INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print), 2222-5234 (Online)
http://www.innspub.net
Vol. 6, No. 3, p. 370-377, 2015

RESEARCH PAPER OPEN ACCESS

The effect of foliar application of zinc (Zn) on yield and yield components of irrigated wheat cultivars in ahvaz weather conditions

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Key words: Wheat, zinc, foliar application, yield and yield components.

http://dx.doi.org/10.12692/ijb/6.3.370-377 Article published on February 18, 2015

Abstract

Lack of access to the soil zinc particularly in calcareous areas with high PH is one of the factors reducing the wheat yield. Therefore, in order to investigate the effect of zinc (Zn) on the growth, yield, and yield components of three wheat cultivars, a split plot experiment in the form of randomized complete block design with three replications was carried out in Hamidiyeh, Ahvaz in 2011-2012. The main plot consisted of foliar application of four levels of zinc fertilizer at stem elongation stage including (without zinc consumption, 0.001 zinc per hectare, 0.003 zinc per hectare, 0.005 zinc per hectare) and the sub plot included three irrigated wheat cultivars (Chamran, Falat, Star). The results indicated that the studied wheat cultivars were significantly different in terms of grain yield at 5% probability level. Chamran cultivar had the highest number of spike per area unit, number of grains per spike, number of spikelet per spike, 1000-grain weight, and consequently the highest grain yield by 4740.83 kg/ha and the lowest grain yield belonged to the Star cultivar by 3700.83 kg/ha. The effect of foliar application of zinc fertilizer on the grain yield was not significant. However, application of 0.005 zinc per hectare (412 kg/ha) increased the grain yield in comparison to the control treatment. Furthermore, the foliar application of zinc had a significant effect on protein percentage and zinc concentration in grain at 1% level. The wheat cultivars were significantly different in terms of the grain zinc concentration at 1% level. The highest and the lowest concentrations of grain zinc respectively belonged to Chamran and Star cultivars. It seems that foliar application of zinc fertilizer had an effective role in increasing the concentration of grain zinc which was followed by the increase of grain yield. Moreover, wheat cultivars had different reactions to the foliar application of zinc and the cultivars with positive reaction to zinc can be used in lands with zinc deficiency.

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Introduction

Wheat is one of the most important and the most consumed crops all over the world. By using fertilizers containing micronutrients it will be easy to increase production and protein percentage and also to increase the concentration of micronutrients such as zinc, iron, manganese, and copper in the wheat grain (Malakooti *et al.*, 1999). Moreover, the lack of trace elements in grain cultivated lands had expanded globally and millions of hectares of arable land in the world are deficient in one or more trace elements. In a comprehensive report about 30 countries, FAO warned that more than 30% of the soil in those areas was deficient in zinc (Brennan, 1992). According to the investigations, 40% of the lands udder the cultivation of irrigated wheat is seriously deficient in zinc. Given the calcareous soils of Iran and alkaline PH, lack of organic matter, and carbonate irrigation water, the deficiency of trace elements particularly zinc in the soils under the cultivation of grains particularly wheat has been a serious problems (Savaghebi *et al.*, 2003). Zinc is known as one of the vital and critical elements for wheat. This element is found in several enzymes such as carbonic anhydrate, dehydrogenase, proteinases, and peptidases. Zinc in wheat reduces the carbohydrate contents in leaves and stem during the formation of spike. It apparently facilitates the flow of carbohydrates into the grain and improves the quality of grain. On the other hand, zinc causes the better transfer of protein to the wheat grain and improves the quality of the product. It has been proved that zinc exist in the structure of enzymes that contribute to the formation of RNA and DNA (Malakooti *et al.*, 2002). Mohammad *et al.* (1990) reported that application of zinc in different ways increased the wheat yield in comparison to the control treatment and the highest grain yield and the zinc concentration in grain were achieved through the foliar application of zinc. Yilmaz *et al.* (1997) did an experiment with 6 treatments including the control, us of soil, foliar application, seed treatment, combination of use of soil and foliar application, and combination of seed treatment and foliar application in order to compensate for the shortage of zinc in wheat. It was found that regardless of the method, the use of zinc increased the yield of all treatments compared with the control treatment. Mousavi *et al.* (1997) found that the use of zinc sulfate and manganese sulfate increases the production and enriched the seeds and also improved the rooting of the wheat seeds due to the storage of nutrients. If a leaf is fed during the flowering stage, the above status occurs definitely. Mohseni *et al.* (2005) stated that consumption of zinc sulfate had a significant effect on the grain yield and biological yield and increased them. Rengel and Graham (1950) found that the new cultivars of wheat can have better efficiency when the soil is well fertilized and the micronutrients particularly zinc are provided properly. By providing zinc and other elements needed by plant, the number of spikes per plant and the number of grains per spike and consequently the grain yield will increase. According to studies, The purpose of this study was to evaluate the application of zinc on Yield and yield components of wheat, determine appropriate The intake of zinc in wheat, study Effect on the growth and consumption rates Reproductive wheat, wheat production increased as a product Strategic country.

Materials and methods

The experiment was carried out in 2011-2012 in Hamidiyeh lands located at 30 Km of West Ahvaz at latitude 31°29´ N and longitude 48°26´ E and 12 m above the sea level. In order to identify some chemical characteristics of the soil of the site, before preparing the cultivation bed, the soil samples were taken from the depths of 0-25 from 5 points using agar and a compound sample was prepared and sent to the laboratory for more investigation. Chemical characteristics of the field soil are presented in Table (1). The experiment treatments included for levels of foliar application of zinc fertilizer as Z_0 (without zinc consumption), Z_1(0.001 zinc per hectare), Z_2(0.003 zinc per hectare), Z_3(0.005 zinc per hectare) at the stem elongation stage in main plots and three cultivars of irrigated wheat including Chamran (T_1), Falat (T_2), and Star (T_3) in sub plots. Totally, 36 experimental units were prepared. The experiment was carried out as split plot in the form of randomized complete block design with three

replications. Each replication included 12 plots and there were totally 36 plots and each plot had a length of 3 m and a width of 2 m and an area of 6 m^2. The total area of the plots was 216 m^2. The distance between each replication was 2 m and each plot included 5 planting line spaced as 20 cm. the experimental land had been a fallow land the previous year. In order to facilitate the land preparing operations, it was irrigated at first. It was ploughed at the depth of 25 to 30 cm by the plow. Then, the cultivation bed was crush and softened through the disk and 200 kg/ha phosphate fertilizer and one-third of nitrogen fertilizer as the base fertilizer were applied. Then, plots as long as 3 m and as wide as 2 m and some streams for irrigation were made. Seeds planting operation and the first irrigation were done in December 6, 2011. Irrigation was done at five stages of planting, emergence, tillering, stem elongation, and flowering. The other maintaining operations included adding surplus fertilizer at the tillering stage and stem elongation stage. In order to combat the weeds, herbicide was sprayed. Zinc fertilizer as chelated zinc (14%) was sprayed on the treatments at the stem elongation stage. In Z_0 treatment, only water was sprayed. The final harvest was done in May 12, 2012. After eliminating marginal effect (eliminating two side rows of planting in each plot) the grain and straw were harvested from the two middle rows after eliminating half a meter from the beginning and end of each plot. Moreover, the harvest was done in the other row after eliminating the marginal effect and two 0.5 meters from the beginning and end of the plot in order to measure other traits (number of spikes per area unit, number of grains per spike, number of spikelet per spike, 1000-grain weight, spike length, plant height, protein percentage, zinc concentration). In order to measure the zinc concentration, 2 grams of the ground sample ware burned into ash for several hours at electric furnace at the required temperature. Then the extract of the ground samples was taken by N2 hydrochloric acid. The zinc concentration of the extracted was determined via atomic absorption apparatus. The grain protein percentage was also determined after grinding and burning it by means of the electric furnace and N2 hydrochloric acid. Then the total percentage of nitrogen was red using Kjeldahl method and was multiplied the fix number of 5.83 in order to determine protein percentage. MSTAT-C software was used to analyze the data. Statistical calculation of data including mean comparison of the treatments was done via the Duncan's test. Moreover, Excel software was used in order to draw the diagrams.

Results and discussion

Biological Yield

There was a significant difference between the studied cultivars at 1% probability level (Table2). The highest biological yield belonged to Chamran cultivar by 976833 and the lowest biological yield belonged to Star cultivar by 8731.67 kg/ha (Table 3). However, the interactive effect of wheat cultivars and zinc foliar application on biological yield was not significant (Table2). Yet, the highest biological yield belonged to Chamran cultivar and consumption of 0.005 zinc per hectare by 10446.67kg/ha and the lowest biological yield belonged to Star treatment without consumption of zinc fertilizer by /862333 kg/ha. The treatment with foliar application of 0.005 by 9405.56 kg/ha had more effect on biological yield rather than the other treatments (Table 3). Mohseni *et al.* (2005) stated that consumption of zinc sulfate had a significant effect on the grain yield and biological yield and increased them which was not consistent with the findings of the present research even though the effect was not significant. Given the calcareous soils of Iran and alkaline PH, lack of organic matter, and carbonate irrigation water, the deficiency of trace elements particularly zinc in the soils under the cultivation of grains particularly wheat has been a serious problems (Savaghebi *et al.*, 2003).

Grain Yield

The effect of wheat cultivars on grain yield was significant at 5% level, but the effect of foliar application of zinc fertilizer and their interactive effect on the grain yield were not significant (Table 2).Nevertheless, the highest grain yield belonged to Chamran cultivar by 4740.83 kg/ha (Table 3). Mean comparison of the interactive effects of wheat

cultivars and different levels of foliar applications of zinc on the grain yield showed that the highest grain yield belonged to Chamran cultivar and application of 0.005 zinc by 4996.67 kg/ ha and the lowest grain yield belonged to Star cultivar without consumption of zinc by 3543.33 kg/ha (Table 4). The increase of grain yield was observed in the treatment with foliar application of 0.005 zinc fertilizer by 412.12 compared to the control treatment. That is, the consumption of zinc at each level influenced the grain yield in comparison to the control treatment. Malakooti (2000) stated that by application of trace elements in 10 provinces the wheat yield increased between 350 to1900 kg/ha which was consistent with the results of this research.

Table 1. Chemical characteristics of the filed soil.

Electric conductivity (dis/m)	8.2
Acidity Ph	7.25
Concentration percentage	37
Organic carbon (%)	0.65
Total nitrogen (%)	15
Absorbable phosphorus (ppm)	12.5
Absorbable potassium (ppm)	129
Iron (ppm)	6
Zinc (ppm)	5.1
Manganese (ppm)	5.9
Copper (ppm)	1.16

Harvest Index

Mean comparison of different cultivars of wheat showed that the highest and the lowest harvest index respectively belonged to Chamran cultivar by48.58 % and Star cultivar by 42.40%. Moreover, the harvest index of Falat cultivar was 45.74% (Table 3). Mean comparison of the interactive effects of foliar application of zinc and different wheat cultivars showed that the highest harvest index by 49 /65 belonged to Chamran cultivar by consumption of 0.003 zinc per hectare and the lowest percentage by 41.06% belonged to Star cultivar without consumption of zinc (Table 4).

1000-Grain Weight

The effect of cultivars and foliar application of zinc on 1000-graqin weight was not significant, but their interactive effect on 1000-grain weight was significant at 5% probability level (Table 2). According to Table (2) the highest weight of 1000-grain by 41.20 g was related to Chamran cultivar by consumption of 0.003 zinc per hectare and the lowest weight of 1000-grain by 39.90 g was related to Star cultivar without consumption of zinc (control) (Table 4). Hemantaranjan andGray reported that the use of iron and zinc significantly increased the yield and 1000-grain weight in wheat. In this research, the weight of 1000-grain increased through the foliar application of zinc fertilizer.

Number of Grains per Area Unit

According to the ANOVA table the effect of wheat cultivars on the number of grains per area unit was significant at 1% level, but the effect of foliar application of zinc and their interactive effect on the number of grain per area unit were not significant

(Table 2). According to the mean comparison table, the highest number of grains per square meter belonged to the treatment with Chamran cultivar and consumption of 0.005zinc by 34013.33 and the lowest number belonged to the treatment with Star cultivar and without consumption of zinc by 23095 (Table 4). Guenis *et al.* (2003) stated that the foliar application of trace elements led to the marked increase of the number of grains in wheat which was not consistent with the present research. It could be due to the rate of foliar application and the environmental conditions.

Table 2. The ANOVA of the studied traits.

Mean of Squares (MS)											Degree of freedom	Sources of Variations
Zinc concentration in grain	Protein percentage	Spike length	Plant height	Number of spikelet per spike	Number of grains per spike	Number of spikes per m²	Number of grains per m²	1000-grain weight	Harvest index	Biological yield	Grain yield		
0/081^{ns}	1/07^{ns}	1/88^{ns}	112/99*	11/62**	3/33^{ns}	4038/86^{ns}	1456836/78^{ns}	12/23^{ns}	3/36^{ns}	3658/33^{ns}	19469/44^{ns}	2	Replication
9/386**	3/92*	0/61^{ns}	350/21**	13/834**	135/02*	11410/03*	177861760/86**	9/63^{ns}	114/86^{ns}	3742433/33**	3346136/11*	2	cultivar
89/22**	6/71**	1/04^{ns}	2/066^{ns}	0/132^{ns}	7/08^{ns}	1558/33^{ns}	11625968/37^{ns}	0/65^{ns}	8/78^{ns}	371644/44^{ns}	269903/70^{ns}	3	Zinc foliar application
0/196^{ns}	0/09^{ns}	0/013^{ns}	0/181^{ns}	0/90^{ns}	0/060^{ns}	202/58^{ns}	258692/01^{ns}	0/127*	1/88^{ns}	167611/11^{ns}	6639/82^{ns}	6	Cultivar × zinc foliar application

ns, *, ** respectively mean non-significant, significant at 5% and 1% levels.

Number of Spikes per Area Unit

The effect of the wheat cultivars on the number of spikes per square meter was significant at 5% level, but the effect of foliar application of zinc and the interactive effect of wheat cultivar and foliar application of zinc on the number of spike per area unit was not significant (Table 2). However, according to the mean comparison table, the highest number of spikes per square meter belonged to the treatment with Chamran cultivar and consumption of 0.005 zinc per hectare by 912.67 spikes/m² and the lowest number belonged to the treatment with Star cultivar without consumption of zinc by 807.33 spikes/m² (Table 4).Hemantaranjan andGray reported that the use of iron and zinc significantly increased the yield and also the number of spikes per area unit which is not consistent with the present research. Even though the foliar application of zinc fertilizer had no significant effect on the number of spikes/m², the increase of foliar application of zinc from 0.001 to 0.005 increased the number of spikes/m².

Table 3. Mean comparison of the studied traits.

Zinc concentration in grain (mg/kg)	Protein (%)	Spike length (cm)	Plant height (cm)	Number of spikelet per spike	Number of grains per spike	Number of spikes per m²	Number of grains per m²	1000 grain weight	Harvest index (%)	Biological yield (kg/ha)	Grain yield (kg/ha)	Treatments
Cultivar												
33/92a	11/57ab	8/97 a	93/82 a	16/27 a	36/43a	893/75a	32518/00a	40/87 a	48/58 a	9768/33a	4740/83a	Chamran
33/18ab	11/93 a	8/64 a	92/72 a	15/06 a	32/37b	868/67ab	28124/58b	40/25 a	45/74ab	8890/00ab	4061/67b	Falat
32/26b	10/81 b	8/53 a	83/97 a	14/13 a	29/78b	832/42b	248445/08b	39/11 a	42/40 b	8731/67b	3700/83b	Star
Zinc Foliar Application												
30/12d	10/53c	8/43 a	89/89 a	15/19 a	31/64 a	851/33 a	27087/78 a	39/70 a	44.21 a	8918/89 a	3950/00 a	**Control**
31/50c	11/09bc	8/49 a	89/82 a	15/09 a	32/84 a	858/00 a	28209/00 a	40/8 a	45/48 a	9072/22 a	4132/22 a	**0.001**
33/57b	11/57b	8/76 a	90/11 a	15/03 a	33/26 a	869/11 a	28911/11 a	40/24 a	46/28 a	9123/33 a	4226/67 a	**0.003**
37/36a	12/57a	9/18 a	90/87 a	15/31 a	33/70 a	881/33 a	29775/67 a	40/29 a	46/33 a	9405/56 a	4362/22 a	**0.005**

Number of Grains per Spike

The effect of wheat cultivars on the number of grains per spike was significant at5% level, but the effect of zinc foliar application and the interactive effect of cultivar and zinc foliar application on the number of grains per spike were not significant (Table 2). According to the mean comparison table, the highest number of grains per spike belonged to the treatment with Chamran cultivar and consumption of 0.005zinc per hectare by 37.26 grains and the lowest number

belonged to the treatment with Star cultivar without consumption of zinc by 28.37 grains per spike (Table 4). Rengel and Graham (1995)found that the new cultivars of wheat can have better efficiency when the soil is well fertilized and the micronutrients particularly zinc are provided properly. By providing zinc and other elements needed by plant, the number of spikes per plant and the number of grains per spike and consequently the grain yield will increase.

Table 4. Mean comparison of the studied traits.

Zinc concentration in grain (mg/kg)	Protein (%)	Spike length (cm)	Plant height (cm)	Number of spikelet per spike	Number of grains per spike	Number of spikes per m2	Number of grains per m2	1000 grain weight	Harvest index (%)	Biological yield (kg/ha)	Grain yield (kg/ha)	Treatments
Interactive effect of cultivar × zinc foliar application												
30/57h	10/54e	8/67ab	93/70 a	16/30ab	35/41b	884/33bc	313115/00b	40/33 a	47/72ab	9356/67bc	4466/67bc	Chamran× control
32/50f	11/23cd	8/73ab	93/50 a	16/36a	36/28ab	883/67bc	31948/67b	41/07 a	48/95ab	9613/33b	4706/67ab	Chamran× 0.001
34/67d	11/70bc	9/00ab	93/73 a	16/20abc	36/79ab	894/33ab	32795/00ab	41/20 a	49/65a	9656/67b	4793/33a	Chamran× 0.003
38/23a	12/80a	9/47 a	94/37 a	16/22abc	37/26a	912/67a	34013/33a	40/90 a	48/00abc	10446/67a	4996/67a	Chamran× 0.005
30/37h	11/07de	8/30 b	92/63 a	14/99bcde	31/14de	862/33cde	26853/33de	39/87 a	43/85def	8776/67d	3840/00efgh	Falat× control
31/50g	11/47bcd	8/40 b	92/43 a	14/94cde	32/37cd	865/67cde	28026/67cd	40/07 a	45/49cde	8883/33cd	4040/00def	Falat× 0.001
33/43e	11/97b	8/70ab	92/57 a	15/06adcde	32/81c	870/33bcd	28558/33cd	40/47 a	46/36bcd	8950/00cd	4133/33de	Falat× 0.003
37/43b	13/23a	9/17ab	93/27 a	15/26abcd	33/16c	876/33bcd	29060/00c	40/60 a	47/26abc	8950/00cd	4233/33cd	Falat× 0.005
29/43i	9/98f	8/33 b	83/33 b	14/27de	28/37f	807/33g	23095/00g	38/90 a	41/06f	8623/33d	3543/33h	Star × control
30/50h	10/57e	8/33 b	83/53 b	13/99de	29/89ef	824/67fg	24651/67fg	39/10 a	41/99f	8720/00d	3650/00gh	Star × 0.001
32/57f	11/03de	8/57 b	84/03 b	13/81e	30/17e	842/67ef	25380/00ef	39/07 a	42/83ef	8763/33d	3753/33fgh	Star × 0.003
34/40c	11/67bc	8/90ab	84/97 b	14/44de	30/69e	855/00de	26253/67ef	39/37 a	43/72def	8820/00d	3856/67efg	Star × 0.005

Number of Spikelet per Spike

Number of spikelet per spike was significantly affected by the wheat cultivars at 1% level, but the effect of zinc foliar application and the interactive effect of cultivar and zinc foliar spray on the number of spikelet per spike were not significant (Table 2). Comparison of the means shows that the highest number of spikelet per spike by 16.36 belongs to the treatment with Chamran cultivar and consumption of 0.001 of zinc per hectare and the lowest number by 13.81 belongs to the treatment with Star cultivar and consumption of 0.003 of zinc per hectare (Table 4). Moreover, the number of spikelet per spike was more in the foliar application of 0.005 of zinc than the other treatments.Hemantaranjan andGray (1988) and Rengel and Graham (1950) reported that application of zinc in wheat increased the number of spikelet per spike. In this research, by increasing the zinc foliar application some significant results can be achieved.

Plant Height

Plant height was affected by the wheat cultivar at 1% level but the effect of zinc foliar application and the interactive effect of cultivar and zinc foliar application on the plant height were not significant (Table 2). Comparison of the means show that the highest plant height by 94.37 cm belongs to the treatment with Chamran cultivar and consumption of 0.005 of zinc and the lowest height belongs to the treatment with Star cultivar without consumption of zinc fertilizer by 83.33 cm (Table 4). Zinc fertilizer makes the plant produce more chlorophyll and thus the plant foliage develops and consequently the plant yield increases. Brawn *et al.* (1993) stated that consumption of zinc in wheat caused the increase of plant height, the number of tillers and tillering rate and also increases the plant growth rate and caused pre-maturity. The results of experiment were not consistent with the finding of this research. It is possible to increase the plant height significantly by increasing the foliar

application and selecting appropriate time and fertilizer.

Spike Length

The effect of wheat cultivar, zinc foliar application, and the interactive effect of cultivar and zinc foliar application on the spike length were not significant (Table 2). Comparison of the means show that the highest length of spike by 9.47 cm belongs to the treatment with Chamran cultivar and consumption of 0.005 of zinc per hectare and the lowest spike height belongs to the treatment with Star cultivar and consumption of 0.001 of zinc per hectare (Table 4). Silsipor (2002) observed that the length of spike in wheat increased in comparison with the control treatment due to the use of zinc and manganese. Although the experiment was not significant the foliar application of zinc fertilizer increased the length of spike.

Protein Percentage

According to the ANOVA table, the effect of wheat cultivar on protein percentage was significant at 5% level and the effect of zinc foliar application on protein percentage was significant at 1% level but their interactive effect of protein percentage was not significant (Table 2). Comparison of the means showed that the highest percentage of protein by 13.23 belonged to Falat cultivar and consumption of 00.5 of zinc per hectare and the lowest percentage of protein by 9.98% belonged to Star cultivar without consumption of zinc fertilizer (Table 4).Marshner (1986) states that in under zinc deficiency conditions the activity of RNA polymerase and the transfer of amino acids will decrease and RNA degradation and destruction will increase. Consequently, protein synthesis reduces dramatically. If the zinc is available for wheat, the grain protein percentage increases. The results of the experiment are consistent with the findings of the present research.

Zinc Concentration in Grain

According to the ANOVA table, the effect of wheat cultivar and zinc foliar application on the concentration of zing in grain was significant at 1% level, but their interactive effect on zinc concentration in grain was not significant (Table 2). Comparison of the means show that the highest concentration of zinc in grain by 38.23 mg/kg belongs to Chamran cultivar and consumption of 0.005 of zinc per hectare and the lowest concentration by 29.43 mg/kg belongs to Star cultivar without consumption of zinc fertilizer (control treatment) (Table 4-6). Malakooti (2000) investigated the effect of zinc fertilizer on the yield of rain-fed and irrigated wheat in Kurdistan wheat farms and stated that consumption of zinc not only increased the grain yield, but also improved the concentration of zinc in the grain of rain-fed and irrigated wheat respectively from 10.7 and 12 to about 27 and 32 microgram zinc per gram of grain. Hamilton *et al.* (1993) stated that application of 11 kg/ha zinc increased the concentration of this element in plant which is consistent with the results of the present research.

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