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A comparative study of Zn and Fe distribution in two contrasting wheat genotypes

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Abstract: Effect of zinc and iron interaction on their distribution was examined in two wheat genotypes (UP262 and UP2628) under foliar application of 0, 0.25 and 0.50% $ZnSO_4$ solution tagged with 925 KBq of Zn^{65} pot^{-1} for Zn and 0, 0.5 and 1.0% $FeSO_4$ solution tagged with 925 KBq of Fe^{59} pot^{-1} for Fe at 30, 60 and 90 days after planting. Maximum grain yield of UP2628 (2.7 g pot^{-1}) was recorded at 0.5%$ZnSO_4$+0%$FeSO_4$ while that of UP262 (2.63 g pot^{-1}) was recorded at 0.5%$ZnSO_4$+1.0%$FeSO_4$. The highest straw yield of UP2628 (2.75 g pot^{-1}) was noted at 0.5% $ZnSO_4$+1.0%$FeSO_4$ while that of UP262 (2.91 g pot^{-1}) with 0.5%$ZnSO_4$+0.5%$FeSO_4$. Application of 0.5% and 1.0% $FeSO_4$ reduced the accumulation of ^{65}Zn in all parts of both the varieties. Regarding the ^{59}Fe accumulation, it was found to be decreased with the increased application of $ZnSO_4$ solution from 0.25% and 0.5% as compared to without application of Zn. On comparing translocation efficiencies of both the varieties, UP2628 showed better translocation thus accumulated higher zinc and iron. Therefore, variety UP2628 can be used further for crop improvement programme.

Keywords: Foliar application, Fe , Translocation, Wheat, Zn

INTRODUCTION

Humans require at least 49 nutrients to meet their metabolic requirements (Prakash *et al*., 2016). Inadequate consumption of even a single of these nutrient results in adverse metabolic disturbances such as sickness, poor health, impaired development in children, etc. (Welch and Graham, 2004). Populations residing in developing countries consume cereals as primary food components. Poor grain nutritive value of cereals is an important reason for widespread micronutrient malnutrition among populations eating rice as a staple food (Chandel *et al*., 2010). Besides, the plant-derived food contains a wide variety of minerals that may have beneficial or detrimental effects on human health and well being. Of the 17 micronutrients, the deficiencies of iron (Fe) and zinc (Zn) alone in human foods affect a large proportion of the world's population (Shahzad *et al*., 2014). The key reasons for human mineral malnutrition are the relatively low content of Fe and Zn in plant based foods in combination with the abundance of antinutrient compounds that severely reduce their bioavailability (Ghandilyan *et al*., 2006).

The main soil factors responsible for causing micronutrients deficiency in staple food crops are low content of nutrient itself, soil pH, high content of calcite, a high concentration of bicarbonate ions and salts, high level of available phosphorus and interaction with another nutrient element (Mathpal *et al*., 2015). The critical value of Zn to occur its deficiency in soil was found in the range of 0.6 ppm to 2.0 ppm depending upon extraction method (Singh *et al*., 2005) while for Fe it was reported 3.4 mg kg^{-1} (Elgala *et al*., 2008). Interactions among micronutrients affect their uptake, distribution, and utilization in plants (Imtiaz *et al*., 2003). Many studies have examined these interactive effects, especially between Fe and Zn. These studies showed antagonism between Fe and Zn in soybean (Sliman, 1990). Other studies reported that Fe reduces Mn concentration in Indian mustard (Hamlin *et al*., 2008) and in soybean leaves (Izaguirre-Mayoral *et al*., 2005), but increases Mn concentration in soybean shoots (Heenan and Campbell, 1983). Other studies reported a negative correlation between Zn and Cu (Kumar *et al*., 2009) and a negative correlation was reported between Zn and Fe in wheat (Ai-Qing *et al*., 2011).

As cereals are the major food source for humans, therefore an attempt has been made through present investigation to evaluate the translocation pattern and accumulation of ^{65}Zn and ^{59}Fe in two contrasting

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wheat genotypes.

MATERIALS AND METHODS

A bulk surface (0-15 cm) soil (Typic Hapludoll) was collected by a square method from E1 plot of Norman E. Borlauge Crop Research Center, G. B. Pant University of Agriculture and Technology, Pantnagar, India. The experimental soil had sandy loam texture, 7.4 pH and 0.266 dSm^{-1} E.C., 10.5 g organic C, 0.47 mg DTPA extractable Zn kg^{-1} soil and 25.3 mg DTPA extractable Fe kg^{-1} soil. The seeds of two contrasting genotypes of wheat viz. UP262 (Zn inefficient) and UP2628 (Zn efficient) were obtained from the Department of Genetics and Plant Breeding of the University.

The soil was air dried and crushed with a wooden roller and passed through a sieve having openings of 2 mm diameter. The soil was filled in plastic pots of 4 kg capacity. A basal dose of nitrogen, phosphorus and potassium were applied to all pots at the rate of 22.3 mg N, 11.6 mg P and 18.5 mg K kg^{-1} soil using stock solutions of urea, KH_2PO_4 and KCl, respectively. Five seedlings were planted in each pot. The foliar spray treatments consisted of factorial combination of 0, 0.25, 0.5% $ZnSO_4$ solution tagged with 925 KBq of ^{65}Zn pot^{-1} and 0, 0.5, 1.0% $FeSO_4$ solution tagged with 925 KBq of ^{59}Fe pot^{-1} at 30 (tillering), 60 (panicle initiation) and 90 (grain filling) days after sowing in triplicate. For each foliar spray of Zn and Fe solution, 10 ml volume was used per pot. The experimental design was three factorial completely randomized designs.

At maturity (115-120 days after sowing), the plants were harvested, and the aerial parts of the plant were partitioned into leaves, stem and grains. Plant samples were washed with tap water, 0.1N HCl and subsequently with distilled water to remove the surface contamination. Then the samples were dried, and 1g of each plant part was digested in di-acid (HNO_3: $HClO_4$ in 10:4 v/v) (Pirzadeh *et al*., 2010) and final volume was made upto 14 ml with double distilled water. Two ml aliquot of the digested sample was used to assay activities of ^{65}Zn and ^{59}Fe on gamma ray spectrometer with NaI crystal (model GRS 101P). Activity was expressed as cpm g^{-1} dry weight of plant sample. After recording the activities final volume of this two ml aliquot was made 10 ml and concentration of Zn and Fe was recorded in grains by atomic absorption spectrophotometer (AAS, ECIL, Hyderabad India).

The experiment was carried out in three factorial completely randomized design and statistical analysis of all the parameters was done by using analysis of variance (ANOVA) using SPSS 16 (Bristol, UK). The means were tested at the $P \leq 0.05$ level of significance.

RESULTS AND DISCUSSION

Counts per minute of ^{65}Zn and ^{59}Fe: The counts per minute of ^{65}Zn in leaves, stem and grain of two wheat genotypes at maturity are presented in Table 1. The varieties were significantly different in the accumulation of ^{65}Zn in different plant parts and UP2628 accumulated more ^{65}Zn (10% more in leaf, 26.8% more in the stem and 35.7% more in grain) as compared to UP262. Similarly, Zn levels also influenced the accumulation of ^{65}Zn significantly, and it was found improved in all the plant parts with increasing Zn levels. The application of 0.5% Zn sulphate solution increased the ^{65}Zn accumulation by 5.6% in leaves, 16.7% in the stem and 7.4% in grains as compared to 0.25% Zn sulphate solution. The application of increasing levels of ferrous sulphate decreased the accumulation of ^{65}Zn in all the plant parts except the stem. The application of 0.5% and 1.0% ferrous sulphate solution decreased the accumulation of ^{65}Zn in leaves by 12.7 and 14.9%, in grains by 1.7 and 3.1% respectively, as compared to 0 level of ferrous sulphate solution. In stem somewhat

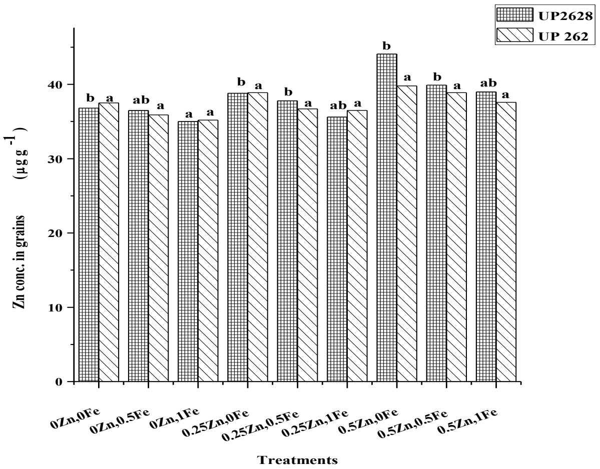

Fig. 1. *Effect of foliarly applied zinc and iron levels on zinc concentration (µg g^{-1}) in grains of two contrasting wheat genotypes.*

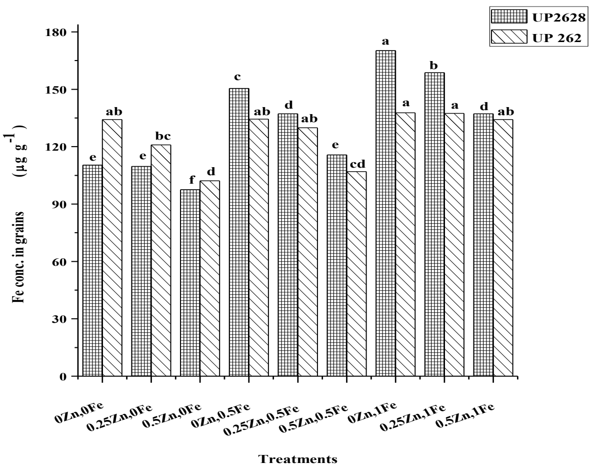

Fig 2. *Effect of foliarly applied zinc and iron levels on iron concentration (µg g^{-1}) in grains of two contrasting wheat genotypes.*

Table 1. Effect of different levels of zinc and iron on distribution of ^{65}Zn (counts per minute) in different plant parts of two contrasting wheat genotypes.

A. Leaves									
Fe levels (%)	**UP2628**			**UP262**			**Zn x Fe interaction**		
	Zn levels (%)			**Zn levels (%)**			**Zn levels (%)**		
	0.25	**0.50**	**Av.**	**0.25**	**0.50**	**Av.**	**0.25**	**0.50**	**Av.**
0.0	10219	10344	10281	9844	10969	10406	10031	10656	10343
0.5	9375	10438	9905	6906	9375	8140	8141	9906	9023
1.0	8938	10000	9469	9500	6750	8125	9219	8375	8797
Av.	9510	10260	9885	8750	9031	8890	9130	9645	9387
Effect	**V**	**Zn**	**Fe**	**V x Zn**	**Zn x Fe**	**V x Fe**	**V x Zn x Fe**		
S.Em. ±	81	81	99	115	141	141	199		
LSD at ≤0.05	197	197	241	NS	342	342	483		
B. Stem									
Fe levels (%)	**UP2628**			**UP262**			**Zn x Fe interaction**		
	Zn levels (%)			**Zn levels (%)**			**Zn levels (%)**		
	0.25	**0.50**	**Av.**	**0.25**	**0.50**	**Av.**	**0.25**	**0.50**	**Av.**
0.0	2079	2723	2401	1449	2069	1759	1764	2396	2080
0.5	2636	2342	2489	1736	1733	1734	2186	2037	2111
1.0	1922	2454	2188	1484	1883	1683	1703	2168	1935
Av.	2212	2506	2359	1556	1895	1725	1884	2200	2042
Effect	**V**	**Zn**	**Fe**	**V x Zn**	**Zn x Fe**	**V x Fe**	**V x Zn x Fe**		
S.Em. ±	18	18	22	25	31	31	44		
LSD at ≤0.05	44	44	54	NS	76	76	108		
C. Grains									
Fe levels (%)	**UP2628**			**UP262**			**Zn x Fe interaction**		
	Zn levels (%)			**Zn levels (%)**			**Zn levels (%)**		
	0.25	**0.50**	**Av.**	**0.25**	**0.50**	**Av.**	**0.25**	**0.50**	**Av.**
0.0	1040	1197	1118	672	767	719	856	982	919
0.5	1064	1103	1083	711	735	723	887	919	903
1.0	1054	1145	1099	690	672	681	872	908	890
Av.	1052	1148	1100	691	724	707	871	936	903
Effect	**V**	**Zn**	**Fe**	**V x Zn**	**Zn x Fe**	**V x Fe**	**V x Zn x Fe**		
S.Em. ±	7	7	9	10	13	13	18		
LSD at ≤0.05	18	18	NS	26	32	NS	NS		

unexpected results were recorded, where the application of 0.5% ferrous sulphate increased the ^{65}Zn accumulation by 1.4% while a further reduction of 6.9% was found by the application of 1.0% level of ferrous sulphate. The interaction effect of variety × Zn × Fe influenced the accumulation of ^{65}Zn in leaves and stem significantly however no significant effect was observed in the grains. Similarly, foliarly applied solutions of 0.25% and 0.5% Zn sulphate at 0.5% ferrous sulphate solution increased the accumulation of ^{65}Zn in leaves and grains while a slight reduction was recorded in stem. Foliar spray of 0.25% and 0.5% Zn sulphate solution at 1.0% ferrous sulphate enhanced the accumulation of ^{65}Zn in all the plant parts of UP2628 but in UP262 these were found effective in improving the ^{65}Zn in stem only.

Accumulation of ^{59}Fe in leaves, stem and grain of both wheat varieties was significantly affected by different ferrous sulphate levels (Table 2). Regarding the variety, UP2628 accumulated higher ^{59}Fe (6.5% in leaf, 7.5% in the stem and 16% in grain) as compared to UP262. The accumulation of ^{59}Fe increased with the increase in Fe concentration from 0.5% to 1.0% ferrous sulphate by 5.2 percent in the stem, by 3.9 percent in grains for both the varieties except in the leaves where the accumulation was reduced at 1.0% ferrous sulphate solution as compared to 0.5% ferrous sulphate. However, the main effect of Zn levels was found to be statistically non-significant on ^{59}Fe accumulation. The interaction effect of variety × Zn × Fe significantly influenced the ^{59}Fe accumulation in stem while the effect was statistically not significant in leaves and grains of both the varieties. After comparing both the varieties under all the levels of Zn and Fe, it was depicted that at 0% level of zinc sulphate, foliar spray of 0.5% and 1.0% ferrous sulphate solution increased the accumulation of ^{59}Fe in all the plant parts except in leaves of UP262. Similarly, at 0.25% zinc sulphate solution the foliar application of 0.5% and 1.0% ferrous sulphate solution increased the ^{59}Fe accumulation in all the plant parts except in leaves of UP262. The foliar application of 0.5% and 1.0% ferrous sulphate at 0.5% zinc sulphate level solution enhanced the accumulation of ^{59}Fe in stem and grains but reduced in the leaves of both the varieties.

The results clearly indicated that UP2628 accumulated higher Zn in all the plant parts in comparison to UP262. Therefore, it could be concluded that variety

Table 2. Effect of different levels of zinc and iron on distribution of ^{59}Fe (counts per minute) in different plant parts of two contrasting wheat genotypes.

A. Leaves												
Fe levels (%)	**UP2628**				**UP262**				**Zn x Fe interaction**			
	Zn levels (%)				**Zn levels (%)**				**Zn levels (%)**			
	0.00	**0.25**	**0.50**	**Av.**	**0.00**	**0.25**	**0.50**	**Av.**	**0.00**	**0.25**	**0.50**	**Av.**
0.50	2798	2776	2713	2762	2760	2726	2713	2733	2779	2751	2713	2747
1.00	2820	2810	2670	2766	2466	2364	2479	2436	2643	2587	2574	2601
Av.	2809	2793	2691	2764	2613	2545	2596	2584	2711	4044	2643	3132
Effect	**V**	**Zn**	**Fe**	**V x Zn**		**Zn x Fe**		**V x Fe**		**V x Zn x Fe**		
S.Em. ±	33	40	33	57		47		57		81		
LSD at ≤0.05	80	NS	80	NS		NS		139		NS		
B. Stem												
Fe levels (%)	**UP2628**				**UP262**				**Zn x Fe interaction**			
	Zn levels (%)				**Zn levels (%)**				**Zn levels (%)**			
	0.00	**0.25**	**0.50**	**Av.**	**0.00**	**0.25**	**0.50**	**Av.**	**0.00**	**0.25**	**0.50**	**Av.**
0.50	831	805	789	808	742	745	770	752	786	775	779	780
1.00	842	860	869	857	771	803	785	786	806	832	827	821
Av.	836	832	829	832	756	774	777	769	796	803	803	800
Effect	**V**	**Zn**	**Fe**	**V x Zn**		**Zn x Fe**		**V x Fe**		**V x Zn x Fe**		
S.Em. ±	1.8	2.2	1.8	3.1		2.5		3.1		4.4		
LSD at ≤0.05	4.3	NS	4.3	7.6		6.2		7.6		10.7		
C. Grain												
Fe levels (%)	**UP2628**				**UP262**				**Zn x Fe interaction**			
	Zn levels (%)				**Zn levels (%)**				**Zn levels (%)**			
	0.00	**0.25**	**0.50**	**Av.**	**0.00**	**0.25**	**0.50**	**Av.**	**0.00**	**0.25**	**0.50**	**Av.**
0.50	247	248	253	249	212	211	214	212	229	229	233	230
1.00	274	262	257	264	219	213	210	214	247	237	234	239
Av.	260	255	255	256	215	212	212	213	238	233	233	234
Effect	**V**	**Zn**	**Fe**	**V x Zn**		**Zn x Fe**		**V x Fe**		**V x Zn x Fe**		
S.Em. ±	2.1	2.6	2.1	3.7		3.0		3.7		5.3		
LSD at ≤0.05	5.2	NS	5.2	NS		NS		9.1		NS		

UP2628 showed better uptake as well as translocation efficiency than UP262. Accumulation of Zn was found to increase with increasing zinc sulphate levels, but the increasing ferrous sulphate levels showed an antagonistic effect in all the plant parts except in stem of UP2628 and UP262. Like in case of ^{65}Zn accumulation, UP2628 accumulated more ^{59}Fe in all the plant parts as compared to UP262. The accumulation of Fe was increased with increasing levels of ferrous sulphate in all the plant parts except that in leaves of UP262. The increasing levels of zinc sulphate reduced the ^{59}Fe accumulation in leaves, stem and grains of both wheat varieties except in the stem of UP262. The reduced accumulation of ^{59}Fe in different plant parts under varying levels of Zn and vice versa might be due to the antagonistic interaction between both the elements at the uptake site and along the long distance transport (Alloway, 2008). It was reported that application of 8 mg Fe kg^{-1} soil decreased the uptake of Zn by 31.9% in wheat in comparison to its no application (Ghasemi-Fasaei and Ronaghi, 2008). Similarly, it was also shown by (Ai-Qing *et al*., 2011) that an increase in Fe supply from 0 ppm to 5 ppm reduced the Zn content in stem and leaves of wheat plant by a factor of one-fifth to two-fifths while a reduction in Fe accumulation in different plant parts of wheat was also recorded with the application of 10 ppm of Zn as compared to 0 ppm. High concentration of Fe in soil was also found to reduce uptake and translocation of Zn in different crop plants (Das, 2014). Likewise, above mentioned results also find support of the study done by (Chilian *et al*., 2015), who reported that increasing levels of Zn were also found to reduce accumulation of Fe in different plant parts of corn.

Grain yield and straw yield: The main effect of zinc levels and interaction effect of variety × iron on grain yield was found to be statistically significant (Table 3). The foliar application of 0.25% and 0.5% zinc sulphate solution increased the mean grain yield of both the wheat varieties by 1.7 and 4.9 percent over no application of zinc sulphate respectively. The application of 0.5% and 1.0% ferrous sulphate solution increased the grain yield by 0.92 and 11.5 percent in UP262 while in UP2628, 0.5% level of ferrous sulphate increased the grain yield by 2.5 percent but at higher level (1.0%) of ferrous sulphate a reduction of 1.7 percent was observed as compared to no application of ferrous sulphate. Overall, the maximum (2.70 g pot^{-1}) grain yield was recorded at 0.5%Zn+0%Fe for UP2628 while the minimum (1.86 g pot^{-1}) was also recorded for UP2628 at 0%Zn+0%Fe.

Zinc and iron significantly affect the straw yield of both wheat varieties (table 4). Foliar application of 0.25% and 0.5% level of zinc sulphate increased the

Table 3. Effect of different levels of zinc and iron on grain yield (g pot^{-1}) of two contrasting wheat genotypes.

Fe levels (%)	UP2628				UP262				Zn x Fe interaction			
	Zn levels (%)				Zn levels (%)				Zn levels (%)			
	0.00	0.25	0.50	Av.	0.00	0.25	0.50	Av.	0.00	0.25	0.50	Av.
0.0	1.86	2.39	2.70	2.31	1.98	2.08	2.45	2.17	1.92	2.23	2.57	2.24
0.5	2.02	2.46	2.64	2.37	1.91	2.31	2.35	2.19	1.97	2.39	2.50	2.28
1.0	1.94	2.38	2.51	2.27	2.16	2.48	2.63	2.42	2.05	2.43	2.57	2.35
Av.	1.94	2.41	2.61	2.32	2.01	2.29	2.47	2.25	1.98	2.35	2.54	2.29
Effect	**V**	**Zn**	**Fe**	**V x Zn**		**Zn x Fe**		**V x Fe**		**V x Zn x Fe**		
S.Em. ±	0.03	0.04	0.04	0.06		0.06		0.07		0.10		
CD at 5%	NS	0.12	NS	NS		NS		0.21		NS		

Table 4. Effect of different levels of zinc and iron on straw yield (g pot^{-1}) of two contrasting wheat genotypes.

Fe levels (%)	UP2628				UP262				Zn x Fe interaction			
	Zn levels (%)				Zn levels (%)				Zn levels (%)			
	0.00	0.25	0.50	Av.	0.00	0.25	0.50	Av.	0.00	0.25	0.50	Av.
0.0	2.34	2.43	2.52	2.43	2.07	2.59	2.71	2.45	2.20	2.51	2.61	2.44
0.5	2.35	2.50	2.74	2.53	2.31	2.50	2.91	2.57	2.33	2.50	2.83	2.55
1.0	2.31	2.53	2.75	2.47	2.37	2.56	2.82	2.58	2.34	2.55	2.79	2.56
Av.	2.33	2.48	2.67	2.49	2.25	2.55	2.81	2.53	2.29	2.52	2.74	2.51
Effect	**V**	**Zn**	**Fe**	**V x Zn**		**Zn x Fe**		**V x Fe**		**V x Zn x Fe**		
S.Em. ±	0.03	0.03	0.03	0.05		0.05		0.06		0.09		
CD at 5%	NS	0.10	0.10	NS		NS		NS		NS		

mean straw yield of wheat varieties by 4.5 and 4.9 percent respectively over no application of zinc sulphate. Similarly, the foliar application of 0.5% and 1.0% ferrous sulphate solution also increased the straw yield by 10.0 and 19.6 percent as compared to no application of ferrous sulphate solution, respectively. In general, the highest straw yield was recorded in UP262 under 0.5%Zn+0.5% Fe levels of zinc and iron whereas the lowest was also recorded in UP262 at 0%Zn+0%Fe level. Statistical analysis revealed the main effect of variety and interaction effect of variety × zinc × iron had no significant effect on straw yield of both the wheat varieties.

An increase in zinc and iron levels increased the mean grain yield of both the wheat varieties. Regarding straw yield, both the varieties responded well under foliar application of zinc and iron but UP262, a zinc inefficient variety produced more straw yield as compared to UP2628, a zinc efficient variety. A better response regarding grain yield of wheat was reported when zinc and iron were applied in combination as compared to the individual application of each (Habib, 2009). Similar results have been also reported by (Seilsepour, 2007) and (El-Majid *et al.*, 2000). Seilsepour (2007) found that the mean grain yield of wheat was found to be enhanced by combined application of zinc and iron in comparison to their individual use (317 mg kg^{-1} iron and 330 mg kg^{-1} zinc).

Zn and Fe content in grains: Zinc levels significantly affect the grain Zn content of both the varieties (Fig 1). The mean Zn content of both the varieties increased with increasing Zn levels. The foliar spray of 0.25% and 0.5% zinc sulphate solution increased the mean Zn content by 2.7 and 10.5 percent as compared to 0 level of zinc sulphate. The application of 0.5% and 1.0% ferrous sulphate solution decreased the mean Zn content by 5.5 and 7.9 percent, respectively in comparison to no application of ferrous sulphate. The main effect of Fe, variety and the interaction effect (variety × Zn × Fe) were found statistically non significant regarding their influence on grain Zn content. Overall, the maximum (44.1 µg g^{-1}) Zn content was recorded at 0% Fe+0.5% Zn in UP2628 whereas the minimum (35.0 µg g^{-1}) was also recorded in variety UP2628 at 0% Zn+1.0% Fe.

Zinc and Fe levels significantly affect the Fe content in grains of both contrasting wheat genotypes (Fig 2). Both the varieties were significantly different from each other with respect to Fe content in their grains. The mean Fe content of both the varieties increased with increasing Fe levels. The foliar application of 0.5% and 1.0% ferrous sulphate solution increased the Fe content by 14.7 and 29.6 % as compared to without application of ferrous sulphate, respectively. The interaction effect of variety × Zn × Fe influenced Fe content in grains significantly. The foliar application of 0.25% and 0.5% zinc sulphate solutions at 0% ferrous sulphate decreased the Fe content by 0.6% and 11.6% in UP2628 and by 9.9% and 23.8% in UP262, respectively. Similarly, at 0.5% ferrous sulphate, the foliar spray of 0.25% and 0.5% zinc sulphate solution reduced the Fe content in UP2628 by 8.8 and 23.1% while in UP262 the percent reduction was 3.3 and 20.3%, respectively. At 1.0% ferrous sulphate level, a reduction of 6.8 and 19.4% was recorded in UP2628 by the foliar application of 0.25% and 0.5% zinc sulphate solution respectively, whereas in UP262 the reduction of 0.2 and 2.5% was found. Overall, the highest Fe content was recorded in both the varieties at a combination of 0% Zn+1.0% Fe while the minimum was recorded under the combination of 0% Zn+0.5% Fe for both the varieties.

The data on the Zn content depicted that grain Zn content of both the varieties increased with increasing (0% to 0.5%) Zn levels and whatever the reduction in Zn content was recorded most probably due to increased (0% to 1.0%) levels of Fe in both the varieties. Similarly, increasing Zn levels decreased the Fe content in grains of both the wheat varieties. Antagonistic interaction of Zn and Fe was revealed by three mechanisms like a competition between Zn and Fe with each other for the active site, interference in the process of chelation during Fe uptake and translocation and competition between both the micronutrient during xylem unloading (Ai-Qing *et al*., 2011). We found the support of (Ghasemi-Fasaei and Ronaghi, 2008), who revealed that soil application of 8 mg Fe kg^{-1} soil decreased the mean uptake of Zn by 31.9 % in two wheat genotypes in comparison to its zero application. It was also reported that high concentration of Fe in the medium hampered availability and uptake of Zn (Das, 2014). A reduction in Fe concentration in different plant parts under increasing regimes of Zn was also reported by (Chilian *et al*., 2015).

Conclusion

An unambiguous antagonism between Zn and Fe distribution was observed in both contrasting wheat genotypes but UP2628, a Zn efficient variety, exhibited better uptake and translocation efficiency, thus accumulated higher Zn and Fe as compared to UP262. Irrespective of varietal effect, treatments 0.5% Zn+0% Fe and 0% Zn+1.0% Fe can be used for better availability of Zn & Fe respectively. More Zn efficient varieties can be identified based on their better uptake and translocation efficiencies and can also be incorporated in crop improvement programmes to solve the worldwide problem of micronutrient deficiency.

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