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Research Paper

Zinc fertilization effect on macro and micro-nutrients concentrations and uptake in wheat (*Triticum aestivum*) varieties

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ABSTRACT

A field experiment was conducted during the winter (*rabi*) seasons of 2013–14 and 2014–15 at New Delhi, to find out the effect of zinc (Zn) fertilization on concentration and uptake of macro and micro-nutrients in high-yielding wheat (*Triticum aestivum* L.) varieties. Treatments comprised 6 high-yielding varieties of wheat in the main plots and 5 Zn management treatments as sub-plots. Results indicated that nitrogen (N), phosphorus (P) and potassium (K) content in different parts of wheat varieties was found in the order of grain > straw > spike straw, grain > spike straw > straw and straw > spike straw > grain, respectively. However the concentration of iron (Fe) and manganese (Mn) was found in order of straw > spike straw > grain and straw > grain > spike straw respectively. With respect to nutrients, the highest N (2.28%), P (3,711.6 mg/kg), K (0.48%), Zn (40.6 mg/kg), Fe (124.8 mg/kg) and Mn (33.7 mg/kg) contents were registered in grain of 'HD 2967', 'HD 2967', 'HD 2687', 'HD 2851', 'HD 2687' and 'HD 2894', respectively. The concentration of macro and micro-nutrients were recorded statistically identical in different treatments of Zn fertilization. However, significant increase in macro and micro-nutrients uptake was registered due to Zn fertilization and the highest uptake of nutrients was recorded with application of 1.25 kg Zn/ha through Zn-EDTA + 0.5% foliar spray of Zn-EDTA at maximum tillering and booting stages. Thus, soil (1.25 kg Zn/ha) + foliar (0.5%) application of Zn-EDTA was found superior with respect to macro and micro-nutrients uptake.

Key words : Nutrient concentration, Nutrient uptake, Wheat varieties, Zn-EDTA, Zn fertilization

Wheat is a major cereal crop and source for dietary calorie intake, proteins and micro-nutrients, mostly in the developing countries, accounting ~50% of the daily calorie intake (Cakmak, 2008). In humans, Zn-deficiency is the fifth major cause of diseases and mortality in the developing countries (WHO, 2002). About 2.7 billion people are estimated to be Zn-deficient globally (Muller and Krawinkel, 2005). In many parts of the world, micronutrient deficiency is a more widespread problem than poor dietary quality and low energy intake (Stewart *et al*., 2010), and about 20% of deaths in children under 5 years can be attributed to vitamin A, Zn, Fe, and/or iodine deficiency (Prentice *et al*., 2008). The productivity and quality of wheat depends on several factors like climate, agronomic management practices, varietal response, soil type. Thus, in order to attain the maximum yield potential through adopting agronomic practices for enhancing yield and improving grain Zn-concentration and quality traits, micronutrient management in wheat is an area of research, which needs immediate attention. It is expected that adoption of micronutrient-dense wheat varieties will be driven by their improved agronomic properties, higher yield potential, resistance to new strains of rusts, and tolerance to climate change-induced heat and drought stresses. The provision of wheat grains with higher micronutrients levels is a challenging task for wheat breeders, but one that would complement the use of supplemental fertilizers, particularly on soils inherently low in these nutrients.

Zinc-deficiency is prevalent in wheat growing areas both in temperate and tropical climates (Shivay *et al.*, 2008). As per report of Takkar (1996), about 47% of Indian soils are not having enough Zn-content, which leads to decline in wheat yields due to Zn stress in countries like India, Australia and Turkey. Similarly, Zn deficiency also

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leads to decrease in nutritional quality of wheat grain, especially in developing countries, where cereals are major staple foods (Welch and Graham, 1999). Compared to other cereals, wheat cultivars possess high sensitivity to Zn-deficiency, and thus, an application of Zn fertilizers is an important strategy for enhancing productivity and quality of wheat. Simultaneously, application of one nutrient may also affect the concentration and uptake of other essential nutrients by forming different compounds in soil and/or in plant. Many researchers have reported a positive correlation between nitrogen and phosphorus which leads to increase in P absorption and high yield. Differences in Fe uptake in rice grains at various N levels were reported highly significant and indicated that Fe increased with the addition of N as NH_4^+. However, Zn-concentration did not increase with the addition of N (IRRI, 1999). Positive interactions between P and Mg are expected since Mg is an activator of kinase enzymes and activates most reactions involving phosphate transfer (Fageria, 2001). Application of phosphatic fertilizers at a high dose increases the severity of such deficiency in soils that are low or marginal in available Zn (Soltangheisi *et al.*, 2014). Role of micronutrients in crop production has significantly increased in the recent years due to availability of better analysis techniques and better understanding of their functions in crop plants (Singh, 2013). Since sufficient experimental data case with lacking in conducting the effects of micronutrients effects on uptake and utilization of other essential plant nutrients, the present investigation was undertaken to find out the effect of Zn fertilization on concentration and uptake of macro and micro-nutrients in different high-yielding varieties of wheat.

MATERIALS AND METHODS

A field experiment was initiated during winter (*rabi*) seasons of 2013–14 and 2014–15 at ICAR-Indian Agricultural Research Institute, New Delhi, India. The climate of the experimental site is semi-arid with dry hot summers and cold winters with average annual rainfall of 650 mm, 80% of which is received through south–west monsoon during July–September. Soils are alluvium-derived sandy clay loam (*Typic Ustochrept*) in texture with 50.2% sand, 23.2% silt and 26.6% clay. A uniformity trial on wheat was undertaken during *rabi* 2012–13 to ensure uniform soil physico-chemical status in the entire field. The soil (0–30 cm layer) had *p*H 7.8 (1 : 2.5 soil and water ratio), oxidizable-SOC 0.51%, alkaline $KMnO_4$-oxidizable N 252.8 kg/ha, 0.5 M $NaHCO_3$ extractable-P 13.1 kg/ha, and 1 N NH_4OAc-extractable K 291.2 kg/ha. The soil contained diethylene triamine penta acetate (DTPA)-extractable Zn was 0.63 mg/kg of soil.

The experiment was laid-out in a split-plot design and replicated thrice. Six wheat varieties, viz. 'HD 2851', 'HD 2687', 'HD 2967', 'PBW 343', 'HD 2894', and 'HD 2932', were taken in main-plots; and 5 Zn fertilization treatments, viz. control (no Zn), soil application of Zn @ 5 kg/ha through $ZnSO_4.7H_2O$, soil application of Zn @ 2.5 kg/ha through $ZnSO_4.7H_2O$ + 0.5% foliar spray of $ZnSO_4.7H_2O$ (ZnSHH) at maximum tillering (MT) and booting stages, soil application of Zn @ 2.5 kg/ha through Zn-EDTA, soil application of Zn @ 1.25 kg/ha through Zn-EDTA + 0.5% foliar spray of Zn-EDTA at MT and booting stages, in sub-plots. The field was cultivated twice with the disc harrow followed by rotavator and a fine seed-bed was obtained by giving 2 ploughings with a tractor-drawn cultivator followed by planking. The N was applied @ 120 kg/ha through urea in 3 equal splits, i.e. one-third at the time of sowing and the remaining N in 2 equal splits– first, 3 weeks after sowing and second, 3 weeks afterward by broadcasting. Phosphorus @ 60 kg P_2O_5/ha as di-ammonium phosphate and potassium @ 60 kg K_2O/ha as muriate of potash were applied at the time of final field preparation. Zinc was applied as per treatments before sowing of wheat except in the control (no-Zn treatment). The plot size was 4.0 m × 3.0 m for each treatment. Wheat crop was raised as per the standard recommended package of practices and harvested in the second fortnight of April during both the years.

Macro and micro-nutrients content at different growth stages and at the time of harvesting in the plant was determined by drying the samples in hot-air oven at 60°C ± 2°C till a constant dry weight obtained. Nitrogen content in samples was analyzed by using Kjeldahl's apparatus and expressed as percentage. The P content was determined by using Vanado-molybdo-phosphoric acid yellow colour method (Piper, 1966). The K content was determined by using the flame photometer and was expressed as percentage. The manganese (Mn) and Fe content in dry matter of wheat at different growth stages, straw and different parts of grain were determined using Atomic Absorption Spectrophotometry (AAS). The macro and micro-nutrients uptake was computed by multiplying the nutrient content with respective plant biomass and was expressed as nutrient uptake in kg/ha. The data obtained from study 2 years were analysed statistically using the F-test, as per the procedure given by Gomez and Gomez (1984). LSD values at P=0.05 were used to determine the significance of difference between treatment means.

RESULTS AND DISCUSSION

Grain yield

Of the 6 wheat varieties, 'HD 2967' gave significantly the highest grain yield (4.89 t/ha) and remained at par with 'PBW 343' (Table 1). The lowest grain yield was recorded in 'HD 2687' variety. Among the Zn-fertilization treatments, an application of 1.25 kg Zn/ha through EDTA + 0.5% foliar spray was found superior and resulted in the maximum grain yield, which was at par to that rest of treatments except the control. Grain yield increased by 9.5 to 12.1% among different Zn-fertilization treatments in comparison to the control. Mixed Zn-fertilization methods, i.e. soil + foliar application, were found superior to single fertilization approach. Imran and Rehim (2016) also reported that combined application of Zn (soil + foliar) is more promising in improving plant growth and yield than the other fertilization approaches.

Macronutrients concentration

Significant difference in nutrient concentration was noticed in different wheat varieties at different growth stages. The N, P and K concentrations were higher during initial growth stages of crop and decreased subsequently at crop growth stages. Concentrations of N, P and K in different parts of wheat was recorded in the order of grain > straw > spike straw, grain > spike straw > straw and straw > spike straw > grain, respectively (Tables 1, 2). Among the different varieties, the highest N, P and K contents in grain were recorded in 'HD 2967', 'HD 2967' and 'HD 2687' respectively. However, the highest N, P and K content in straw was recorded in 'HD 2851', 'PBW 343' and 'HD 2894' varieties, respectively. Significant variation in different varieties with respect to macronutrient concentrations might be due to differential capability of varieties to acquire and utilize nutrient from the soil. Akter *et al.* (2014) also reported significant differences in N content of different rice varieties.

Effect of Zn application on N, P and K contents were found statistically identical with respect to different Zn-fertilization treatments; although numerically higher values were observed in Zn-applied treatments than control. The highest content of N, P and K was recorded with the application of 1.25 kg Zn/ha through Zn-EDTA as soil application + 0.5% foliar spray at maximum tillering and booting stages. Non-significant effects of Zn fertilization on N, P and K contents might be due to application of recommended doses of N, P and K fertilizers in all the treatments. Pooniya and Shivay (2011, 2013) also reported significant increase in N, P and K contents with the application of Zn.

Micronutrients content

Higher concentration of Zn, Fe and Mn was observed during the initial stages of crop growth and decreased subsequently with the increasing growth stage. The Zn, Fe

Table 1. Effect of varieties and zinc fertilization on grain yield and nitrogen and phosphorus content at 90 DAS in different part of wheat (mean of 2 years)

Treatment	Grain yield (t/ha)	N content (%)				P content (%)			
		90 DAS	Straw	Grain	Spike straw	90 DAS	Straw	Grain	Spike straw
Varieties									
'HD 2851'	4.59	2.26	0.83	2.02	0.48	0.219	0.057	0.319	0.082
'HD 2687'	4.31	2.28	0.62	2.14	0.45	0.243	0.062	0.359	0.081
'HD 2967'	4.89	2.26	0.64	2.28	0.41	0.246	0.048	0.371	0.069
'PBW 343'	4.62	2.40	0.76	2.07	0.39	0.231	0.068	0.332	0.056
'HD 2894'	4.58	2.12	0.62	2.21	0.42	0.257	0.045	0.367	0.043
'HD 2932'	4.50	2.10	0.66	2.07	0.45	0.215	0.053	0.351	0.056
SEm±	0.11	0.025	0.01	0.03	0.015	0.0054	0.0006	0.0057	0.0006
CD (P=0.05)	0.30	0.09	0.045	0.09	0.05	0.0171	0.0018	0.0181	0.0019
Zinc fertilization									
Control (no Zn)	4.22	2.21	0.67	2.09	0.42	0.228	0.055	0.342	0.064
5.0 kg Zn/ha through $ZnSO_4.7H_2O$ as SA	4.62	2.21	0.68	2.12	0.43	0.233	0.055	0.347	0.065
2.5 kg Zn/ha through $ZnSO_4.7H_2O$ as SA + 0.5% foliar spray at MT and booting stage	4.70	2.25	0.69	2.15	0.44	0.238	0.056	0.353	0.065
2.5 kg Zn/ha through Zn-EDTA as SA	4.63	2.23	0.69	2.13	0.44	0.236	0.055	0.349	0.065
1.25 kg Zn/ha through Zn-EDTA as SA + 0.5 % foliar spray at MT and booting stage	4.73	2.28	0.70	2.16	0.45	0.241	0.057	0.358	0.064
SEm±	0.04	0.03	0.01	0.02	0.015	0.0046	0.0007	0.0053	0.0007
CD (P=0.05)	0.11	NS	NS	NS	NS	NS	NS	NS	NS

DAS, Days after sowing; SA, soil application; MT, maximum tillering; NS, non-significant and Mn concentrations in different parts of wheat was in the order of grain > spike straw > straw, straw > spike straw > grain and straw > grain > spike straw respectively (Tables 2, 3). Of the different varieties, 'HD 2851' exhibited the highest Zn concentration. The Mn concentrations was the highest in grain of 'HD 2894' wheat variety. How-

Table 2. Effect of varieties and zinc fertilization on potassium and zinc content at 90 DAS in different parts of wheat (mean of 2 years).

Treatment	K content (%)				Zn concentration (mg/kg dry matter)			
	90 DAS	Straw	Grain	Spike straw	90 DAS	Straw	Grain	Spike straw
Varieties								
'HD 2851'	2.36	1.77	0.405	0.715	61.4	25.1	40.6	42.3
'HD 2687'	2.85	1.71	0.480	0.675	58.4	23.8	38.1	20.9
'HD 2967'	2.97	2.05	0.425	0.810	56.3	21.8	38.7	32.4
'PBW 343'	2.93	1.61	0.390	0.900	62.7	24.4	38.0	20.9
'HD 2894'	2.91	2.06	0.415	1.080	63.5	24.7	38.0	24.0
'HD 2932'	2.49	1.79	0.430	0.785	61.8	22.8	35.8	20.2
SEm±	0.03	0.03	0.015	0.04	0.94	0.37	0.45	0.335
CD (P=0.05)	0.095	0.095	0.045	0.13	2.95	1.165	1.42	1.065
Zinc fertilization								
Control (no Zn)	2.72	1.79	0.420	0.790	57.45	22.20	35.35	26.05
5.0 kg Zn/ha through $ZnSO_4.7H_2O$ as SA	2.75	1.82	0.420	0.820	60.85	23.80	37.95	26.75
2.5 kg Zn/ha through $ZnSO_4.7H_2O$ as SA + 0.5% foliar spray at MT and booting stage	2.78	1.85	0.440	0.880	61.70	24.10	39.40	27.10
2.5 kg Zn/ha through Zn-EDTA as SA	2.74	1.84	0.425	0.815	61.05	24.15	38.45	26.95
1.25 kg Zn/ha through Zn-EDTA as SA + 0.5% foliar spray at MT and booting stage	2.8	1.88	0.415	0.835	62.15	24.45	39.85	27.30
SEm±	0.035	0.035	0.015	0.03	0.82	0.29	0.43	0.37
CD (P=0.05)	NS	NS	NS	NS	2.325	0.825	1.22	1.035

DAS, Days after sowing; SA, soil application; MT, maximum tillering; NS, non-significant

Table 3. Effect of varieties and zinc fertilization on manganese and iron concentration at 90 DAS in different parts of wheat (mean of 2 years).

Treatment	Mn concentration (mg/kg dry matter)				Fe concentration (mg/kg)			
	90 DAS	Straw	Grain	Spike straw	90 DAS	Straw	Grain	Spike straw
Varieties								
'HD 2851'	71.2	62.1	32.5	26.8	433.3	333.5	108.8	150.9
'HD 2687'	61.1	55.6	33.4	28.5	440.1	302.8	124.8	138.4
'HD 2967'	72.9	58.9	32.2	28.1	366.2	288.0	100.7	131.8
'PBW 343'	67.7	55.5	28.3	26.8	359.7	280.7	110.3	97.0
'HD 2894'	71.9	61.6	33.7	30.0	440.1	328.0	122.8	135.4
'HD 2932'	71.1	59.1	31.7	30.7	448.4	301.2	116.9	142.9
SEm±	1.14	0.94	0.77	0.54	5.5	4.6	2.6	1.5
CD (P=0.05)	3.6	2.95	2.44	1.72	17.4	14.6	8.2	4.7
Zinc fertilization								
Control (no Zn)	68.8	57.5	32.0	27.6	416.6	308.7	117	131.6
5.0 kg Zn/ha through $ZnSO_4.7H_2O$ as SA	69.0	58.8	32.7	28.2	420.1	300.6	112.9	132.4
2.5 kg Zn/ha through $ZnSO_4.7H_2O$ as SA + 0.5% foliar spray at MT and booting stage	68.8	59.4	31.6	28.8	415.1	310.0	115.5	133.1
2.5 kg Zn/ha through Zn-EDTA as SA	69.9	58.8	31.1	28.4	409.4	299.1	112.2	132.7
1.25 kg Zn/ha through Zn-EDTA as SA + 0.5% foliar spray at MT and booting stage	70.0	59.7	32.6	29.4	411.9	310.0	112.6	133.8
SEm±	0.99	0.82	0.68	0.62	6.30	5.59	2.74	1.32
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

DAS, Days after sowing; SA, soil application; MT, maximum tillering; NS, non-significant ever, the highest Fe concentration in grain was recorded in variety 'HD 2687'. The lowest Zn, Fe and Mn concentrations were recorded in grain of 'HD 2932', 'HD 2967' and 'PBW 343' varieties respectively. The higher Fe and Mn concentration in straw indicated that mobilization of these 2 nutrient elements are very less. Similar results were also reported by Prasad *et al.* (2012). Nawaz *et al.* (2015) also reported significant differences in micronutrient concentrations in different varieties of wheat. Application of Zn significantly increased Zn concentration among different parts of wheat with the highest concentration in treatment-soil 1.25 kg Zn/ha + foliar (0.5%) application of Zn-EDTA. However, Zn-fertilization failed to bring any significant effect on Fe and Mn concentration at different crop growth stages and in different parts of wheat.

Nutrient uptake

Significant differences were recorded in N, P, K, Zn, Fe and Mn uptake by different varieties of wheat (Table 4). Among the tested varieties of wheat, the highest uptake of N, P, K, Zn, Fe and Mn was registered in 'HD 2967', 'HD 2967', 'HD 2894', 'HD 2967', 'HD 2894' and 'HD 2894' varieties respectively. Nawaz *et al.* (2015) also reported significant differences in nutrient uptake in different wheat varieties. Higher uptake of macro and micro-nutrients were recorded in Zn-applied plots in comparison to the control plot. Higher N, P, K, Zn, Fe and Mn uptake were registered in soil + foliar application of Zn over soil application alone. Zn-EDTA significantly increased uptake of different nutrients than $ZnSO_4.7H_2O$. The highest nutrient uptake was recorded with application of 1.25 kg Zn/ha through Zn-EDTA as soil application + 0.5% foliar spray at maximum tillering and booting stages followed by 2.5 kg Zn/ha through $ZnSO_4.7H_2O$ as soil application + 0.5% foliar spray at the maximum tillering and booting stages. The Zn-fertilization significantly increased uptake of macronutrients and micronutrients because of increased growth and biomass production owing to high availability of Zn in treated plots as compared to the control and finally resulted in higher grain yield and uptake of macro and micro-nutrients. Higher uptake of nutrients under Zn-EDTA applied plots as compared to $ZnSO_4.7H_2O$ might be owing to higher availability of Zn in soil as chelated Zn does not participate in harmful reaction as occurred in $ZnSO_4.7H_2O$ applied Zn. The Zn applied through $ZnSO_4.7H_2O$ reacts easily with other elements in the soil and converts in the unavailable form to plant uptake, resulting in less availability as compared to chelated Zn. Due to higher availability of chelated Zn in soil, the higher uptake of nutrients in chelated Zn applied treatments was also reported by Qadir *et al.* (2014).

On the basis of 2 years experimentation, it can be concluded that concentration and uptake of macro and micro-nutrients differ significantly among wheat varieties. Soil

Table 4. Effect of varieties and zinc fertilization on uptake of different nutrient in wheat (mean of 2 years)

Treatment	Total nutrient uptake					
	N (kg/ha)	P (kg/ha)	K (kg/ha)	Fe (kg/ha)	Mn (g/ha)	Zn (g/ha)
Varieties						
'HD 2851'	143.0	18.6	119.2	2.46	516.0	366.3
'HD 2687'	134.3	20.3	120.8	2.41	495.5	332.4
'HD 2967'	153.3	22.1	134.0	2.22	517.5	371.9
'PBW 343'	148.2	20.4	122.5	2.35	511.2	360.5
'HD 2894'	146.1	20.2	155.5	2.80	583.0	362.2
'HD 2932'	142.1	20.0	143.5	2.67	568.0	336.7
SEm±	3.14	0.63	4.75	0.095	15.89	9.18
CD (P=0.05)	9.90	1.99	14.98	0.29	50.07	28.9
Zinc fertilization						
Control (no Zn)	132.7	18.5	126.1	2.43	502.6	310.9
5.0 kg Zn/ha through $ZnSO_4.7H_2O$ as SA	143.5	20.2	126.8	2.38	521.6	352.7
2.5 kg Zn/ha through $ZnSO_4.7H_2O$ as SA + 0.5% foliar spray at MT and booting stage	149.0	21.0	136.7	2.56	544.5	372.6
2.5 kg Zn/ha through Zn-EDTA as SA	145.6	20.4	132.9	2.45	530.8	359.9
1.25 kg Zn/ha through Zn-EDTA as SA + 0.5 % foliar spray at MT and booting stage	151.7	21.3	140.5	2.60	559.9	378.6
SEm±	1.83	0.30	4.04	0.06	11.96	4.76
CD (P=0.05)	5.21	0.85	11.48	0.165	34.02	13.55

SA, soil application; MT, maximum tillering

(1.25 kg Zn/ha) + foliar application (0.5%) of Zn-EDTA was found superior with respect to macro and micro-nutrients uptake.

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