and straw yield, respectively. The favourable effect of Zn on productivity of wheat might be due to its function as catalyst or stimulant in most of the physiological and metabolic processes and metal activator of enzymes helping in carbohydrate and protein synthesis. Such physiological and biochemical processes might have resulted in increased growth and development of plant which ultimately gave higher grain and straw yield of wheat. The positive effect of Zn application on wheat productivity in deficient soil is understandable. These findings are in accordance with those reported by Shaheen *et al.* (2007) Abbas *et al.* (2009) and Sharma et al. (2016) in wheat.

Irrespective of K and Zn levels, application of B exhibited significant positive influence on grain and straw yield of wheat. The grain yield recorded under 1 kg B ha^{-1} and no B application was 37.65 and 35.64 q ha^{-1}, respectively. The increase in grain and straw yield of wheat with the application of 1 kg B ha^{-1} was also significant and the extent of increase was 5.6 and 6.3 %, respectively. The increase in crop yield of wheat may be ascribed to positive influence of boron on physiological processes involved in plant growth and maturation (Hossain *et al.* 2002). The increase in yield due to the application of B might be due its involvement in reproductive functions of the plant. It helps in the translocation of sugar and starch to the sink. The response of B to wheat has also been recorded by Debnath et al. (2011), Nadim et al. (2011) and Sharma et al. (2016).

In the present study, wheat responded upto 150% of the recommended dose of potassium. This highlights the need of revising the present recommendation of K. Moreover, significant increase in wheat yield was recorded with the application of Zn and B. Therefore, to realize the yield potential of wheat, Zn and B should also be applied along with NPK in the soils where the content of these micronutrients are marginal or deficient.

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