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Utilization Efficiency of Zinc by Some Wheat Cultivars Under Stress Condition of Zinc Deficiency

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Abstract: A pot experiment was carried out in the greenhouse of Faculty of Agriculture, Alexandria University to evaluate the response of three wheat cultivars (Sakha-93, Gemiza-7 and Giza-168) grown in sandy calcareous soil to soil application of Zn as $ZnSO_4$ or as Zn-EDTA. In addition, a field experiment was carried out to evaluate the response of the three wheat cultivars to foliar application of Zn as either $ZnSO_4$ or Zn-EDTA. The results showed significant increases in dry weight of shoot, Zn concentration and Zn uptake with addition of Zn to Zn deficient soil. Sakha-93 cultivar showed the highest response to Zn soil application as either $ZnSO_4$ or Zn-EDTA compared to the other two cultivars with respect to the shoot dry weight. The relative increase in shoot dry weight in addition to Zn concentration and uptake in shoots was almost higher from Zn-EDTA than from $ZnSO_4$ with the three cultivars. This is also indicated by the highest values of Zn use efficiency (ZnUE) by shoots, which were higher from Zn-EDTA than $ZnSO_4$. Foliar application of Zn as Zn-EDTA or $ZnSO_4$ increased significantly the straw and grain yields of the three wheat cultivars. However, Sakha-93 showed the highest yields, while Giza-168 showed the lowest yields. The responses of the straw and grains yields and Zn concentration in grains and flag leaf of Sakha-93 to foliar application by Zn-EDTA were greater than $ZnSO_4$ and higher than those of Gemiza-7 and Giza-168 cultivars.

Key words: Pot and field experiments • Utilization efficiency • Wheat cultivars • Zinc deficiency

INTRODUCTION

Zinc (Zn) deficiency is common in soils of arid and semi-arid regions and zinc is considered as the most limiting factor for producing crops in different regions of the world [1-3]. While, Zn is the primary plant nutrient, relatively small amounts of Zn are required to support the process of growth and quality of the plants. However, the high lime contents, alkaline soils with low organic matter and imbalanced application of fertilizers may also enhanced Zn deficiencies in the many agricultural crops. In calcareous soils, Zn availability decreases due to the high bicarbonate and pH levels [4]. Plants grown in such soils suffer, in different degrees, from Zn deficiency and consequently decrease in plant growth [5-8]. Zinc fertilizer practice affect yield, quality and Zn use efficiency in crops [9, 10]. During the last two decades, new generations, varieties and cultivars are being available for different plant species to be grown in soil suffering from Zn deficiency. However, these new cultivars have not been subjected to examination for growth under nutrients stress conditions. Cultivars that can efficiently use Zn might tolerate Zn deficiency to some extent and have higher yields [11-13]. The studies should be carried out to investigate and recommend the most suitable plant cultivar, for high yield and good crop quality production, that to be grown in zinc deficient soils. The soils of the western area of Nile Delta, Egypt are mostly calcareous and low fertile and therefore the selection of the suitable wheat cultivars to be cultivated in these soils is being a national objective. During the last ten years, the Ministry of Agricultural and Land Reclamation of Egypt has produced several numbers of wheat cultivars for cultivation under different stress conditions. The selection of the certain wheat cultivars to be grown in Zn low or deficient soil is a vital objective and can act to minimize fertilizer use. The objective of the present study, therefore, was to evaluate the response and utilization of zinc applied by either soil or foliar by three wheat cultivars grown under stress condition of zinc deficiency soil.

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Table 1: Some physical and chemical properties of the deficient zinc soil.

Texture	pH	EC (dS/m)	Organic matter (%)	$CaCO_3$ (%)	Zn (mg/ kg)
Sandy	9.0	0.25	0.06	10.2	0.06

MATERIALS AND METHODS

A pot experiment was carried out in the greenhouse of Faculty of Agriculture, Alexandria University, Egypt, during winter season of 2012/ 2013 to evaluate the utilization efficiency of three wheat (*Triticum aestivum* L.) cultivars (Sakha-93, Gemiza-7 and Giza-168) grown in sandy calcareous soil (Table 1) to soil and foliar application of Zn as $ZnSO_4$ or Zn-EDTA. Zinc treatments including (i) soil application of Zn as $ZnSO_4$ (0.0, 2.5, 5.0 mg Zn/kg soil) or as Zn EDTA (0.0, 0.5, 1.0 mg Zn/kg soil) and (ii) foliar application of Zn as $ZnSO_4$ (0.5% $ZnSO_4$) or Zn- EDTA (0.05% Zn EDTA) in addition to the control.

Plastic pots of 15 cm diameter and 20 cm height were used. Each pot was filled by one kg soil and irrigated with distilled water for a week. Grains of each wheat cultivar were planted, irrigated daily with 50 ml distilled water then the seedling were thinned to six seedlings per pot after one week from planting. These seedlings were irrigated with 120 ml of half strength nutrient solution according to Hewitt [14] which containing the different levels of Zn then after two days, the seedling were irrigated by 50 ml nutrient solution free of Zn. The plants were irrigated systematically every two days. After 45 days from planting the shoots were collected, washed with tap water followed by distilled water, oven dried at 70°C for 48 hours, grounded using stainless steel mill and stored for analysis [15]. Zinc use efficiency, Zn utilization efficiency and Zn uptake were calculated as follow:

Zn uptake (total amount of Zn in shoot mg /plant) = shoot DW (g/plant) × Zn concentration (mg/kg)

Zinc use efficiency (ZnUE) g DM/mg $Zn_{applied}$ = g of DM pot/mg Zn applied per pot

Znic utilization efficiency (ZnUtE) g DM /mg Zn_{uptake}= g of DM per plant/mg Zn [16, 17].

A field experiment was carried out in the western area of Nile Delta, Egypt on November 20 (2012/ 2013 winter season). The main soil properties are shown in Table 1. Grains of the three wheat cultivars were sown in field plots (4 x 5m). The soil plots were fertilized by super phosphate (15.5% P_2O_5) before planting at a rate of 30 kg P_2O_5 per feddan (one feddan = 0.42 ha) and by potassium sulfate (50% K_2O) at two equal doses (25 kg K_2O) after 30 days and 90 days after planting). Also, N fertilizer as ammonium nitrate was applied at three equal doses (40 kg N/ feddan) at three growth stages. The sources of micronutrients were Fe-EDTA, Mn-EDTA and Cu-EDTA was foliar applied at concentrations of 0.5 g/l in water at tillering and at panicle initial. The experimental design was a randomized complete block design (RCBD) in strip plots with five replicates. Zn treatments were applied as foliar application at 45 and 100 days after planting. The flag leaves collected before and after the second foliar application of Zn treatment and the straw and grains were collected after maturing. The plant samples were washed with tap water followed by distilled water, oven dried at 70°C for 48 hrs, ground using stainless steel mill and stored for analysis [15].The oven dried plant material was subjected to dry ashing at 500°C for 6 hrs and the ash was dissolved in 2N HNO_3 and Zn concentration was measured by atomic absorption spectrophotometer GBC 932 AA. The data obtained were statistically analyzed for the least significant difference using PC-SAS software [18].

RESULTS AND DISCUSSION

Soil Application of Zinc: Data presented in Table 2 showed that increasing Zn rate applied to Zn-deficient sandy calcareous soil significantly increased the dry weight of shoots in the three wheat cultivars. The obtained results are in agreement with the findings of Cacmak *et al*. [17], who reported that shoot dry matter production was decreased under soil Zn deficiency, while applied Zn increased shoot dry matter from 0.52 to 0.98 g. It was also found that Zn-EDTA was more effective for stimulating shoot growth of Sakha-93 or Gemiza-7 cultivar than $ZnSO_4$, especially at the highest Zn rate. Wheat cultivar Sakha-93 had also the highest dry weights, while Giza-168 had the lowest, with or without Zn additions. The relative increases of shoot dry weight were increased with increasing zinc rates for the three wheat cultivars, but these values were differed according to wheat cultivars and source of Zn. These results confirmed the results obtained by Salama and El-Fouly [19], who concluded that the high value of Zn efficiency mainly attributed to the tolerance to Zn deficiency in different

Table 2: The average values of the dry weight of shoots (g/plant) and Zn concentration (mg/kg), Zn uptake (mg/plant), Zn use efficiency (g DW/mg Zn applied) and Zn utilization efficiency (g DW/mg Zn absorbed) of the three wheat cultivars grown on Zn-deficient soil as affected by Zn treatment

	Zinc treatment						
Wheat cultivars	Source	Zn/kg soil (mg)	Dry weight	Zn conc.	Zn uptake	Zn U E	Zn UtE
Sakha-93	Control	0.07	0.18	21	3.78	15.43	0.048
	Zn-EDTA	0.5	0.21	36	7.56	2.52	0.028
		1	0.26	43	11.18	1.56	0.023
	$ZnSO_4$	2.5	0.20	32	6.40	0.48	0.031
		5	0.23	37	8.51	0.30	0.027
Gemiza-7	Control	0.07	0.15	29	4.35	12.86	0.034
	Zn-EDTA	0.5	0.17	43	7.31	2.04	0.023
		1	0.21	67	14.07	1.26	0.015
	$ZnSO_4$	2.5	0.17	36	6.12	0.42	0.028
		5	0.19	48	9.12	0.24	0.021
Giza-168	Control	0.07	0.15	26	3.90	12.86	0.039
	Zn-EDTA	0.5	0.17	48	8.16	2.04	0.021
		1	0.19	70	13.30	1.14	0.014
	$ZnSO_4$	2.5	0.17	34	5.78	0.42	0.029
		5	0.19	44	8.36	0.24	0.023
L.S.D 0.05			0.02	5.00	1.00	--	--

Table 3: The mean values of Zn concentration in the flag leaf and grains of the three wheat cultivars as affected by foliar Zn application

	Treatment			
Wheat cultivars	Source	Zn (g/l)	Zn-flag leaf (mg/kg)	Zn-grains (mg/kg)
Sakha-93	Control	0.0	13.2	28.1
	Zn-EDTA	0.5	27.9	40.2
	$ZnSO_4$	5.0	24.3	37.3
Gemiza-7	Control	0.0	12.6	27.6
	Zn-EDTA	0.5	26.4	36.5
	$ZnSO_4$	5.0	25.3	34.3
Giza-168	Control	0.0	12.8	25.2
	Zn-EDTA	0.5	29.4	38.6
	$ZnSO_4$	5.0	25.7	39.2
L.S.D. 0.05			1.5	2.1

wheat cultivars and can be used as a useful parameter for recognizing the efficiency of wheat cultivars differing in their response to zinc deficiency. Data in Table 2 showed significant increases in Zn concentration in shoots for the three wheat cultivars grown in Zn- deficient sandy calcareous soil with increasing Zn rates as Zn-EDTA or $ZnSO_4$.The highest relative increase related with the high rate of Zn applied whether as Zn-EDTA or $ZnSO_4$ but Zn-EDTA was higher.

Also, the results in Table 2 showed that wheat cultivars varied widely in Zn concentration in the plant whether with or without Zn application which the Zn concentration in shoot of wheat plants were greater when Zn applied as Zn-EDTA than as $ZnSO_4$ with the three wheat cultivars. Shoots of Sakha-93 plants contained the lowest Zn concentration than in shoots of Gemiza-7 and Giza-168 cultivars, especially when Zn applied as Zn-EDTA and Gemiza-7 cultivar was the highest. The response to treatment varied widely among wheat cultivars. Similar results were reported by El-Bendary *et al.* [20], who found that a significant variations in Zn concentration in shoot among wheat cultivars. These data pointed out that the relative increase of Zn concentration in shoots were greater from Zn-EDTA than $ZnSO_4$. This is evident with the three wheat cultivars. Data in Table 2 showed decreased values of Zinc use efficiency (ZnUE) and Zn utilization efficiency (ZnUtE) with increasing Zn as Zn-EDTA or $ZnSO_4$, while were higher in Zn-EDAT treatments with the three wheat cultivars. Also, high values of ZnUE and Zn UtE were noted with Sakha-93 and Gemiza-7 wheat cultivars than Giza-168 cultivar. The differences among wheat genotypes for Zinc use efficiency (ZnUE) had also been reported by Maqsood *et al*. [21].

Table 4: The mean values of the straw yield, grain yield and 1000 grains weight of the three wheat cultivars as affected by foliar Zn application

	Zn treatment						
Wheat cultivars	Source	Zn (g/l)	Grain yield (kg/m^2)	Increase%	Straw yield (kg/m^2)	Increase%	1000 grains weight (g)
Sakha-93	Control	0.0	0.41	-	1.06	-	45.6
	Zn-EDTA	0.5	0.66	61	1.26	19	55.7
	$ZnSO_4$	5.0	0.58	41	1.13	7	49.0
Gemiza-7	Control	0.0	0.42	-	1.15	-	46.3
	Zn-EDTA	0.5	0.60	43	1.20	4	50.3
	$ZnSO_4$	5.0	0.57	36	1.24	8	47.7
Giza-168	control	0.0	0.38	-	1.02	-	49.9
	Zn-EDTA	0.5	0.54	42	1.21	19	50.9
	$ZnSO_4$	5.0	0.49	29	1.05	3	50.8
LSD 0.05			0.06		0.05		1.05

Foliar Application of Zinc: Data in Table 3 showed significantly differences between cultivars in control treatments which indicated that Zn content in grains and flag leaf of Sakha-93 was the highest, while the lowest in Giza-168. El-Bedary *et al*. [20] concluded that distinct differences among wheat cultivars in terms of sensitivity to Zn-deficiency were closely related to zinc. Also, applied Zn to wheat plants as foliar application increased significantly Zn concentration in grains and flag leaf for all cultivars. And found that Zn-EDTA had the higher effect than $ZnSO_4$. It was also found that there were a significantly differences between cultivars; Sakha-93 was the highest and Gemiza-7 was the lowest. These results are in full agreement with those obtained by El-Bendary *et al*. [20], Brennan [22], Yilmaz *et al*. [23], Liu *et al*. [24] and Ranjbar and Bahmaniar [25]. The results in Table 4 also showed that foliar application of zinc either as Zn-EDTA or $ZnSO_4$ significantly increased straw and grain yields. These increases were greater in plants treated with Zn-EDTA than $ZnSO_4$. The response of straw and grain yields of Sakha-93 to foliar application was higher than those of Gemiza-7 and Giza-168.

It can be concluded that Zn applied as Zn-EDTA to Zn - deficient sandy calcareous was more effective than $ZnSO_4$ in most of the parameters studied in this experiment. Values of Zinc use and utilization efficiency were decreased with increasing Zn as Zn-EDTA or $ZnSO_4$. High values of ZnUE were noted with Sakha-93 and Gemiza-7 cultivars than Giza-168 cultivar. Also, Sakha-93 cultivar was more efficient for using zinc applied which reflected in increasing Zn concentration in the flag leaf and grains, straw and grain yields and 1000 grains weight than other cultivars. So, Sakha-93 cultivar can be recommended under stress condition of Zinc and future breeding programs.

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