Sapna Kapoor *et al*, International Journal of Advances in Agricultural Science and Technology,
Vol.3 Issue.6, November- 2016, pg. 25-39 **ISSN: 2348-1358**
Impact Factor: 6.057

Effect of the Application of Nitrogen, Zinc and Boron on Micro-Nutrients Concentration and Uptake in Grain and Straw of Wheat in a Silty Clay Loam Soil of Mid Hills

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ABSTRACT: Sixteen treatment combinations consisting of four levels of N (0, 50,100 and150 per cent of recommended dose), two levels of Zn (0 and 10 kg ha^{-1}) and two levels of B (0 and 1 kg ha^{-1}) were evaluated in a silty clay loam soil at Palampur, that was medium in organic carbon, low in available N, medium in available P and K, adequate in DTPA extractable Fe, Mn and Cu, marginally adequate in DTPA Zn and insufficient in hot water soluble B. In general, application of nitrogen increased the concentrations of Mn, Fe, Cu, Zn and B in wheat grains and straw. In grain, Mn, and Cu concentration increased upto 150% of recommended N; Zn and Fe upto 100% N and B upto 50% N. In straw, Fe and Cu concentration increased upto 150% N; Mn upto 100% N; and Zn and B upto 50% N. In grain, application of Zn @ 10 kg ha^{-1} resulted in increased Zn and B concentration and decreased Fe, Mn and Cu concentrations. In straw, Zn concentration increased while Fe, Mn and Cu concentration decreased with the addition of Zn. Boron @ 1 kg ha^{-1} significantly increased Zn and B concentration in grains and Zn, Fe, Cu and B concentration in straw over no boron application. In general, there was consistent increase in uptake of Fe, Mn, Cu, Zn and B in wheat grain and straw and thereby of total with application of nitrogen. Application of Zn @ 10 kg ha^{-1} resulted in increased Zn and B uptake by grain and straw of wheat. Boron @ 1 kg ha^{-1} significantly increased Zn, Fe, Mn, Cu and B uptake by grains and straw. Grain yield of wheat increased with increase in dose of N upto 150 per cent of recommended. Application of 10 kg Zn ha^{-1} increased grain yield by 9.7 per cent. Similarly, boron application @ 1 kg ha^{-1} increased grain yield by 8.1 per cent.

Key words: Nitrogen, zinc, boron, nutrient concentration, grain, straw, wheat

Introduction

Fertilizers have played a prominent role in increasing food grain production. About half of the total increase in food grain production in the post-green revolution era has been attributed to the use of fertilizers. More than one-third of such increase is due to nitrogenous fertilizers alone. However, continuous heavy application of only one nutrient disturbs the nutrient balance and leads to depletion of other nutrients and under-utilization of nutrients supplied through fertilizers. Single nutrient approach has often posed problems of multiple nutrients deficiencies in cereal-based cropping systems. Therefore, balanced application of nutrients based on available soil nutrient status is pre-requisite for achieving higher sustained yields. A soil deficit in a particular nutrient needs to be supplied with that nutrient in a optimum dose. Further, there is considerable drain of plant nutrients through crop harvests. Therefore, assessing nutrient concentrations in grains and straws helps in future planning for nutrients replenishments as a consequence of nutrient drains through crop harvests. The soil of the test site was rated as low in available status of N, Zn and B. Therefore, the present investigation was carried out to study their effect on micro-nutrient concentration in grain and straw of wheat under mid hills condition of Himachal Pradesh.

Materials and Methods

A field experiment was conducted at the Experimental Farm of the Department of Soil Science, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur ($32^0\ 6^{'}$ N latitude $76^0\ 3^{'}$ E longitude and 1290 m altitude) during *rabi 2010*-2011. The area is characterized by wet temperate climate having severe winter and mild summer with mean annual temperature from 10.4^0C in January to around 30^0C during May-June. The average annual rainfall ranges between 1500 to 3000 mm, out of which about 80 per cent is received during June to September. The mean relative humidity in the region varies from 29 to 84 per cent, the minimum being in April and maximum in July and August. The soil of experimental site was *Typic hapludalf* and acidic in reaction with pH value of 5.3. The experimental soil was silty clay loam in texture, medium in organic carbon, low in available N and medium in available P and K. The contents of DTPA extractable Fe, Mn and Cu were adequate whereas DTPA Zn was marginally adequate and hot water soluble B was insufficient. Sixteen treatment combinations were replicated thrice in factorial RBD and comprised four levels of nitrogen (0, 50,100 and 150 per cent of recommended dose of N), two levels of zinc (0 and 10 kg ha^{-1}) and two levels of boron (0 and 1 kg ha^{-1}).

Recommended dose of N, P_2O_5, K_2O for wheat is 120, 60, 30 kg ha^{-1}. Half dose of N and full dose of P, K, Zn and B were applied at sowing time. The remaining half dose of 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 wheat variety 'HPW-155' was sown on 29th November 2010 and harvested on 25th May 2011. The crop was grown with recommended package of practices under irrigated conditions. The wheat plant samples were collected at maximum tillering stage. Grain and straw samples were collected during threshing. The wheat plant samples collected at tillering stage and grain and straw samples collected after the harvest were brought to laboratory fresh. Then washed immediately in order to make them free from dust or any other adhering substances. Samples were first washed under running tap water. Subsequently, these samples were washed with acidified distilled water (1 ml concentrated HCl per liter) followed by thorough rinsing twice with distilled water. The samples were then dried in an oven at 60^0C. The dried samples were then ground in a grinder fitted with stainless steel parts to pass through 1 mm sieve. These are then kept in paper bags for subsequent analysis. The detail of methods employed for chemical analysis is given below in Table 3.3.

Table 1. The methods used for determination of nutrient concentration in plant samples

Parameter	Method employed
Nitrogen	Digestion with concentrated H_2SO_4 in the presence of digestion mixture (K_2SO_4, $CuSO_4$ and Selenium powder in 10:1:0.1 ratio) and further determination by modified kjeldahl Method (Jackson 1973).
Phosphorus	Digestion in diacid mixture (HNO_3 and $HClO_4$ in 9:4 ratio) and further determination following vanadomolybdate acid yellow colour method (Jackson 1973).
Potassium	Digestion in diacid mixture and further estimation by flame photometric method (Black 1965).
Boron	Digestion by dry ashing in muffle furnace at 550°C for 2 hrs followed by digestion with 6.0 N HCl and further determination using carmine method (Hatcher and Wilcox 1950).
Fe, Mn, Zn and Cu	Digestion in di-acid mixture and further estimation using atomic absorption spectrophotometer (AAS) (Jackson 1967).

The nutrient uptake was calculated by multiplying per cent concentration of a particular nutrient with grain and straw yields. The uptake of the nutrients obtained in respect of grain and straw was summed up in order to compute the amount of total nutrient removed by the crop.

Uptake (kg ha^{-1}) = [% concentration of nutrient x yield of crop in q ha^{-1} (on dry wt. basis)]

Total uptake was calculated as follows:

Total uptake = uptake in grain + uptake in straw

Results and Discussion

Micro-nutrient concentration in grain

There was significant and consistent increase in Zn concentration upto application of 100 per cent recommended dose of nitrogen (Table 2). The increase in zinc concentration with N_{50} and N_{100} over N_0 was 17.4 and 27.6 per cent, respectively. Such an increase could be attributed to the synergistic effect of N and Zn as N helps in Zn absorption. Similar results were reported by Khanda and Dixit (1996). Application of zinc @ 10 kg ha^{-1} (Zn_{10}) increased Zn concentration in grain by about 26 per cent over no zinc application. Similar increase in Zn concentration due to Zn application was reported by other workers (Patel *et al*. 2008, Aref 2010). Boron increased the zinc concentration in grain by 11 per cent. These findings corroborate the results of Kaur (2012).

Table 2. Effect of nitrogen, zinc and boron on macro (%) and micronutrient concentration (mg kg^{-1}) in grain of wheat

Treatment	Grain					Straw				
	Zn	Mn	Fe	Cu	B	Zn	Mn	Fe	Cu	B
Nitrogen (% of recommended dose)										
0 (N_0)	18.67	41.17	34.83	23.92	5.84	11.33	47.80	88.58	32.42	11.28
50 (N_{50})	21.92	45.58	40.67	27.58	6.74	13.25	49.47	94.83	36.25	12.47
100 (N_{100})	23.83	46.92	43.33	30.75	7.06	14.00	55.63	107.25	39.25	12.53
150 (N_{150})	24.25	48.50	44.50	32.67	7.08	14.67	56.88	112.42	41.83	12.70
LSD (P=0.05)	1.73	1.23	2.64	1.33	0.65	1.58	1.89	5.60	0.92	0.78
Zinc (kg ha^{-1})										
0 (Zn_0)	19.63	46.33	42.42	29.38	6.56	11.29	53.69	105.58	38.17	12.21
10 (Zn_{10})	24.71	44.75	39.25	28.08	6.80	15.33	51.20	96.46	36.71	12.28
LSD (P=0.05)	1.23	0.87	1.86	0.94	NS	1.12	1.33	3.96	0.65	NS
Boron (kg ha^{-1})										
0 (B_0)	21.00	45.29	40.33	28.42	5.99	12.50	51.85	96.17	37.00	11.63
1 (B_1)	23.33	45.79	41.33	29.04	7.37	14.13	53.03	105.88	37.88	12.86
LSD (P=0.05)	1.23	NS	NS	NS	0.46	1.12	NS	3.96	0.65	0.55

Nitrogen had significant and consistent influence on manganese concentration in grain upto application of super optimal dose of nitrogen. Application of half dose (N_{50}), recommended dose (N_{100}) and super optimal dose of nitrogen (N_{150}) brought about 10.7, 13.9 and 17.8 per cent increase in Mn concentration, respectively over control. Mn concentration decreased significantly from 46.33 under Zn_0 to 44.75 mg kg^{-1} under Zn_{10}. Decrease in Mn concentration with the Zn application has also been observed in other crop which probably happens due to the inhibitory effect of Zn on Mn translocation (Narwal and Malik 2011). Boron application had no significant effect on the concentration of Mn in grains.

Iron concentration in grain increased with increase in nitrogen levels significantly and consistently upto N_{100}. Similar results were reported by Aciksoz *et al*. (2010). Application of zinc @ 10 kg ha^{-1} decreased iron concentration in grain from 42.42 mg kg^{-1} under Zn_0 to 39.25 mg kg^{-1} under Zn_{10}. This may be due to antagonistic effect of Zn on Fe (Gupta and Potalia 1991). Conversely, application of boron did not show any significant effect on iron concentration.

Significant increase in Cu concentration was noted in grain with increased levels of nitrogen. However, application of zinc @ 10 kg ha^{-1} significantly decreased the copper concentration in grain from 29.38 mg kg^{-1} under Zn_0 to 28.08 mg kg^{-1} under Zn_{10}. Such antagonistic relationship between Zn and Cu might be attributed to the same ionic radii and charge of zinc and copper ions which compete with each other for the identical absorption site (Narwal and Malik 2011). Application of boron @ 1 kg ha^{-1} could not significantly influence Cu concentration in grains over control.

Boron concentration in grain increased upto 50 per cent of recommended dose of nitrogen. Further increase in N did not significantly increase B concentration. Application of zinc did not significantly enhance the boron concentration in grains. There was significant increase in B concentration in grains by boron application. Boron application @ 1 kg ha^{-1} increased the B concentration by about 23 per cent over no boron application. Similar results were also observed by Aref (2010) and Debnath et al. (2011).

Micro-nutrient concentration in straw

Zinc concentration increased from 11.33 mg kg^{-1} under N_0 to 14.67 mg kg^{-1} under N_{150}. However, the increase in zinc concentration in straw was consistent only upto N_{100} which increased Zn concentration by about 23.5 per cent over control. Zinc application significantly increased zinc concentration in wheat straw from 11.29 mg kg^{-1} under Zn_0 to 15.33 mg kg^{-1} under Zn_{10}. Application of zinc @ 10 kg ha^{-1} (Zn_{10}) increased Zn concentration by about 35 per cent over no zinc application (Zn_0). Similar results were found by Shivay and Prasad (2009) in wheat. Boron application significantly increased the zinc concentration in wheat straw by about 13 per cent over no application of boron. Hossain *et al*. (2011) found similar results.

Manganese concentration in straw varied from 47.80 mg kg^{-1} under N_0 to 56.80 mg kg^{-1} under N_{150}. The increase was significant only upto 100 per cent recommended application of N. Application of 100 per cent of recommended N dose increased Mn concentration in straw by 16.3 per cent over control. Similar results were found by Cimrin *et al*. (2004). Manganese concentration decreased significantly with the application of zinc @ 10 kg ha^{-1} (Zn_{10}) from 53.69 mg kg^{-1} under Zn_0 to 51.20 mg kg^{-1} under Zn_{10}, respectively. Boron application did not significantly influence Mn concentration in straw.

Application of nitrogen increased iron concentration in straw upto 100 per cent of recommended dose of nitrogen. Application of zinc @ 10 kg ha^{-1} significantly decreased iron concentration from 105.58 mg kg^{-1} to 96.46 mg kg^{-1} under Zn_0 and Zn_{10}, respectively. This may be due to the antagonistic effect of Zn on Fe (Gupta and Potalia 1991). Conversely, application of boron had significant effect on iron concentration in wheat straw. Boron application increased Fe concentration by 6.8 per cent over no boron application.

There was consistent increase in Cu concentration in wheat straw with increasing level of nitrogen. Application of zinc @ 10 kg ha^{-1} significantly reduced copper concentration in wheat straw. The decreased Cu concentration at higher level of Zn application might be due to their antagonistic effect as Zn strongly depressed Cu absorption and affect redistribution within plants (Webb and Loneragan 1988). Boron @ 1 kg ha^{-1} significantly increased Cu concentration in wheat straw.

Boron concentration in wheat straw increased with increase in nitrogen levels from 0 to 150 per cent of the recommended dose. Application of 50, 100 and 150 per cent of recommended dose of N increased B concentration in wheat straw by 10.5, 11.0 and 12.5 per cent, respectively. Zinc application did not significantly increase boron concentration in straw over no zinc application. There was significant increase in B concentration in wheat straw with its application @ 1 kg ha^{-1}. Increase in B concentration by wheat straw was 10.5 per cent over no boron application. The positive significant influence on B concentration might be attributed to its supply through borax.

Micro-nutrients uptake

With increasing level of nitrogen Zn uptake by wheat increased consistently (Table 3). Total Zn uptake by wheat varied from 97.9 g ha^{-1} to 200.9 g ha^{-1} under N_0 and N_{150}, respectively. Application of 50, 100 and 150 per cent of recommended dose of N increased total Zn uptake in wheat by 52.5, 83.9 and 105.2 per cent, respectively over control. Similar results were obtained by Cimrin *et al*. (2004) and Behera and Singh (2009). Zn_{10} (182.8 g ha^{-1}) resulted in significantly higher total Zn uptake over Zn_0 (131.3 g ha^{-1}). The above findings are in accordance with Keram *et al*. (2012). Application of 1 kg B ha^{-1} (170.9 g ha^{-1}) significantly increased Zn uptake over B_0 (143.2 g ha^{-1}). An increase in Zn uptake with B application was also reported by Hossain *et al*. (2011).

Iron uptake by wheat grains and straw increased with increase in N level. The increased Fe uptake with the increased N level might be attributed to the proliferous root system developed under balanced nutrient application resulting in better absorption of nutrients. Zinc application @ 10 kg ha^{-1} did not significantly influence Fe uptake by wheat (grain, straw and total) due to antagonism between the elements. Boron was statistically superior to no boron in influencing Fe uptake by wheat grain and straw Since B application increased Fe concentration and wheat productivity significantly, as such the increase in total Fe uptake was obvious. Similar observations have been documented by Annie and Duraisami (2005).

Mn uptake by wheat (grain, straw and total) increased consistently with increasing N levels. Application of 50, 100 and 150 per cent of recommended dose of N increased total Mn uptake in wheat by 33.8, 62.6 and 80.1 per cent, respectively over control. Similar results were also obtained by Cimrin *et al*. (2004). Manganese uptake by wheat grains under Zn_{10} (175.9 g ha^{-1}) was significantly higher over Zn_0 (166.0 g ha^{-1}). Manganese uptake by wheat straw and thereby total Mn uptake did not differ significantly. Boron application significantly increased Mn uptake in wheat grains, straw and thereby total. Application of boron @ 1 kg ha^{-1} increased total Mn uptake by 8.0 per cent over no boron application.

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Vol.3 Issue.6, November- 2016, pg. 25-39 ISSN: 2348-1358
Impact Factor: 6.057

Table 3. Effect of nitrogen, zinc and boron on Zn, Fe, Cu and Mn uptake (g ha^{-1})

Treatment	Zn			Fe			Cu			Mn		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
Nitrogen (% of recommended dose)												
0 (N_0)	46.7	51.2	97.9	85.9	393.5	479.4	58.9	144.2	203.2	101.9	212.8	314.7
50 (N_{50})	80.7	68.6	149.3	148.2	493.2	641.4	101.1	186.4	287.5	166.7	254.4	421.1
100 (N_{100})	99.1	81.1	180.2	178.2	614.2	792.4	126.8	225.0	351.8	193.0	318.9	511.8
150 (N_{150})	111.5	89.4	200.9	204.3	680.8	885.1	149.7	253.3	403.0	222.1	344.7	566.8
LSD (P=0.05)	8.2	10.8	17.7	13.0	38.0	45.0	9.1	12.8	18.1	10.5	21.7	27.2
Zinc (kg ha^{-1})												
0 (Zn_0)	71.4	59.9	131.3	152.5	554.0	706.5	106.1	200.6	306.8	166.0	281.5	447.4
10 (Zn_{10})	97.6	85.2	182.8	155.8	536.8	692.6	112.2	203.8	316.0	175.9	283.9	459.8
LSD (P=0.05)	5.8	7.6	12.5	NS	NS	NS	NS	NS	NS	7.5	NS	NS
Boron (kg ha^{-1})												
0 (B_0)	76.8	66.4	143.2	145.8	506.8	652.6	103.4	194.9	298.3	163.4	272.7	436.0
1 (B_1)	92.8	78.7	170.9	162.5	584.1	746.6	114.9	209.6	324.5	178.5	292.7	471.2
LSD (P=0.05)	5.8	7.6	12.5	9.2	26.9	31.8	6.4	9.1	12.8	7.5	15.3	19.2

Application of nitrogen increased Cu uptake by wheat (grain, straw and total) consistently upto 150 per cent of recommended dose. The increased uptake with increasing N levels might be due to greater dry matter accumulation in plants. Similar results were also obtained by Cimrin *et al*. (2004). Application of zinc did not significantly influence Cu uptake by grain and straw. Therefore, effect of zinc application on total Cu uptake was also not significant. Kanse *et al*. (2006) also found similar results. Application of boron @ 1 kg ha^{-1} significantly increased uptake of Cu over no boron application (B_0). Boron application @ 1 kg ha^{-1} increased total Cu uptake by 8.7 per cent over no boron application. Similar findings have also been reported by Annie and Duraisami (2005).

Application of nitrogen resulted in significant and consistent increase in boron uptake by wheat grains and straw (Table 4). Application of 50, 100 and 150 per cent of recommended dose of N increased B uptake by wheat by 37.5, 55.8 and 69.2 per cent, respectively over control. Zinc @ 10 kg ha^{-1} resulted in significantly higher boron uptake over Zn_0. Zinc application increased B uptake in wheat grains by 13.0 per cent over no zinc application. Application of Zn did not significantly influence boron uptake by wheat straw. Total B uptake increased significantly with application of zinc (Zn_{10}) as compared to no zinc application (Zn_0). Similar results have also been recorded by Sinha and Sakal (1983). Boron @ 1 kg ha^{-1} increased boron uptake by 20.9 per cent over no boron. The increased uptake was probably due to higher B concentration and yield with B application. Similar findings were reported by Hossain *et al*. (2011).

Table 4. Effect of nitrogen, zinc and boron on boron uptake (g ha^{-1}) and grain and straw yield of wheat

Treatment	B uptake			Grain yield	Straw yield
	Grain	Straw	Total		
Nitrogen (% of recommended dose)					
0 (N_0)	14.5	50.3	64.8	24.79	50.3
50 (N_{50})	24.8	64.3	89.1	36.59	64.3
100 (N_{100})	29.1	71.9	101.0	41.14	71.9
150 (N_{150})	32.6	77.1	109.7	45.83	77.1
LSD (P=0.05)	2.8	5.7	6.2	2.19	5.7
Zinc (kg ha^{-1})					

0 (Zn_0)	23.7	63.9	87.6	35.37	63.9
10 (Zn_{10})	26.8	67.9	94.7	38.81	67.9
LSD (P=0.05)	2.0	NS	4.4	1.55	NS
Boron (kg ha^{-1})					
0 (B_0)	21.5	60.9	82.5	35.63	60.9
1 (B_1)	29.0	70.8	99.8	38.54	70.8
LSD (P=0.05)	2.0	4.1	4.4	1.55	4.1

Grain yield

Application of nitrogen consistently and significantly increased the grain yield of wheat upto 150 kg N ha^{-1}. Increase in yield by N might be due to increased vegetative growth, more synthesis of carbohydrates and their translocation for the synthesis of organic nitrogen compounds which are constituents of protoplasm and chloroplasts. The results are substantiated by the findings of the studies conducted by Mattas *et al*. (2011). Significantly higher grain yield was recorded with the application of Zn. The per cent increase in grain yield with Zn application was 9.7 over no zinc application. The increase in grain yield on zinc addition might be due to enhanced formation of growth hormones such as auxin, formation of starch and seed maturation. Such a response to application of zinc in deficient soil was quite obvious. Similar findings were reported by Keram *et al*. (2012). Application of boron @ 1 kg ha^{-1} also increased the grain yield of wheat. The per cent increase in grain yield with B application was 8.1 over no B application. The increase in grain yield of wheat on boron application might be due to positive role of B in reproductive physiology essential for grain formation and development in the boron deficient soil (Agarwal *et al*. 2007).

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