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Effect of Zinc foliar application on growth characteristics and Grain Yield of some Wheat varieties under Zn deficient sandy soil condition

El Habbasha, S.F., Elham A. Badr and Ezzat Abdel Latef

Field Crops Research Dept., National Research Centre, Dokki, Giza, Egypt.

Abstract: Two field experiments were carried out under Zn deficient sandy soil during the two winter seasons of 2011-12 and 2012-13 at the Farm of Research and Production Station, National Research Centre, El Nubaria District, Al Behaira Governorate, Egypt. Three concentrations of foliar applied zinc (0, 100 and 200 g Zn /ha as $ZnSo_4.7H_2O$) were applied to three wheat varieties (Sids1, Sids12 and Sids13). The results revealed that significant differences among wheat varieties in all studied characteristics. Sids12 variety surpassed the other tested wheat varieties in growth and yield, dry weight/unit area (g), total chlorophyll content, spike length (cm), number of spikelets/spike and biological yield (ton/ha). Meanwhile, Sids13 variety significantly exceeded the other cultivars in number of spikes/m^2, grain yield (ton/ha), harvest index (%) and protein content (%) but cultivar Sids1 produced the highest plant height (cm), seed index, straw yield (ton/ha) and carbohydrate content. Results indicated that foliar application of zinc (200 g Zn/ha) caused highest significant increases in the studied characteristics except number of spikelet/spike, seed index and harvest index (%). It could be concluded from this study that Zn deficiency correction in wheat in such poor soils depends on using the proper variety. Sids 12 variety seemed to be the most suitable variety with high ability to Zn response in this district.
Key Words: Wheat – varieties- foliar application.

Introduction

Wheat (*Triticum aestivum* L.) is one of the most important cereal crops in Egypt and over the world used in human food and animal feed. Wheat provides 37 % of the total calories for the people and 40 % of the protein in the Egyptian diet[1]. Recently, a great attention of several investigators has been directed to increase the productivity of wheat to minimize the gap between the Egyptian production and consumption by increasing wheat production through increasing unit land area productivity and increasing cultivated area. Increasing wheat yield per unit area can be achieved by breeding high yielding varieties and applying the optimum cultural practices such as organic fertilization which reduce pollution and sustain soil fertility through their effect on the physical, chemical and biological properties of soil, but its use alone is not sufficient to meet the requirement of nutrients. The yield of wheat is a function of many factors among them the cultivars and elements fertilization being the most ones. One of the most important elements which are necessary for organic matter synthesis in wheat. Also, it is a major source of straw for animal feeding.

Micronutrients, such as transition metals like Zinc (Zn) is one of the most functional micronutrients in plants, animals and humans it plays an important physiological role in their growth and development[2] . Zn deficiency is common in both crop plants and human beings, causing various serious health complications such as stunting, increased susceptibility to infectious diseases, impaired brain function and mental development, poor birth outcomes and anemia[3,4] . It is estimated that more than one third of the population is affected by Zn deficiency, particularly children and pregnant women and low dietary intake of Zn has been discussed as a major reason[5,4,6]. Enrichment of cereal crops with Zn is an important global challenge and a high-priority research area. Zn is required for the growth and grain nutritional quality of wheat, a staple food in a number of developing countries in the world and essential to ensure food safety and healthy diet[7,2]. It has been reported that Zn concentration in wheat grains is different among wheat cultivars and subjects to reported that Zn concentration in wheat grains is different among wheat cultivars and subjects to the regulation of the environment and cultivation measures[8,9,10,11]. Genetic biofortification and agronomic biofortification are two important agricultural tools to improve Zn concentration in grains[12,13,2,11]. It has been reported that grain Zn concentration can be enhanced to a certain extent by increasing the application of Zn fertilizer[14]. Application of Zn fertilizers not only improves nutritional quality but also contributes significantly to grain production in Zn-deficient soils[15,16,2,17]. [18]found that after applying Zn fertilizer, Zn absorption in wheat increased significantly and its concentration in wheat grains increased by 18.8%. Studies have shown that exogenous Zn can significantly improve the dry weight of seedling roots and shoots[19], ease winter wheat seedlings peroxidation, enhance SOD and CAT activities and promote chlorophyll synthesis, thereby affecting photosynthesis[20]. Adequate Zn can accelerate the wheat growth, tillers and anthesis, while excessive Zn content in the environment will inhibit the growth of wheat seedlings, exacerbate flag leaf membrane peroxidation at the grain filling stage and lead to yield loss[21,22,23,24]. Current studies on the influence of Zn on crops are mainly concentrated on the influence of Zn on seedling growth, photosynthetic physiology and grain yield. Only few researchers studied the effects of zinc on the relationship between wheat physiological characteristics after anthesis and the growth of flag leaf and grains. Therefore the aim of this work was to study the response on different wheat varieties to Zn correction deficiency under Zn deficient sandy soil conditions.

Materials and Methods

Two field experiments were conducted at the Farm of Research and Production Station, National Research Center, El Nubria district, Al Behira Governorate, Egypt in 2011-2012 and 2012-2013 successive winter seasons to investigated the effect of Zinc foliar application on growth characteristics and yield and yield attributes of some wheat varieties to Zn correction deficiency under Zn deficient sandy soil condition. The experimental soil was analyzed according to the method described by[25]. Soil texture was sandy and having the following characteristics: Sand 93.7%; pH 7.8; organic matter 0.65%; $CaCO_3$ 1.30%; EC 0.50 dS/m; total N 8.1 ppm, P 3.60 ppm and K 23.5 ppm, Zn 9.45 ppm (the soil was classified as Zn deficient sandy soil). Egyptian wheat varieties (Sids1, Sids 12 and Sids13) were subjected to three levels of zinc applied as foliar application (0, 100 and 200 g Zn/ha as $ZnSo_4.7H_2O$).

Wheat varieties and zinc foliar spray treatments were arranged in randomized complete block design with three replicates where the plot area was 10.5 m^2.Wheat grains were sown in mid November in both seasons. The experiment was fertilized with ammonium nitrate (33.5 %) at the rate of 135 kg N/ha, the dose of N was applied in 10% was added before sowing as activation dose, 50% in the tillering stage and 40 % before heading stage. Calcium superphosphate was added during the preparation of grain bed at the rate of 35 kg P_2O_5/ha. Sprinkler irrigation was applied was as plants needed. Normal cultural practices of growing wheat conducted in the usual manner followed by the farmers of this district.

Data recorded

A random sample of 25 cm length X 40 cm width from each plot was taken at 60 and 90 days after sowing to determine, plant height (cm) and dry weight /unit area (g) and total chlorophyll content[26]. At harvest stage, 50cm x 50cm were taken from each plot and the following characters were determined spike length (cm), number of spikelets/spike, seed index, number of spikes/m^2, the all area of the plot was harvested to evaluate grain yield (ton/ha), straw yield (ton/ha), biological yield (ton/ha), harvest index (%). Protein content (%), total N-content in grains determined and protein% was calculated by multiplying N-content by 5.75 according to[25]. Carbohydrate content (%) was determined (as glucose) after acid hydrolysis and spectro photometrically determined using phenol sulfuric acid regent according to[27].

Statistical analysis

Data were subjected to statistical analysis of variance as described by[28] and the combined analysis of the two season's results was conducted according to the method adopted by[29]. Mean values of the recorded data were compared by using the least significant differences (L.S.D 0.05).

Results and Discussions

1. Effect of wheat varieties and zinc foliar application on growth characteristics

Table (1): Effect of wheat varieties and zinc foliar application on growth characteristics after 60 and 90 days after sowing (combined data of first and second seasons)

Treatment	Plant height (cm)		Dry weight/unit area (g)		Total chlorophyll	
	60 days	90days	60 days	90days	60 days	90days
varieties						
Sids1	102.1	120.37	149.40	183.90	41.35	35.95
Sids12	101.6	119.98	162	200.69	42.51	36.96
Sids 13	100.9	119.15	158.04	195.58	36.75	31.94
L.S.D	NS	NS	6.19	9.93	1.97	1.32
Zinc foliar application						
0	98.03	115.74	133.20	165.03	32.95	28.65
100 g Zn/ha	101.90	120.26	156.60	192.96	40.19	34.95
200 g Zn/ha	104.64	123.52	179.64	222.97	47.46	41.25
L.S.D	1.53	1.98	6.86	9.99	4.82	4.22

Data presented in (Table1) indicated that Sids12 cultivar surpassed Sids1 and Sids13 in dry weight /unit area (g) and total chlorophyll. However Sids 1 gave the highest value in plant height (cm) compared with other varieties.

Zinc foliar application at rate 200 g zinc/ha gave the highest values of plant height (cm), dry weight (g) and total chlorophyll compared with other treatment (Table 1). Such effect of micronutrient fertilization with zinc indicate the importance of Zn to plants, being involved many in enzymatic reactions and consequently for better growth and development. Zinc is required for the synthesis of auxin, which is a growth-regulating compound (indole acetic acid). In zinc deficient plants stunted growth and small leaves are the most distinct visible symptoms and result from the disturbance in the auxin metabolism[30,31]. [30,32]mentioned that if zinc contents are lower, zinc deficiency can cause a 50 to 70% reduction in photosynthesis, decreased protein production, loss of membrane integrity and reduced yield. The visual symptoms of zinc deficiency include chlorosis, rosetting of leaves, stunted growth, malformation of leaves and dwarf leaves. Chlorosis is the change of leaf color from bright green to pale green, yellow or even white. It is caused by the reduced amount of chlorophyll in the plants.

2. Effect of interaction between wheat varieties and zinc foliar application on growth characteristics

Table (2): Effect of interaction between wheat varieties and zinc foliar application on growth characteristics after 60 and 90 days after sowing (combined data of first and second seasons)

variety	Zinc foliar	Plant height (cm)		Dry weight/area (g)		Total chlorophyll	
		60 days	90 days	60days	90days	60days	90days
Sids 1	0	99.16	116.87	118.8	147.2	34	29.6
	100 g Zn/ha	102.56	120.97	158.8	193.4	41.05	35.7
	200gZn/ha	104.55	123.28	170.6	211.1	47	42.6
Sids 12	0	96.05	113.33	141.5	175.4	35.4	30.8
	100g Zn/ha	103.41	122.29	160.9	199.5	43.1	37.5
	200g Zn/ha	105.4	124.32	183.8	227.2	48.9	42.6
Sids 13	0	98.88	116.97	139.3	172.5	29.4	25.6
	100g Zn/ha	99.73	117.5	150.1	186.3	36.4	31.7
	200g Zn/ha	103.98	122.97	184.7	228.2	44.4	38.6
LSD		3.19	3.76	NS	NS	NS	NS

The interaction effect between wheat varieties and zinc foliar application was insignificant on the studied characters except plant height in both growth samples after 60 and 90 days after sowing. The data of the interaction between wheat varieties and zinc foliar application in Table 2 indicated that Sids12 + 200 g zinc/ha gave the highest values of plant height and total chlorophyll after 60 and 90 days after sowing with significant differences in case of plant height compared with must treatments. Treatment Sids 13 +200 g zinc /ha gave the highest values of dry weight/area in both growth samples with no significant with other treatments.

3. Effect of wheat varieties and zinc foliar application on yield and yield attributes

Table (3): Effect of wheat varieties on yield and yield components (combined data of first and second seasons)

Variety	Spike length, cm	No. Spiklets /spike	Seed index	Number of spikes/m2	Grain yield/ha	Straw yield/ha	Biological yield/ha	Harvest index (%)	Protein Content (%)	Carbohydrates content (mg/g fresh weight)
Sids1	11.15	15.49	5.28	476.25	2.870	4.010	6.876	0.41	10.53	76.82
Sids12	11.60	16.42	5.00	476.85	2.969	3.986	6.958	0.41	11.08	75.43
Sids13	11.17	14.63	4.20	482.99	3.078	3.785	6.863	0.43	11.35	66.15
L.S.D 5%	NS	1.24	0.49	NS	0.612	0.422	0.676	NS	NS	2.28

Among the wheat varieties, Sids13 had the maximum number of spikes/m^2 (482.99), grain yield (3.078 ton/ha), harvest index (0.434%) and protein content (11.355%). On the contrary, Sids12 showed maximum spike length (11.602 cm), number of spikelet/spike (16.423) and biological yield (6.958 ton/ha) but Sids1 had maximum seed index (5.288), straw yield (4.010 ton/ha) and carbohydrate content (76.822%). These results agree with findings of [33] they reported that individual genotypes responded differently to varying seeding rates. [34] also stated that grain and straw yields included N, P and K uptake differed within varieties and increased with seed rates from normal. Genetic variability also play role for nitrogen uptake in wheat[35,36]. [37]reported that most modern cereal cultivars have relatively short strong stems and transmit the aboveground forces to the root system, because most of the wheat lodging that occurs is believed to be root lodging. Large differences amongst wheat varieties have been observed for lodging tendency[38,39].

Table (4) Effect of zinc foliar application on yield and yield components (combined data of first and second seasons)

Variety	Spike length, cm	No. Spiklets /spike	Seed index	Number of spikes/m2	Grain yield/ha	Straw yield/ha	Biological yield/ha	Harvest index (%)	Protein Content (%)	Carbohydrates content (mg/g fresh weight)
0	10.99	15.03	4.31	455.26	2.203	3.557	5.758	0.37	10.05	69.85
100 g Zn/ha	11.36	15.33	4.84	489.82	3.191	3.801	6.994	0.44	11.26	71.71
200 g Zn/ha	11.58	16.98	5.33	491.02	3.522	4.423	7.995	0.44	11.66	76.85
L.S.D 5%	NS	1.24	0.50	16.40	0.512	0.425	0.706	NS	0.4	2.91

Data illustrated in Table 4 show that increasing of foliar applied zinc from 0 to 200 g zinc/ha gave the highest values for all studied characters spike length (11.58), number of spiklets/spike(16.98), seed index (5.33), number of spikes/m^2 (491.05), grain yield/ha (3.52 ton/ha), straw yield/ha (4.42 ton/ha), biological yield/ha (7.99 ton/ha) and harvest index (0.44%). The increase due to Zn fertilization might be attributed to the fact that Zn plays an important role in biosynthesis of the IAA and initiation of primodia for reproductive parts and a result of favorable effect of zinc on the metabolic reactions within the plants. The results are in close conformity with findings of [40, 41] and [42] also reported that increasing levels of zinc increased wheat yield, total nutrient (N, P, K and Zn) uptake. Table (4) revealed that the maximum total carbohydrate and protein content in wheat grain (76.85 and 11.66 %, respectively were recorded by 200 g Zn/ha while 100 g Zn/ha records 71.71 and 11.26% total carbohydrate and protein content, respectively, which was significantly higher than the control. This indicates that there is value to increase Zn level for obtaining high total carbohydrate and protein of grains. This might be due to Zn contributed in photosynthesis, chlorophyll, metabolism of starch formation and enzyme carbonic anhydrase accelerating carbohydrate formation, the maximum requirements Zn were enough to accumulate suitable carbohydrate contents. It also activate glutamic dehydrogenase enzyme, synthesis of RNA and DNA enhancing gliadin and glutenin content, which are main protein components of gluten accumulated in the later stages of grain filling. The quality of wheat (total carbohydrate and protein content) depends on their inherent chemical compositions, which have a response function in various enzymatic activities in grain. The results are in conformity with the findings of [41, 43, 44].

4. Effect of interaction between wheat varieties and zinc foliar application on yield and yield attributes

Table (5): The effect of interaction between zinc foliar application and wheat varieties on yield and yield components (combined data of first and second seasons)

varieties	zinc foliar	spike length, cm	No. spiklets/ spike	seed index	number of spikes/ m2	grain yield/ha	straw yield/ ha	biological yield/ha	Harvest index (%)	Protein Content (%)	Carbohydrates content (mg/g fresh weight)
Sids1	0	11.226	15.663	5.700	444.113	2.531	3.594	6.109	0.41	9.300	74.633
	100 g Zn/ha	11.423	15.393	5.266	489.050	2.841	3.909	6.752	0.416	10.566	76.633
	200 g Zn/ha	10.810	15.430	4.900	495.610	3.238	4.528	7.767	0.406	11.733	79.200
Sids12	0	11.076	16.763	5.666	450.250	2.010	3.722	5.743	0.35	10.300	72.166
	100 g Zn/ha	11.446	15.953	4.966	503.010	3.368	3.981	7.349	0.453	11.566	72.533
	200 g Zn/ha	12.283	16.553	4.366	477.276	3.528	4.255	7.783	0.450	11.400	81.600
Sids13	0	10.670	16.216	4.633	471.416	2.068	3.355	5.422	0.373	10.533	62.766
	100 g Zn/ha	11.213	14.670	4.300	477.386	3.365	3.515	6.880	0.456	11.666	65.966
	200 g Zn/ha	11.653	13.026	3.666	500.190	3.800	4.486	8.286	0.473	11.866	69.733
L.S.D 5%		NS	3.73	1.49	49.50	.434	.266	.334	NS	NS	6.84

Data in Table 5 revealed that the interaction effect of wheat varieties and zinc foliar application was significant in most of studied characters except, spike length, harvest index and protein content. The data of the interaction between wheat varieties and zinc foliar application indicated that the maximum spike length (12.28cm) and carbohydrate content (81.6%) was recorded when Sids12 was fertilized with zinc (200 g Zn/ha) and gave the highest values of number of spike/m^2 recorded by the same varieties with zinc foliar application (100 g zinc /ha). While Sids1 recorded the highest straw yield (4.52 ton/ha) when crop fertilized with 200 g zinc/ha and seed index (5.7) in control without fertilizer. The maximum grain yield (3.8 ton/ha), biological yield (8.286 ton/ha), harvest index (0.46%) and protein content (11.87%) was recorded when Sids 13 variety was fertilized with 100 g zinc/ha. These results are in accordance with[45,46,47]. They reported that the 1000-grain weight of wheat increases by adding zinc fertilizer to crop plants.

It could be concluded from this study that Zn deficiency correction in wheat in such poor soils depends on using the proper variety. Sids 12 variety seemed to be the most suitable variety with high ability to Zn response in this district

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