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Effects of Soil and Foliar Application of Zn Fertilizer on Yield and Growth Characteristics of Bread Wheat (*Triticum aestivum* L.) Cultivars

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Abstract: In order to investigate role of zinc application (soil + foliar application) on growth traits, yield, its concentration and accumulation in wheat leaves and grains, two common cultivars of wheat namely Tajan and Nye 60 have been selected. Four zinc fertilizer levels including Zn0 (no zinc fertilizer), Zn1 (5 kg Zn ha^{-1} in soil + 300 g Zn ha^{-1} in foliar application), Zn2 (10 kg Zn ha^{-1} in soil + 600 g Zn ha^{-1} in foliar application) and Zn3 (15 kg ha^{-1} in soil + 900 g Zn ha^{-1} in foliar application) both from zinc sulfate source have been applied in planting and booting stage in soil and as foliar application. A pot experiment was conducted as a factorial design with 3 replications during 2005. Results showed that using zinc caused increasing effects on grain yield, total dry matter, yield, 1000 grain weight, number of tiller, grain zinc content, flag leaf zinc content, plant height, number of node, protein content and grain Fe content. Number of tiller, grain zinc content and percentage of protein were higher in Tajan cultivar than Nye 60. In other hands, Nye 60 had higher grain yield and 1000 grain weight than Tajan, however, other measured traits showed no significant difference.

Key words: wheat, zinc fertilizer, foliar application, zinc concentration

INTRODUCTION

Zinc deficiency is a global nutritional constraint for plant growth, particularly in calcareous soils of arid and semi arid regions (Takkar and Walker, 1993). One of the most important micronutrient deficiencies is attributed to zinc deficiency that is a worldwide problem in human nutrition. More than 2 billion people suffer from micronutrient deficiency including zinc deficiency (Graham and Welch, 1996; Welch and Graham, 1999). The major reasons for the widespread occurrence of Zn deficiency in humans, especially in developing countries is a high proportion of cereal-based foods in the human being daily diet (Erdal *et al*., 2002). Zinc deficiency causes a number of health problems like impairment in linear growth, sexual maturation, learning ability, immune functions and the central nervous system (Prasad, 1984; Tamura and Goldenberg, 1996). Selection and breeding of plant genotypes for higher resistance against Zn deficiency is a realistic and long-term solution to overcome Zn deficiency in soils (Graham and Rengel, 1993; Bouis, 1995). Breeding genotypes for resistance to Zn deficiency may, however, take considerable time. Therefore, Zn fertilization is still a widely used agronomic practice for farmers to correct Zn deficiency (Yilmaz *et al*., 1997).

Wheat as one of the most critical nutrient sources for human and animals plays an important role in production of food combinations worldwide. Among necessary elements for growth and development, Zn has been considered as one of fundamental elements for natural growth of wheat and other crops. Zinc also plays tremendous role for increasing Fe concentration which, in turn, is an integral part of many proteins and enzymes that maintain good health (Quary *et al*., 2006). Zinc deficiency have tremendously affected on growth and cause severe yield losses. Soils with low organic material and pH of above 7 have potentially high zinc deficiency and in such a situation the problem is easily fixable using insoluble zinc granule fertilizers (Amrani *et al*., 1997, 1999). Application of 23 kg Zn ha^{-1} has 37% increased grain yield of various wheat cultivars (Torun *et al*., 2001). Application of zinc in soil corresponding with its foliar application caused an increasing in yield, dry matter and number of tiller per square meter. Furthermore, zinc concentration in shoot and grains have increased under influence of zinc application (Yilmaz *et al*., 1997). Kata and Higgs (2001) have suggested that foliar zinc application causes in tomato an increase in leaf zinc concentration and decrease in leaf iron concentration. Gangloff *et al*. (2002) found that in maize plants application of zinc sulfate has increased dry matter and leaf and grain zinc accumulation. Also, Ebrahim and Aly (2004) found that foliar application of zinc fertilizer increased leaf zinc accumulation and grain protein content of wheat plants. Finally, application of zinc on soil increased growth, yield

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and leaf zinc concentration in pepper (Aktas *et al*., 2006). This study is going to consider zinc application roles in growth, yield, leaves and grain zinc concentration of wheat cultivars.

MATERIALS AND METHODS

To consider effects of zinc fertilizer application (soil + foliar) on plant growth, yield, zinc concentration of leaf and grain, two commonly-grown wheat cultivars in Mazandaran province of Iran, i.e., Tajan and Nye 60, have been used in 2005 growing season. Four zinc fertilizer levels in soil with 0, 3, 6 and 9 mg Zn kg^{-1}(nearly 0, 5, 10 and 15 kg Zn ha^{-1}) in addition 4 zinc fertilizer levels as foliar application with concentration of 0.0, 0.1, 0.2 and 0.3% (roughly 0, 100, 200 and 300 g ha^{-1}) from zinc sulfate source ($ZnSO_4$. $7H_2O$) have been utilized simultaneously on plants grown in a pot experiment as a factorial design with 3 replications [24 pots (10 inches diameter) including 2 cultivars, 4 zinc treatments and 3 replications]. Zinc application treatments used in present experiment were Zn0 (no zinc fertilizer), Zn1 (5 kg Zn ha^{-1} in soil + 300 g Zn ha^{-1} in foliar application), Zn2 (10 kg Zn ha^{-1} in soil + 600 g Zn ha^{-1} in foliar application) and Zn3 (15 kg ha^{-1} in soil + 900 g Zn ha^{-1} in foliar application). The fertilizers in soil and foliar application have been added in planting time and booting stage, respectively. Type of soil texture, amount of total nitrogen, organic matters, lime, pH and available Zn in soil were determined prior to planting time (Table 1).

Ten seeds were sown in each pot and only 5 plants per pot were used and the rest were removed. To spray as foliar application distilled water were used and pots were watered with EC = 560 μmhos cm^{-1} 5 days intervals to reach to field capacity. Also, 100 kg ha^{-1} triple super phosphate, 50 kg ha^{-1} potassium sulfate and 75 kg nitrogen ha^{-1} from urea source have been applied. The experimental soil has been taken from top layer and it contains considerable lime but low available zinc. A number of physical and chemical properties of this experimental soil have been shown in Table 1.

At maturity, number of tiller, plant height, length and width of flag leaf, number of node, length of spike, length of awn, dry matter weight, grain yield, 1000 grain weight has been measured. At maximum growth stage all plants of each pot were harvested and above mentioned traits were determined.

The amount of grain protein content (using Kjeldhal method) accumulated Zn and Fe concentration in flag leaf and grains has been determined. To determine Zn concentration in leaf and grain, after drying at 60°C and grinding, seed and leaves samples were changed to ash at 550°C for 8 h and then the ashes were dissolved in 3.3% HCl (v/v) to determine Zn and Fe by an atomic absorption spectrometer (Varian SpectrAA-10). Statistical analysis has been conducted using MSTAT C statistical software and means were compared by Duncan's multiple range test.

RESULTS AND DISCUSSION

Analysis of variance of growth characteristics, yield and yield components have clearly confirmed the existence of highly significant differences between two studied cultivars for yield, 1000 grain weight, number of tillers, amount of zinc concentration in grain and grain protein contents (Table 2). Application of zinc fertilizer demonstrated various directions of significant differences for grain yield, dry matter weight, 1000 grain weight, number of tillers, grain Zn content, flag leaf Zn content, height, number of nodes, grain protein content and grain Fe content, however, effects of zinc on other measured characters were not significant. Interaction between zinc application and cultivars were significant in all measured characters except spike and awn lengths (Table 2). In proceed to the previous studies (Kalayci, 1993; Cakmak *et al*., 1996; Yilmaz *et al*., 1996, 1997), all methods of Zn application for plants significantly increased grain yield of different wheat cultivars of current experiment.

Grain yield performance of cultivar Nye 60 (12.53 g pot^{-1}) was higher than cultivar Tajan (11.89 g pot^{-1}), so that, it can be concluded that cultivars have different efficiency using effectively zinc fertilizer for producing higher amount of yield. Because of zinc fertilizer application, yield of each pot have increased from 11.31 g in no zinc treatment (Zn0) to 12.83 g in Zn3 treatment, which imply that application of zinc fertilizer was effective and there is an additive trend in yield performance in comparison with increasing the level of zinc application from Zn0 to Zn3 (Table 3).

According to Yilmaz *et al*. (1997) there are different outcomes for durum and common wheat when Zn fertilizer were applied using various methods. Based on their findings low levels of Zn in soils was probably a major reason for the low grain yield of durum cultivars. The same reason may govern on lower results of 0 zinc treatment of our experiment. The increases in grain yield by Zn application treatments were relatively high

Table 1: Some physical and chemical properties of soil applied in present experiment

Available Zn (μg g^{-1})	Available P (μg g^{-1})	Total N (%)	pH	$CaCO_3$ (%)	OM (%)	Clay (%)	Silt (%)	Sand (%)
0.45	9.6	0.14	7.53	17.8	2.11	44	49	7

Table 2: Analysis of variance for grain yield and a number of yield components of bread wheat cultivars with various zinc treatments

Characters	Cultivar	Zinc	Zinc × Cultivar	CV (%)
Grain yield	**	**	*	6.76
Total dry matter	ns	**	*	5.16
1000 grain weight	**	*	*	6.11
Harvest index	ns	ns	*	3.59
No. of tillers	*	**	*	11.13
Grain Zn content	*	**	*	10.84
Flag leaf Zn content	ns	**	*	11.24
Height	ns	*	*	4.10
Spike length	ns	ns	ns	4.29
Awn length	ns	ns	ns	11.26
Flag leaf length	ns	ns	*	12.15
Flag leaf width	ns	ns	*	7.48
No. of nodes	ns	**	*	3.97
Protein content	**	**	*	2.08
Grain Fe	ns	*	*	9.94

*,**: Significant and highly significant differences (p=0.05 and p=0.01, respectively), ns = Non significant differences

Table 3: Means Comparison of cultivars and various treatments for yield, growth indices, accumulation Zn and Fe in grain and leaf

Characters	Tajan	Nye-60	Zn0	Zn1	Zn2	Zn3	LSD (5%)	CV (%)
Grain yield (g)	11.89b	12.53a	11.31c	12.02b	12.68ab	12.83a	0.78	6.76
Total dry matter (g)	26.01a	27.48a	23.96b	26.42ab	27.62a	28.99a	2.24	5.16
1000 grain weight (g)	45.39b	50.68a	45.05b	47.47ab	49.50a	50.11a	3.63	6.11
Harvest index	0.46a	0.46a	0.47a	0.46a	0.46a	0.44a	0.06	3.59
No. of tillers	16.42a	14.42b	13.00c	14.50bc	16.00b	18.17a	2.12	11.13
Grain Zn content ($\mu g\ g^{-1}$)	59.42a	54.08b	45.45b	52.08b	62.20a	67.27a	7.63	10.84
Flag leaf Zn content ($\mu g\ g^{-1}$)	272.50a	271.11a	58.58d	150.00c	365.17b	513.67a	61.38	11.24
Height (cm)	65.24a	64.10a	61.51b	64.89a	65.32a	66.97a	3.28	4.10
Spike length (cm)	10.22a	10.10a	9.94a	10.06a	10.32a	10.29a	0.76	4.29
Awn length (cm)	6.52a	6.36a	6.60a	6.42a	6.30a	6.39a	0.68	11.26
Flag leaf length (cm)	19.23a	21.68a	18.83a	19.99a	21.07a	21.93a	6.14	12.15
Flag leaf width (cm)	1.47a	1.53a	1.44a	1.44a	1.55a	1.58a	0.20	7.48
No. of nodes	4.03a	4.11a	3.77c	4.06b	4.16ab	4.29a	0.20	3.97
Protein content (%)	18.86a	18.06b	17.94c	18.40bc	18.53ab	18.97a	0.47	2.08
Grain Fe ($\mu g\ g^{-1}$)	39.35a	37.26a	34.09b	37.42ab	42.06a	39.63a	4.71	9.94

Zn0 = no zinc fertilizer, Zn1 = 5 kg Zn ha^{-1} in soil + 300 g Zn ha^{-1} in foliar application, Zn2 = 10 kg Zn ha^{-1} in soil + 600 g Zn ha^{-1} in foliar application and Zn 3 = 15 kg ha^{-1} in soil + 900 ha^{-1} in foliar application. Different letter(s) in each row and in each treatment show a significant difference ($p<0.05$)

indicating the necessity of Zn application to plants and the determination of a suitable Zn application method. Total dry matter has been increased from 23.96 to 28.99 g pot^{-1} due to application of zinc; also there was not significant difference in between studied cultivars (Table 3). Meanwhile, character 1000 grain weight has significantly been increased by application of zinc fertilizer from Zn0 (45.05 g) to Zn3 (50.11 g), respectively. Regarding to seed size, cultivar Nye 60 produced heavier and greater seeds (50.68 g) than cultivar Tajan (45.39 g), respectively (Table 3). Regardless of the methods and levels of Zn application, the effects of Zn application on grain yield were higher than those of biomass (total dry matter) or 1000 grain weight (Table 3 and 4). These results as mentioned by Yilmaz *et al.* (1997) emphasizes that Zn nutrition has more important role for seed set than vegetative growth.

Harvest index, length of spikes and awn, length and width of flag leaves have not illustrated significant differences; however, there was significant difference between studied cultivars for mentioned characters. Number of tiller per plant was significantly influenced by zinc fertilizer application and with additional consuming of zinc application, the number of tiller per plant increased from 13 to 18.17. Tajan cultivar with 16.42 has produced more tillers than Nye 60 with 14.42 (Table 3). Concentration of zinc in grain has been increased by zinc application from 45.45 to 67.27 $\mu g\ g^{-1}$. Application of zinc increased the amount of zinc concentration and cultivars showed variations in their grain zinc accumulation; so that, the amount of zinc concentrated in grains of cultivar Tajan was higher than cultivar Nye 60 (Table 3). Plant height is also under influence of zinc fertilizer application and has been increased from 61.51 to 66.97 cm in treatment Zn3; however, there was no significant variation between heights of two tested cultivars (Table 3). Number of node per stem was increased by zinc fertilizer utilization from 3.77 to 4.29 but was not significant between tested cultivars (Table 3).

Meanwhile, zinc accumulation in flag leaf were not significant between tested cultivars, however, zinc application caused an increase in zinc accumulation of flag leaves from 58.38 to 513.67 $\mu g\ g^{-1}$ (Table 3). Furthermore, application of zinc is severely effective in

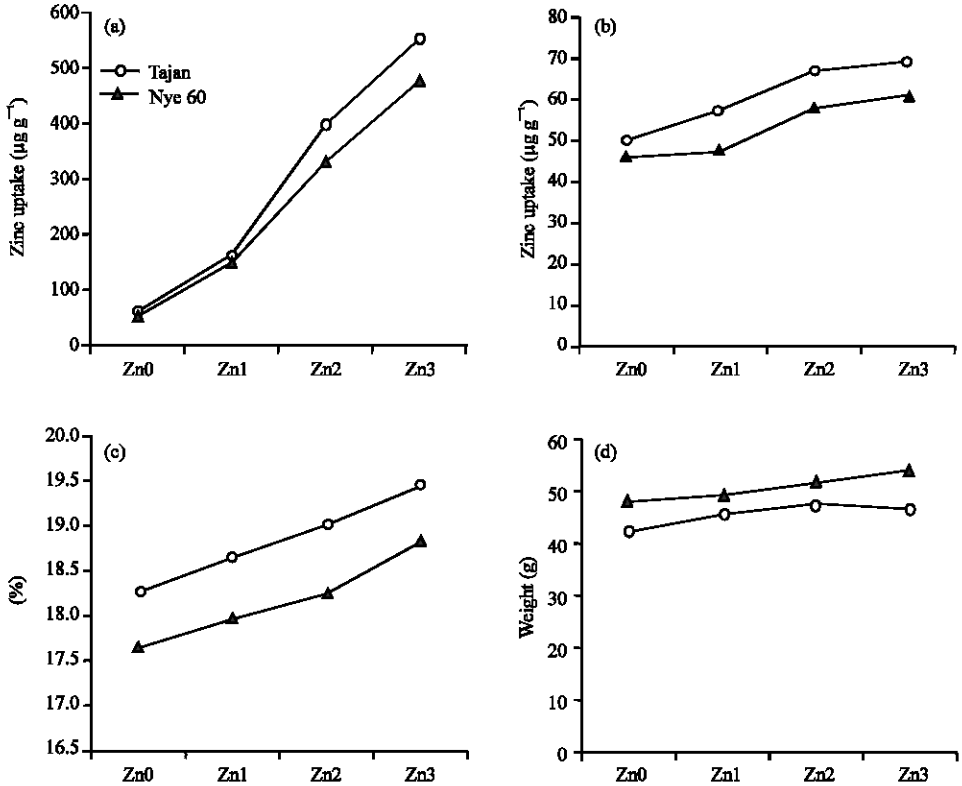

Fig. 1: Difference of cultivars Tajan and Nye 60 for (a) leaf zinc content, (b) grain zinc content, (c) grain protein content and (d) 1000 grain weight affected by various levels of zinc application

increasing wheat grain protein content from 17.94 to 18.97%, respectively. Protein content of cultivars Tajan (18.86%) and Nye 60 (18.06%) has demonstrated significant difference (Table 3). The amount of accumulated Fe in grain has been increased due to Zn fertilizer application. Maximum amount of Fe (42.06 μg g^{-1}) has been accumulated by application of Zn2 treatment (Table 3). According to Qury *et al.* (2006), by zinc application on soil, it should be possible that iron have been exchanged by zinc in soil colloid surface. Then the released iron is able to enter into soluble phase, thus, it can be absorbed by wheat plants and its Fe concentration can ordinarily be increased. The results of current study is in good agreement with the results presented by McGrath (1985) and Qury *et al.* (2006), who reported significant genotype effects for Zn, but not for Fe in the same conditions. Also, Qury *et al.* (2006) demonstrated positive correlation between Zn fertilizer application and wheat grain and leaf Fe concentration.

Zinc accumulation in flag leaf of cultivar Tajan in treatments by lower amounts of zinc application (Zn1) was higher than cultivar Nye 60, however, in treatment with higher amount of applied zinc (Zn3), the amount of zinc accumulation in leaf of cultivar Tajan was inversely higher than cultivar Nye 60 (Fig. 1a). However, the amounts of zinc accumulation in grain of cultivar Tajan in all the applied treatments were higher than that of cultivar Nye 60. This process showing that the amount of accumulation of a number of micro elements have depended restrictedly on plants genetic backgrounds, so that, cultivar Tajan in comparison with cultivar Nye 60 showed higher potential for zinc accumulation and zinc transmission (Fig. 1b).

Grain protein content of studied cultivars was different. Cultivar Tajan compared to cultivar Nye 60 produced more protein in all treatments (18.25, 18.99, 19.01 and 19.15 for cultivar Tajan and 17.64, 17.76, 18.04 and 18.80 for cultivar Nye 60, respectively) (Fig. 1c). However, 1000 grain weight of cultivar Tajan was higher than that of cultivar Nye 60, therefore, as it is already mentioned, cultivar Nye 60 produced higher yield than cultivar Tajan (Fig. 1d). It seems that the main factor affecting yield performance may be attributable to seed size.

Interaction of Zn with cultivar on grain yield and total dry matter were significant, so that, maximum grain yield were produced by Nye 60 using treatment Zn2 and Zn3, however, maximum total dry matter were obtained by cultivars Tajan and Nye 60 in treatments Zn3 and Zn1, respectively (Table 4). Furthermore, characters one thousand grain weight and tiller number per plant were

Table 4: Interaction of various levels of Zn application by cultivar on yield and some growth characters

	Tajan				Nay 60				
Characters	Zn0	Zn1	Zn2	Zn3	Zn0	Zn1	Zn2	Zn3	LSD 5%
Grain yield (g)	11.01	11.78	12.16	12.62	11.60	12.26	13.20	13.05	1.10
Total dry matter (g)	23.80	24.82	27.24	28.18	24.12	28.01	27.99	29.79	3.16
1000 grain weight (g)	42.39	45.54	47.30	46.32	47.72	49.40	51.71	53.91	5.14
Harvest index	0.46	0.47	0.45	0.45	0.48	0.44	0.47	0.44	0.05
No. of tillers	14.67	15.67	17.00	18.33	11.33	13.34	15.00	18.00	3.01
Grain Zn content ($\mu g\ g^{-1}$)	44.84	57.08	66.79	68.97	46.06	47.08	57.67	65.57	10.88
Flag leaf Zn content ($\mu g\ g^{-1}$)	63.00	152.67	398.33	476.00	53.77	147.33	332.00	551.33	86.80
Height (cm)	61.65	66.78	66.23	66.30	61.36	63.00	64.40	67.63	4.65
Spike length (cm)	9.93	10.42	10.17	10.35	9.95	9.71	10.48	10.24	0.76
Awn length (cm)	7.17	6.59	6.21	6.12	6.15	6.25	6.40	6.66	2.06
Flag leaf length (cm)	18.68	19.17	19.52	19.55	18.98	20.81	22.61	24.31	1.98
Flag leaf width (cm)	1.47	1.37	1.54	1.50	1.41	1.51	1.56	1.65	0.20
No. of nodes	3.78	4.04	4.05	4.25	3.76	4.08	4.28	4.33	0.28
Protein content (%)	18.25	19.03	19.01	19.13	17.64	17.76	18.04	18.81	0.67
Grain Fe ($\mu g\ g^{-1}$)	34.57	38.25	45.77	38.80	33.61	36.60	38.36	40.46	6.67

Zn0 = no zinc fertilizer, Zn1 = 5 kg Zn ha^{-1} in soil + 300 g Zn ha^{-1} in foliar application, Zn2 = 10 kg Zn ha^{-1} in soil + 600 g Zn ha^{-1} in foliar application and Zn 3 = 15 kg ha^{-1} in soil + 900 ha^{-1} in foliar application

also influenced by Zn application (Table 4). Maximum 1000 grain weight and tiller number were achieved from treatment Zn3 in cultivars Nye 60 and Tajan, respectively (Table 4). Maximum amounts of grain Zn and protein have been obtained by cultivar Tajan in treatment Zn3 (Table 4). Meanwhile, Interaction of Zn by cultivar cause significant differences in flag leaf Zn concentration and grain Fe content, in which cultivar Nye 60 in treatment Zn3 has provided maximum amounts of the mentioned characters (Table 4).

Zinc deficiency is one major micronutrient deficiency in humans, particularly in developing countries, where cereals contain very low levels of Zn are the primary stable foods for human consumption (Graham and Welch, 1995). Besides its positive effects on growth of seedlings, higher levels of Zn in grain have also beneficial consequences for human health. According to Yilmaz *et al*. (1997) where Zn deficiency is a serious problem, combined applications of Zn to soils and foliar application may be necessary for short-term solutions to Zn deficiencies in plants and human.

Soil and foliar application of Zn fertilizer alone were not as effective as soil + foliar applications to increase yield. The lower effectiveness of soil and foliar applications in comparison with soil + foliar applications of Zn fertilizer may be attributed to the lower levels of Zn in wheat shoot. Yilmaz *et al*. (1997) have also concluded that Zn was first diluted in plant tissues due to enhanced shoot dry matter. In contrast to results of Yilmaz *et al*. (1997) and Martens and Westerman (1991) the most effective method for correcting Zn deficiency in our experiment was soil + foliar application of Zn. For example, in soil method only Zn application as $ZnSO_4$ was adequate to correct Zn deficiency in plants for four to seven years (Martens and Westerman, 1991; Takkar and Walker, 1993). Soil + foliar application should be considered as an effective method, if a high grain yield together with high Zn concentration in seeds are desired (Yilmaz *et al*., 1997).

CONCLUSIONS

According to results obtained from present study, treatment Zn3 has totally demonstrated higher yield performance, so that, it can be concluded that there exist a potential for production of higher yield using higher levels of Zn fertilizer. In addition to the direct effects of Zn fertilization in increasing yield and other growth characters, it is also possible to increase grain Fe contains; which both of grain Zn and Fe contents play very many important roles in human health. The higher rate application of Zn has resulted in higher yield and growth characters production, means that application of more Zn per unit of area is recommendable for future works. Finally, for grain yield, 1000 grain weight, protein content and enriching purposes including grain Zn content cultivar Tajan showed higher outcomes.

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