Effect of zinc foliar application at different physiological growth stages on yield and quality of wheat under sandy soil conditions

El-Dahshouri. M. F.[1*], M. M. El-Fouly[1], R. Kh. M. Khalifa[2], H. M. Abd El-Ghany[1]

(1. *Fertilization Technology Department*,

2. *Field Crop Research Department, National Research Centre, Dokki, P.O. Box 12622, Cairo, Egypt*)

Abstract: Micronutrients are critical factor for plant production. The main target of this study was to evaluate the effect of rates and time of zinc foliar application on growth, nutrient contents, yield and its components of wheat Sakha 94 and Gemmieza 9 cultivars under sandy soils conditions. In this regard two field experiments were conducted during 2013/2014 and 2014/2015 seasons at Ismailia Agricultural Experimental Station of the Agricultural Research Center (ARC), Ismailia Governorate, Egypt. Statistical analysis of the illustrated data indicated that all studied characters were significantly affected by zinc foliar application. The highest values of grain and straw yield were resulted under two sprays as compared to the other treatments of zinc application. The results showed that there were high significant differences among varieties in response to zinc application for all studied characteristics except No. of grains/spike in the first season. Gemmieza 9 cultivar surpassed Sakha 94 for all studied traits of yield component. The interaction between zinc foliar treatments and the two cultivars had highly significant effects for all studied characters except No. of spikes/m^2 in the first season only. The grains content from N, Zn and Fe were significantly affected due to Zn foliar application and there were significant differences between the two wheat cultivars for their grain nutrients content in their responding to Zn foliar application in both seasons. The Gemmieza 9 cultivar gave the highest N grain content, while Sakha 94 gave the highest Zn and Fe grain content in both seasons. Also, the data of grains nutrient content were significantly affected by the interaction between treatments of Zn foliar spray and wheat cultivars in both seasons, where the twice foliar spray of Zn gave a higher content of grains from N and Zn, while in spraying once gave a higher iron grains content in both cultivars and seasons. Generally, it can be concluded from this study that Gemmieza 9 wheat cultivar achieved the highest values of grain and straw yields and yield attributes by zinc as foliar application under sandy soil condition. In addition, the long-term of zinc foliar application has the most beneficial effects on grain yield among the other types of fertilization.

Keywords: wheat, growth, nutrient status, yield, zinc foliar application, sandy soils

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1 Introduction

Wheat (*Triticumasetivum* L.) is an important cereal crop in Egypt and over the world used in human food and animal feed as well as, with regard to cultivated area and total production, as well as nutritive value. It provides 37% of the total calories for the people and 40% of the protein in the Egyptian diet (El-Habbasha *et al*., 2015). Recently, a great attention has been devoted to cultivate wheat in the newly reclaimed sandy soils. In general, under unfavorable conditions of such soil which characterized with low fertility, low organic matter content, micronutrients deficiency, high leaching rate and salinity (Abd El-Ghany, 2007 and El-Fouly *et al*., 2011).

A great attention of several investigators has been directed to increase the productivity and quality of wheat especially in the newly reclaimed sandy soil to reduce the gap between the production and consumption especially in Egypt. There are several ways for increasing wheat production; one of them is the appropriate application of

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*** Corresponding author: Mohamad Farouk El-Dahshouri,** Fertilization Technology Department National Research Centre-El-Behoos St., Dokki, Cairo, Egypt. Email: mfarouknrc@yahoo.com.

micronutrient especially with balanced and recommended N, P and K in the newly reclaimed areas. (Zeidan *et al*., 2010).

Zinc is well known to have an important role either as a metal component of enzymes or as a functional, structural or regulatory co-factor of a great number of enzymes (Hotz and Braun, 2004). Furthermore, Zn have an influence on some plant life process , such as nitrogen uptake and metabolism, photosynthesis synthesis, resistance to a biotic and biotc stresses , pollen function and fertilization (Cakmak, 2008; Kaya and Higgs, 2002; Pandey *et al*., 2006) .

Wheat responds to the application of micronutrients during its growing stages and results in enhanced output in terms of yield. Many studies have been shown that one of the effective and productive ways to improvement in cereal grains is application of zinc fertilizer either to the soil or foliar application (El-Metwally *et al*., 2012). Foliar Zn application represents an effective practice to improve both productivity and grain Zn content up to three or four fold (Cakmak, 2008). Also, Bameri *et al*., (2012); El-Habbasha *et al*. (2015) and Esfandiari *et al*. (2016) reported that foliar application of Zn had positive significant effect on wheat grain yield and its components, as well as quality of grains.

Concerning the genetic variation in response to foliar application of Zn, El-Habbasha *et al*. (2015) and Sharifi-Soltani *et al*. (2016) they found significant differences among wheat cultivars and genetic variation in terms of growth traits , grain yield and yield components, as well as grains Zn and Fe content and quality in response to Zn application. From the above mentioned results, Zn foliar application seems to be promising method to increase grain Zn content, but its effectiveness may depend on several factors, one of these factors is the growth stage of foliar Zn application. In this context results obtained by Ozturket al. (2006); Cakmak *et al*. (2010) and Phattarakul *et al*. (2012) showed that the highest Zn concentration in wheat grains was achieved when foliar Zn was applied after the flowering stage compared to the application before the flowering stage. In addition, Cakmak *et al*. (2010) showed that the highest grain Zn concentrations were obtained when Zn was applied four times (stem elongation + booting + milk + dough stages). Li *et al*. (2014) showed that foliar Zn application at the primary grain filling period considerably increased the grain Zn content and the Zn utilization efficiency by 82.9% and 49%, respectively compared early stages.

Therefore, the present study was conducted to determine the effectiveness of foliar Zn application at the different growth stages with different rates on grain yield and its components, and nutritional quality of two bread wheat cultivars grains.

2 Materials and Methods

To improvement of wheat crop production under marginal and unfavorable sandy soils in dry land areas conditions is the main target for crop growers. Therefore, two field experiments were conducted in two successive winter seasons of 2013/2014 and 2014/2015 at Ismailia Agricultural Experimental Station of the Agricultural Research Center (ARC), Ismailia Governorate, Egypt to study the effect of different rates and time of foliar application of zinc on growth, yield and some of yield components of two wheat cultivars, Sakha 94 and Gemmieza 9. The experimental field included 4 zinc foliar treatments, which include the check control and other spry application at different growth stages a companion with wheat cultivars as follows:

A. Zinc treatments:

1. Control (without zinc foliar application) (T_1)

2. One spray; full dose 1 spray with 400 g of $ZnSO_4.7H_2O$ after 50 days of sowing at the end of tillering stage (T_2)

3. Two sprays; 400 g full dose divided into 2 sprays (each 200 g of $ZnSO_4.7H_2O$) at 50 and 85 days (end both of tillering and elongation growth stage) (T_3)

4. Three sprays; 400 g full dose divided into 3 sprays (each 133.5 g of $ZnSO_4.7H_2O_4$) (end both of tillering, elongation and through milk ripe stage) (T_4)

B. Wheat cultivars:

1. Sakha 94 (V_1)

2. Gemmieza 9 (V_2)

The experimental design was split plot in randomized complete block with three replicates. Four zinc rates (mention above) as Zn SO_4. $7H_2O$ as foliar application at different stages after sowing according to each treatment were randomly distributed in the main plots and the wheat cultivars were allocated at random in the sub-plots. Each experimental unit was (3.5 m length and 3 m width) occupying an area of 10.5 m^2 (fed=4200 m^2). As well, chemical and physical characteristics of soil before sowing were estimated according to Jackson (1986) and corresponding data are presented in Table 1.

Table 1 Physico-chemical properties of the experimental soil before sowing for 2013/2014 and 2014/2015 seasons

	Mechanical analysis %			Texture	Physical properties				Macronutrients, mg/100 g					Micronutrients, ppm			
	Sand	Silt	Clay		pH	E.C, ds/m	$CaCO_3$, %	O.M, %	P	K	Ca	Mg	Na	Fe	Mn	Zn	Cu
1st	93	1.2	5.8	Sandy	9.3	0.3	2	0.85	1.9	3.4	48	15.8	7.2	1.4	1.1	0.7	0.6
2nd	93	2.2	4.8		9.2	0.4	1.8	0.92	0.6	4.2	41	5.1	3.6	3.8	1.1	0.5	0.3

Starting point of doses of 50 kg P_2O_5 fed^{-1} and 50 kg K_2O fed^{-1} in the form of Superphosphate (15.5% P_2O_5) and potassium sulphate (48% K_2O) were added before sowing, the recommended dose of nitrogen was added at the rate of 100 kg N/fed as ammonium nitrate (33.5% N) four times; the first one 21 days after sowing and then every 7-10 days.

Wheat grains at the rate of 60 kg fed^{-1} were sown in hand drilled in rows 15 cm apart in the chosen soil on the last third of November for both seasons. Wheat plants in all treatments were irrigated by sprinkler irrigation system at 6 days interval and weeds were controlled by hoeing. The other practices of growing wheat were properly used for the management of the experimental plots throughout the cropping season. At the maturity stage, the plants were harvested in the first half of May in both seasons. Where plants of square meter per each plot were collected and separated into grains and straw to estimate grain yield.

Table 2 Zinc content (μg) in wheat grains before sowing in both seasons

Wheat cultivars	1st season	2nd season
Sakha-94	0.64	0.49
Gemmieza-9	0.98	0.64

2.2 Nutrient analyses

Macro and micronutrients were extracted using the dry ashing digestion method (Chapman and Pratt, 1978). Nitrogen was determined by using the Kjeldahl method, Phosphorus was spectrophotometerically measured according to the method described by Jackson (1986), and K, Fe and Zn were analyzed by using Perkin-Elmer (1100 B) atomic absorption spectrometer

The data were subjected to statistical analysis using computer based software "MS-Excel" and analysis of all the obtained field data was done using (Snedecor and Cochran, 1980)analysis of variance methodology. A least significant difference test was applied at 5% probability level to determine the difference among treatment means (Waller and Duncan, 1969).

3 Results and Discussion

3.1 Effect of zinc foliar application and wheat cultivars on yield and its component:

Data presented in (Table 3) indicated that all the Zn treatments significantly increased grain yield and its components in both seasons as compared to control. The results showed that foliar Zn application at the tillering + stem elongation growth stages significantly increased grain yield and yield components in comparison to control and the other treatments.

The highest grain yield and the studied yield components was obtained by foliar application of Zn at the tillering + stem elongation growth stage followed by the tillering + stem elongation + milking stages, while the lowest values were obtained from the control treatment (Table 3). The obtained data clearly showed that divided the dose of Zn foliar application (400 g of Zn $SO_4.7H_2O$/fed.) at tillering stage + stem elongation stage or at previous two stages + milking stage led to the highest grain yield as compared with spraying the full dose at tillering stage only. The increase of grain weight due to Zn foliar spraying might be attributed to the fact that Zn is known to have an important role as a metal component of enzymes or as a functional, structural or regulatory co-factor of a wide number of enzymes (Hotz and Braun, 2004). Also, Kaya and Higgs (2002), and

Cakmak (2008) reported that zinc plays an important role in the production of biomass. Positive effect of Zn application on the grain yield and agronomic traits have also been reported by several researchers among of them Abdoli *et al*. (2014); El-Habbasha *et al*. (2015); Sultana *et al*. (2016); and Esfandiari *et al*. (2016).

Table 3 Effect of zinc foliar application treatments and wheat cultivars on yield and some of its components during 2013/2014 and 2014/2015 seasons

Treatments	1000 Grains Weight, g		No. of grains/spike		No. of Spikes/m^2		Grains Weight/m^2 (g)		Grains Yield (ard*/fed.)	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Zinc foliar application:										
(T_1)	50.58	53.29	35.0	34.3	317.3	317.2	452.1	392.5	14.8	15.4
(T_2)	53.03	56.18	36.0	34.6	394.8	352.5	632.3	442.5	19.2	18.3
(T_3)	55.25	58.98	37.5	36.8	428.2	425.0	752.5	659.9	22.3	24.6
(T_4)	52.80	56.46	36.0	35.8	414.7	391.5	669.6	566.7	21.8	21.1
LSD at 5%	0.17	1.6	0.96	0.82	28.1	14.7	1.8	2.0	1.7	0.81
Cultivars:										
Sakha 94	52.64	55.40	35	36	371	357	618.9	511.2	18.4	19.1
Gemmieza 9	53.19	57.05	37	35	406	386	634.4	519.6	20.6	20.6
LSD at 5%	0.14	0.38	1.1	1.0	18.7	5.5	1.8	2.2	0.98	0.79

Note: Ard.= 150 kg.

Regarding wheat cultivars effect on grain yield and its components, data recorded in (Table 3) indicated that the performance of used cultivars for all studied yield characters of wheat. The data indicated that the two cultivars Sakha 94 and Gemmieza 9 had significant differences regarding their responding to Zn foliar spraying in concern yield and its attributes in both seasons, except grain number/spike and grain yield in the second season only. The Gemmieza 9 cultivar showed significantly surpassing Sakha 94, for all studied traits except the No. of grain per spike and grain yield in the second season. The highest grain yields (20.6 ard/fed) were obtained by Gemmieza 9 with significant increases than Sakha 94 (18.4 ard/fed) in the first season. These differences may be due to the genetic background for the cultivar and its behavior under these conditions in which zinc foliar application and sandy sosil and its effect on wheat growth. In this respect, many investigators reported that differences of wheat cultivars in their response to zinc fertilization (Rajput *et al*., 1995; Torun *et al*., 2001; Zeidan *et al*., 2010; Hasina *et al*., 2011; Keram, 2014 and Muhammad *et al*., 2015).

3.2 Effect of the interaction between wheat cultivars and Zinc foliar application on yield and its components

The interaction effect between zinc foliar application treatments and the two used wheat cultivars in this study was significant on the yield and yield components are shown in Table 4. It is evident that, the two tested wheat cultivars Sakha 94 and Gemmieza 9 responded significantly to the differences of zinc foliar application treatments for 1000 Grains Weight, No. of grains/spike, number of Spikesm^{-2}, Grains Weight m^{-2} and Grains Yield (ard./fed.) in the first and/or second season.

Table 4 The interaction effect between zinc foliar treatments and the two wheat cultivars on yield and some of itscomponents characters during 2013/2014 and 2014/2015 seasons

Treatments	1000 Grains Weight, g				No. of grains/spike				No. of Spikes/m^2				Grains Weight/m^2 (g)				Grains Yield (ard/fed.)			
	1st		2nd		1st		2nd		1st		2nd		1st		2nd		1st		2nd	
	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2
(T_1)	50.9	52.4	54.2	52.4	34	36	35	34	294	340	301	333	439.4	464.8	403.4	381.6	13.4	16.1	15.2	15.7
(T_2)	52.5	58.0	54.4	58.0	35	37	35	34	395	395	349	356	626.3	638.3	438.7	446.2	19.2	19.2	17.7	18.9
(T_3)	54.9	59.5	58.5	59.5	36	39	38	36	405	451	412	438	746.8	758.1	646.1	673.7	20.6	23.9	24.2	25.0
(T_4)	52.3	58.3	54.6	58.3	35	37	37	35	390	439	364	419	663.0	676.2	556.6	576.8	20.5	23.2	19.5	22.8
LSD at 5%	0.28		0.76		2.21		2.34		37.4		11.0		3.54		4.36		1.96		1.57	

Note: V_1= Sakha 94, V_2= Gemmieza 9.

The data of the interaction for the yield and some components characters showed that the highest values of 1000-grain weight (59.5 g, 59.5 g), number of spikes m^{-2} (451, 438), grain weight/m^2 (758.1, 673.7 g) and grain yield ard./fed. (23.9, 25) was obtained by the Gemmieza 9 cultivar under two sprays of zinc treatment in both seasons, respectively.

3.3 Effect of zinc foliar application and wheat cultivars on shoot nutrient concentrations at 90 days after sowing

All the Zn foliar treatments significantly increased N, P, K, Zn and Fe concentrations in wheat plant at 90 days from sowing compared to control (Table 5) in both seasons. Foliar application of Zn twice at tillering + elongation stages resulted the highest values and significantly increased of N, P, K and Zn concentrations in shoot of wheat in comparison to control and other treatments of Zn in both seasons, followed by three foliar Zn application for P and Zn in both seasons, K and Fe in the first season and one foliar Zn application for N in both seasons.

The increasing of nutrient in the shoot of wheat plant by Zn foliar treatments may be due to enhancing nutrients uptake in this concern, Thiruppathi *et al*. (2001) reported that using Zn as foliar spray or soil application increased the absorption of N, P and K as well as enhanced crop yield and its components.

Table 5 Effect of zinc foliar application treatments and wheat cultivars on shoot nutrient concentrations of wheat during 2013/2014 and 2014/2015 seasons

Treatments	N		P		K		Zn		Fe	
	%		%		%		ppm		ppm	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Zinc foliar application										
(T_1)	1.27	1.21	0.183	0.18	1.63	1.6	61	61	336	334
(T_2)	2.14	2.04	0.192	0.19	1.75	1.85	67	66	543	593
(T_3)	2.25	2.21	0.203	0.2	1.91	1.94	88	90	418	432
(T_4)	1.52	1.49	0.199	0.2	1.82	1.8	86	81	573	494
LSD at 5%	0.02	0.02	0.002	0.005	0.01	0.01	1.4	1.6	1.5	1.3
Cultivars										
Sakha 94	1.85	1.74	0.192	0.194	1.74	1.81	73	72	450	462
Gemmieza 9	1.74	1.73	0.197	0.196	1.81	1.78	78	77	484	465
LSD at 5%	0.01	0.01	0.001	0.002	0.01	0.01	1.4	0.47	1.3	1.1

Regarding the differences between the two wheat cultivars in their shoot nutrient content may be attributed to genetically differences in their absorption and uptake of nutrients. Also, in concern of surpassed Gemmieza 9 wheat cultivar in shoot Zn content compared to Sakha 94 may be due to its grains high Zn content before sowing (Table 2), in this respect, Boonchuay *et al*. (2013) studied the effect of seed Zn concentration on seedling growth and they reported that there was a positive correlation between seed Zn concentration and dry weight of root and shoot during germination period.

3.4 Effect of the interaction between wheat cultivars and Zinc foliar application on nutrient concentrations

Data in Table 6 revealed that the interaction effect of wheat cultivars and Zn foliar application was significant in all studied nutrients in both seasons. The data of the interaction indicated that the maximum values of shoot N, P, K and Zn nutrients content were recorded when both two of studied cultivars were twice sprayed with zinc in most cases, while three or one foliar zinc application gave the highest Fe of shoot content in the first and second seasons, respectively.

3.5 Effect of foliar zinc application and wheat cultivars on grain quality

The results presented in (Table 7) revealed that foliar Zn application significantly increased protein, Zn and Fe content in wheat grains compared with no Zn application in both seasons. Highest protein and Zn content in wheat grains was achieved with foliar Zn spray at tillering + elongation stages, while foliar application at tillering stage only gave the highest Fe grains content in both seasons.

Table 6 The interaction effect between zinc foliar treatments and the two wheat cultivars on yield and some of itscomponents characters during 2013/2014 and 2014/2015 seasons

Treatments	N				P				K				Zn				Fe			
	%												ppm							
	1st		2nd		1st		2nd		1st		2nd		1st		2nd		1st		2nd	
	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2
(T_1)	1.3	1.2	1.3	1.2	0.18	0.18	0.18	0.19	1.6	1.6	1.6	1.6	59	63	58	63	288	384	283	385
(T_2)	2.1	2.1	2.0	2.1	0.19	0.19	0.19	0.20	1.7	1.8	1.9	1.8	65	68	65	67	404	432	594	591
(T_3)	2.4	2.1	2.2	2.2	0.20	0.21	0.20	0.20	1.9	1.9	2.0	1.9	84	92	86	94	554	531	435	429
(T_4)	1.6	1.5	2.2	1.5	0.20	0.20	0.20	0.20	1.7	1.9	1.9	1.8	84	88	94	82	555	591	429	453
LSD at 5%	0.023		0.032		0.002		0.01		0.02		0.02		2.34		0.94		2.58		2.11	

Note: V_1= Sakha 94, V_2= Gemmieza 9.

Table 7 Effect of zinc foliar application treatments and wheat cultivars on grain quality during 2013/2014 and 2014/2015 seasons

Treatments	Grain protein content, %		Grain Zn, ppm		Grain Fe, ppm	
	1st	2nd	1st	2nd	1st	2nd
Zinc foliar application:						
(T_1)	12.36	12.19	32.5	33.5	108	109
(T_2)	12.94	12.82	52.5	53.5	236	237
(T_3)	14.03	13.86	59	60	125	126
(T_4)	13.05	13.11	55.5	56.5	138	139
LSD at 5%	0.06	0.12	1.7	1.73	1.5	1.49
Cultivars:						
Sakha-94	13.05	12.88	51	52	157.5	158.5
Gemmieza-9	13.17	13.11	48.8	49.75	146	147
LSD at 5%	0.06	0.06	0.6	0.5	1	1

Data in (Table 7) indicated that there were significantly differences between the two wheat cultivars under study in their protein, Zn and Fe grains content in both seasons. Highest protein content was achieved with Gemmieza 9 cultivar while Sakha 94 cultivar recorded the highest Zn and Fe content in grains compared with Gemmieza 9 cultivar in both seasons, this results is in good agreement with the studies in wheat in which grain Zn concentration was increased by foliar Zn application up to three times compared with no Zn application (Phattarakul *et al*., 2012; Karim *et al*., 2012; Boonchuay *et al*., 2013; Esfandiariet al., 2016). The positive effect of Zn foliar application on increasing grain protein content was reported by Seadh *et al*. (2009) and El-Habbasha *et al*. (2015). In this context Broadley *et al*. (2007) reported that one of the well-documented functions of Zn is related to its effect on protein synthesis and protein functions. Also, Cakmak *et al*. (2010) reported that there is a close positive correlation between grain protein and Zn concentration.

3.6 Effect of the interaction between zinc foliar application and wheat cultivars on grain protein, Zn and Fe content:

The interaction effect between wheat cultivars and foliar application of Zn on the grains protein, Zn and Fe content was significant in both seasons. The highest grain protein and Zn content was recorded by twice Zn foliar application of both wheat cultivars in both seasons (Table 8), while the highest grain Fe content was obtained by one Zn foliar application of both cultivars in both seasons.

Table 8 The interaction effect between zinc foliar treatments and the two wheat cultivars on grain protein, Zn and Fe content during 2013/2014 and 2014/2015 seasons

Treatments	Grain protein content, %				Grain Zn, ppm				Grain Fe, ppm			
	1st		2nd		1st		2nd		1st		2nd	
	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2
(T_1)	12.13	12.59	12.07	12.25	35	30	36	31	105	111	106	112
(T_2)	13.11	12.76	12.88	12.71	55	50	56	51	257	215	258	216
(T_3)	13.86	14.20	13.46	14.32	59	59	60	60	123	127	124	128
(T_4)	13.11	13.00	13.17	13.05	55	56	56	57	145	131	146	132
LSD at 5%	0.12		0.02		1.7		1.73		1.5		1.49	

Note: V_1= Sakha 94, V_2= Gemmieza 9.

4 Conclusion

In general, from this study it could be concluded that Zn foliar application treatments significantly increased grain yield and its components of the two wheat cultivars as well as plant nutritional status and grain protein, Zn and Fe content. The highest values of the previous studied characteristics were obtained by divided the full dose (400 g $ZnSo_4.7H_2O$) in two foliar spraying (200 g/fed.) at the end of both tillering and elongation stages. Gemmieza 9 cultivar seemed to be the most suitable with high responding to Zn foliar treatments under such sandy soil conditions.

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