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Effect of Spraying Zinc on Yield and Grain Zn-Content in Two Wheat Cultivars

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ZINC deficiency is a common problem in Egypt that can cause poor growth and increase the susceptibility of wheat to various diseases. Therefore, it is important to explore ways to overcome this issue and improve the quality of the wheat produced in the country. The field experiment conducted on two bread wheat cultivars (Giza-168 and Giza-171) at the Agricultural Research Station in Bahteem, Qalyubia Governorate, Egypt showed promising results. Four treatments were performed: 1) control /tap-water only, 2) one Zn-spray at 45 days after sowing, 3) one Zn-spray at 60 days after sowing, and 4) twice Zn-sprays at 45 and 60 days after sowing. The spraying solution was prepared using $ZnSO_4.7H_2O$ at a rate of 5g/L tap water/ spray (200-250L/spray/fed). Results revealed that the yield and some of its components of both studied varieties showed increments. Most of these increments were statistically insignificant, except in the case of Giza-168, where both the yield and number of spikes/m2 in the first and second seasons were significant. These were achieved by spraying wheat plants with Zn 45 days after sowing (during tillering stage). The results, also, indicated that spraying wheat plants with Zn significantly increased grain-Zn concentration. Generally, Spraying wheat plants twice (at 45 and 60 days after sowing) should be recommended

Keywords: Biofortification, Grain yield, *Triticium astevium,* Zinc.

Introduction

It is estimated that zinc deficiency occurs in more than half of the world's population due to low dietary zinc intake (Nriagu, 2019). Cakmak (2008) reported that zinc deficiency affected the population who depends on cereals in their diet. He also added, zinc foliar application proved to be the more effective method in increasing grain Zn concentration. Zinc deficiency, related primarily to diet, was shown to be the cause of dwarfism and hypogonadism among adolescents from the lowest social classes in Egypt (Hussein & Bruggeman, 1997).

Prasad (2013) reported that zinc deficiency was detected in children in Egypt and that zinc supplementation resulted in increase of 12.7–15.2 cm in height of children growth in one year. According to Herrington et al. (2019), north Africa countries (especially, Egypt and Morocco) and Asia should give high priority to increase Zn content in wheat grain yield. Wheat can assist in reducing malnutrition through increasing grain Zn content, which can be increased Zn through foliar application. Cakmak & Kutman (2017) reported that zinc malnutrition is associated with grain-based diets and is due to that half of the soils planted with wheat in the world suffering from a lack of biologically available zinc. The availability of micronutrients especially, Zn, Mn and Fe in different soil types in Egypt are mostly insufficient (low), this revealed not only in apparent deficiency but also

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in hidden hunger (El-Fouly et al., 1984). Also, Cakmak (2008) noted that high yielding cereal cultivars may contribute to the high incidence of zinc deficiency in human being by reducing Zn concentration in grain through dilution and in soil through depletion. Rehman et al. (2018) reported that wheat is the most susceptible to Zn deficiency among cereal crops. The output of the wheat crop has been shown to rise to 32% when Zn-deficient soils are treated with appropriate Zn fertilization. Using foliar fertilization is important as a technique to avoid problems related to soil characteristics, as pH, high calcium carbonate etc, and environmental adverse conditions (El-Fouly & Abou El-Nour, 1999; El-Fouly, 2002). Several researches aiming to increase grain zinc concentration used different application methods, among them, Jianwei et al. (2012), Ranjbar & Bahmania (2012) and Sánchez-Rodríguez (2021). They used both soil and foliar feeding of zinc ($ZnSO_4.7H_2O$). Others as Abdul Sattar et al. (2022) and Potarzycki & Grzebisz (2009) tried to achieve the grain Zn improvement through foliar feeding with $ZnSO_4.7H_2O$. While, Wang et al. (2020) applied Zn- EDTA as foliar spray for increasing grain nutritional value. Abdul Sattar et al. (2022) found that Zn application ($ZnSO_4.7H_2O$) at 18mM as foliar spray increased Zn content in wheat grain by about 36.9% as compared with control treatment. Sánchez-Rodríguez (2021) found that foliar application of Zn produced the highest Zn use efficiency (6 -19%) while, the lowest was recorded as a result of soil Zn application (0.2-10.3%). Moreover, foliar application of Zn increased grain Zn content by 12:51%, while, the increments reached to only 4:13% as a result of applied Zn as soil application. They, also, found that the application of Zn either as soil or foliar application did not affect the grain yield of wheat. Aziz et al. (2019) found that Zn, Fe, B, Mn, and Cu foliar application considerably improved these nutrient concentrations in wheat flour when applying the micronutrients foliar application at different stages (tillering, jointing and booting).

The work was aiming to use agronomic biofortification instead to mean increasing grain-zinc concentration and grain yield as well under Egyptian soil conditions. Also, studying the varietal differences in the response to Zn spraying.

Materials and Methods

A field experiment using two wheat (*Triticum aestivum* L.) cultivars Giza-168 and Giza-171 was conducted during three consecutive winter seasons of 2018/19, 2019/20 and 2020/21.The work was carried out at the Agricultural Research Station, Ministry of Agriculture (MoA), at Bahteem, Qalyubia Governorate, Egypt. The previous crop was maize. Prior to any field practices each season, a composite soil sample was taken from the soil surface layer (0-30cm) of the experimental site and prepared for soil testing. The NPK fertilization was soil-applied in the whole experimental site as recommended by MoA (1998). The rates were 75, 15 and 25kg/fed (feddan = 4200m^2) as N, P_2O_5 and K_2O in the forms of ammonium sulphate (20.6% N), calcium superphosphate (15.5% P_2O_5) and potassium sulphate (48-52% K_2O), respectively. The rates are given per feddan (fed.) which is the official agricultural measure area in Egypt (Feddan is equal to 4200m^2) .

Half area of the experimental site was used for sowing Giza-168 and the other half for Giza-171. Sowing took place on late-November at a seed rate of 60kg/fed. No pesticides or organic manure were applied. Other field practices, *e.g.* surface irrigation and herbicides were performed as needed.

Treatments and experimental design

Zinc solution was freshly prepared using $ZnSO_4.7H_2O$ at a rate of 5g/l tap-water (200-250 l/fed/spray). The foliar spraying was performed with or without Zn to apply 4 treatments as follows:

Control (tap-water only).

One Zn-spray at about 45 days after sowing.

One Zn-spray at about 60 days after sowing.

Twice Zn-sprays as indicated in the second and the third treatments.

These treatments were arranged in a randomized complete block design (Snedecor & Cochran, 1967) with 4 replicates, each of 20m^2 (4x5m) in the first season and of 40m^2 (4x10m) in the second and the third seasons. Plants of the sum of 32 replicates were subjected to various needed determinations.

Chemical analysis

Soil analysis

Representative soil samples were taken after soil preparation and before the fertilization treatments from the experimental site at a depth of (0-50cm) , air dried, ground and passed through a 2mm pores sieve and subjected to physical and chemical analysis pH and electric conductivity (EC) were using method described by, Jackson (1973). Organic matter (O.M %) content according to Walkley & Black (1934). Phosphorus by Olsen et al. (1954). Potassium, calcium, Magnesium and sodium were extracted using ammonium acetate and described by Jackson (1973). Iron, manganese, zinc and copper extracted by DPTA and described by Lindsay & Norvell (1978).

Zinc in grains

In order to determine the zinc concentration in grain ash, a sample of one gram was taken and 5mL of HCL (2N) was added. The zinc concentration was then determined using an atomic absorption spectrophotometer apparatus that was donated by A.v. Humboldt Foundation, Germany. The analysis was carried out according to the method described by Chapman & Pratt (1978).

Parameters and statistical analysis

On mid-May, plants of a random 1 m2/replicate from each plot were harvested to estimate number of spike/m2 and weight (g) of 1000 grains. Weights (kg/fed.) of the biological, straw and grain yields were estimated based on harvesting plants of the whole replicate. Accordingly, the harvest index (%) could be calculated.

A wheat grain sample/replicate was randomly taken and subjected to determine Zn-concentration (ppm) according to Chapman & Pratt (1978). The obtained data were subjected to statistical analysis using a Costat 2.00 computer program, Copyright Cohort Software (1986).

Results and Discussion

Soil testing

Data presented in Table 1 revealed that soil is clay in texture, alkaline in reaction, medium in calcium carbonate content, with no salinity problems. Data also showed that the soil was high in phosphorus and potassium contents and very low in both calcium and magnesium. The soil zinc content was low and both iron and manganese were very low. These results indicated that the plants which grown on this soil are micronutrients deficient as a results of high pH and low micronutrient contents. Soil tests were evaluated on the basis of the tentative values of Ankerman & Large (1974).

Effect of spraying Zn on yield and some yield components

Table 2 and Fig.1 show the effect of spraying Zn on yield and some yield components of wheat (*Triticum aestivum* L.) cv. Giza-168. In spite of the most of the studied traits showed increments in their values, these increments did not reach to the level of significance as compared with control treatment. The exception was found in wheat grain yield during the first and second seasons, where significant effects were recorded due to spraying Zn The highest increment in wheat grain yield was recorded as a result of spraying Zn at 45 days after sowing in the first and second seasons. The increments reached to 11 and 21% in the 1st and 2nd seasons, respectively as compared with control treatment. Also, number of spikes / m^2 in the second season only showed significant increase which amounted by 22% as compared with control treatment.

Data recorded in Table 3 and Fig.2 show the effect of spraying Zn on yield and some yield components of wheat (*Triticum aestivum* L.) cv. Giza -171. Results revealed that there were no significant effects on all the studied traits during the three seasons compared with the control.

The results showed that there is a different response of the studied cultivars to spraying with zinc. The results showed a significant increase in the grain yield and the number of spikes per square meter for the Giza-168 variety. There was insignificant increase for these traits for the Giza-171 variety, which indicates the existence of differences in relation to the response to spray with zinc. This is indication that there are varietal differences in the Zn use efficiency. However, this needs more justification by using more genotypes and calculates the Zn use efficiency. The differences between the yields of the two varieties can be either varietal difference or due to variation in nutrient needs of both varieties. The recommendation of NPK is a general one. Since the NPK fertilizer recommendation is recommended to use as a general recommendation, which may be ideal for one region to achieve an increase in productivity while it is not the optimum for another region. These explanations are confirmed by El-Fouly et al. (2012) who found that the recommended fertilizers of maize when modified, the yield and its components showed significant increases. Also, Shaaban et al. (2018) found the same when the recommended fertilizes of bread wheat was modified.

Effect of spraying Zn on grain Zn concentration

Data presented in Table 4 and Fig 3 indicated that foliar zinc treatments significantly increased grain zinc concentration cv. Giza-168 in the three seasons. The increments ranged between 13-18 %, 12-18% and 39-78 in the 1st, 2nd and 3rd seasons, respectively as compared with control treatment. However, no significant differences among Zn treatments in the first seasons. The sprayed treatment (60 days after sowing) showed the highest significant increase in the second season. While, in the third season, spraying Zn after 45 days after sowing gave the highest grain Zn concentration.

Data presented in Table 4 and Fig. 4 showed the effect of foliar application of Zn on wheat grain Zn concentration of cv. Giza-171 in the three seasons. The recorded increments ranged between 16 - 22%, 0 - 23% and 20-120% in the 1st, 2nd and 3rd seasons, respectively as compared with control treatment .However, in the 1st and 2nd seasons, the highest wheat grain zinc concentration was achieved as a result of Zn foliar application spraying at 45 days from sowing. While, foliar application of Zn two times (at 45 and 60 days from sowing) recorded the highest grain Zn concentration. These results were in agreement with Cakmak & Kutman (2017) who reported in their review article that foliar application of zinc is a cost-effective strategy to improve grain Zn in cereal crops. Also, Ram et al. (2016) reported that wheat grain Zn concentration significantly increased due to foliar spraying with zinc.

TABLE 1. Physical and chemical characteristics of the experimental site soil

Characteristic	First season	Evaluation	Second season	Evaluation	Third season	Evaluation
Physical properties						
Coarse sand %	2.6	-	2.25		3.15	-
Sand (%)	14.4	-	5.75	-	5.58	-
Silt (%)	35	-	40	-	39.91	-
Clay (%)	48	-	52	-	51.36	-
Texture	Clay		Clay		Clay	
Chemical properties						
$CaCO_3$ %	2.64	H	2.72	H	2.35	H
EC (dS/m)	0.96	L	1.02	L	1.22	L
pH	7.54	H	7.45	H	7.66	vH
Macronutrients (mg/100g)						
P	3.60	H	4.55	H	7.25	vH
K	382.4	H	368.25	H	398	H
N	46.25	-	39.35	-	38.12	-
Ca	3.68	vL	3.76	vL	4.12	vL
Mg	2.72	vL	2.89	vL	3.01	vL
Na	2.79	-	2.81	-	4.23	-
Micronutrients (ppm)						
Zn	0.7	L	0.8	L	1.09	M
Fe	2.2	vL	2.3	vL	1.15	vL
Mn	0.9	vL	1.0	vL	1.15	vL
HCO_3^-	2.61	-	2.72	-	2.97	-
Cl^-	2.84	-	2.96	-	3.84	-
SO_4^-	4.21	-	4.34	-	5.23	-

The letters refer to H: High, M : Medium , L : Low , and vL : Very low according to Ankerman & Large (1974).

TABLE 2. Effect of spraying Zn on wheat (*Triticum aestivum* L.) yield and some yield components cv. Giza-168

Treatment (days after sowing)	No. of spike /m^2	Grain yield (kg/fed.)		Straw yield (kg/fed.)	Biological yield (kg/fed.)	1000 grain weight (g)	Harvest index (%)
Season 2018/2019			**%**				
Control	399	2192	100%	2727	4944	43	44.6
Sprayed 45	437	2439	111	3121	5560	43	44.0
Sprayed 60	410	2261	103	3101	5361	44	42.7
Sprayed 45 and60	408	2398	109	2965	5363	44	44.7
LSD 5%	N.S.	135		N.S.	N.S.	N.S.	N.S.
Season 2019/2020			**%**				
Control	349	1917	100	2923	4840	43	39.6
Sprayed 45	425	2310	120	2926	5436	44	42.5
Sprayed 60	364	2082	108	3305	5387	44	39.2
Sprayed 45 and60	389	2213	115	3063	5276	44	41.9
LSD 5%	48	204		N.S.	N.S.	N.S.	N.S.
Season 2020/2021			**%**				
Control	414	2618	100	3769	6387	43	41.0
Sprayed 45	458	2718	103	3906	6624	42	41.0
Sprayed 60	435	2709	103	4005	6714	44	40.3
Sprayed 45 and60	449	2744	104	4068	6812	42	40.3
LSD 5%	N.S.	N.S.		N.S.	N.S.	N.S.	N.S.

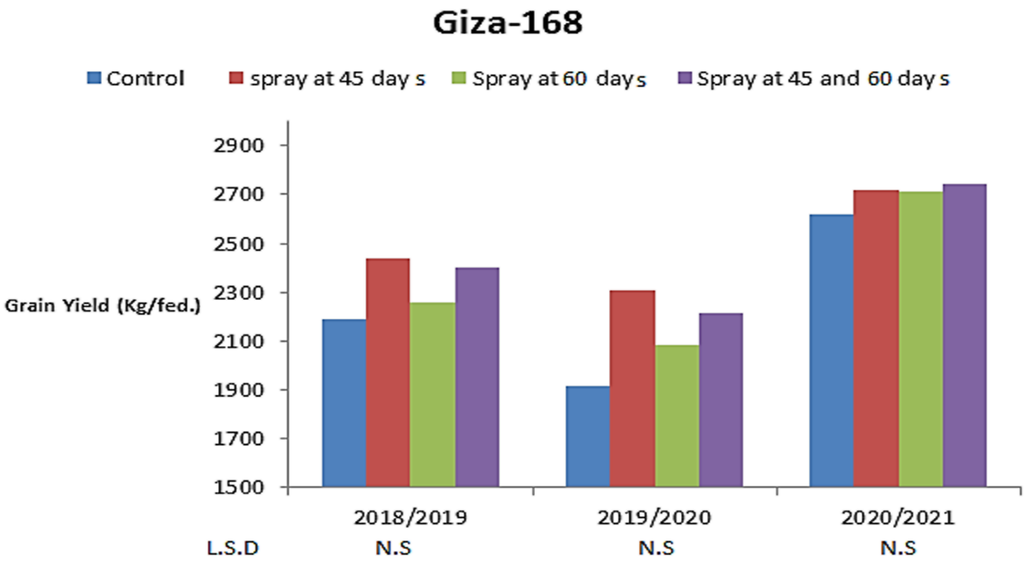

Fig. 1. Effect of zinc foliar application on Giza-168 grain yield within the three seasons

TABLE 3. Effect of spraying ZnSO4.7H2O on wheat (*Triticum aestivum* L.) yield and some yield components cv. Giza-171

Treatment (days after sowing)	No. of spike/ m²	Grain yield (kg/fed.)		Straw yield (kg/fed.)	Biological yield (kg/fed.)	1000 grain weight (g)	Harvest index (%)
Season 2018/2019			%				
Control	425	2479	100	3046	5525	43	45.0
Sprayed 45	455	2470	99	2985	5455	41	45.3
Sprayed 60	446	2560	103	3439	5999	42	42.9
Sprayed 45 and60	453	2639	106	3152	5791	42	45.7
LSD 5%	N.S.	N.S.		N.S.	N.S.	N.S.	N.S.
Season 2019/2020			%				
Control	408	2322	100	3119	5441	43	42.8
Sprayed 45	440	2380	102	2967	5347	41	44.5
Sprayed 60	431	2405	103	3225	5430	44	42.7
Sprayed 45 and60	435	2540	109	3179	5719	43	44.5
LSD 5%	N.S.	N.S.		N.S.	N.S.	N.S.	N.S.
Season 2020/2021			%				
Control	455	2716	100	3997	6713	43	40.5
Sprayed 45	448	2924	107	4432	7356	43	39.8
Sprayed 60	456	2740	100	3999	6739	42	40.7
Sprayed 45 dand60	458	3002	110	4327	7329	42	40.9
LSD 5%	N.S.	N.S.		N.S.	N.S.	N.S.	N.S.

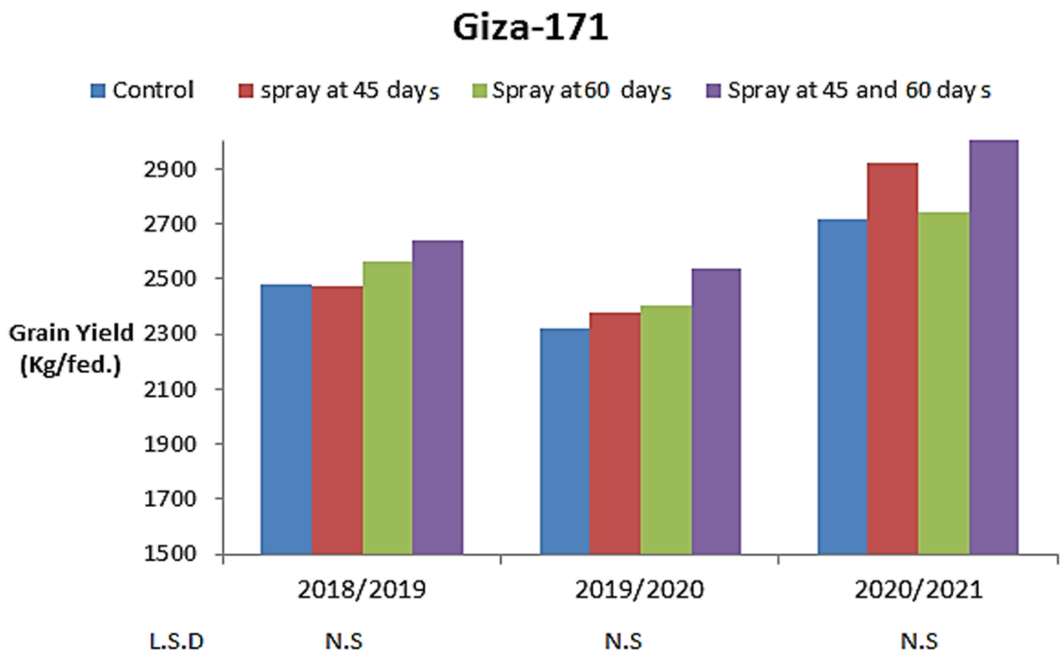

Fig. 2. Effect of zinc foliar application on Giza-171 grain yield within thethree seasons

TABLE 4. Effect of Zn foliar spray on Zn concentration of wheat grain

Treatment (days after sowing)	Grain Zn concentration (ppm)			
	Season 2018/2019			
	Giza 171	**%**	**Giza 168**	**%**
Control	55	100.0	56	100.0
Sprayed 45	67	121.8	63	112.5
Sprayed 60	64	116.3	66	117.8
Sprayed 45 and60	65	118.1	63	112.5
LSD 5%		5		5
	Season 2019/2020			
Control	35	100.0	34	100.0
Sprayed 45	43	122.8	38	111.7
Sprayed 60	35	100.0	40	117.6
Sprayed 45 and60	35	100.0	39	114.7
LSD 5%		4		2
	Season 2020/2021			
Control	24	100.0	23	100.0
Sprayed 45	29	120.8	36	156.5
Sprayed 60	40	166.6	32	139.1
Sprayed 45 and60	53	220.8	41	178.2
LSD 5%				4

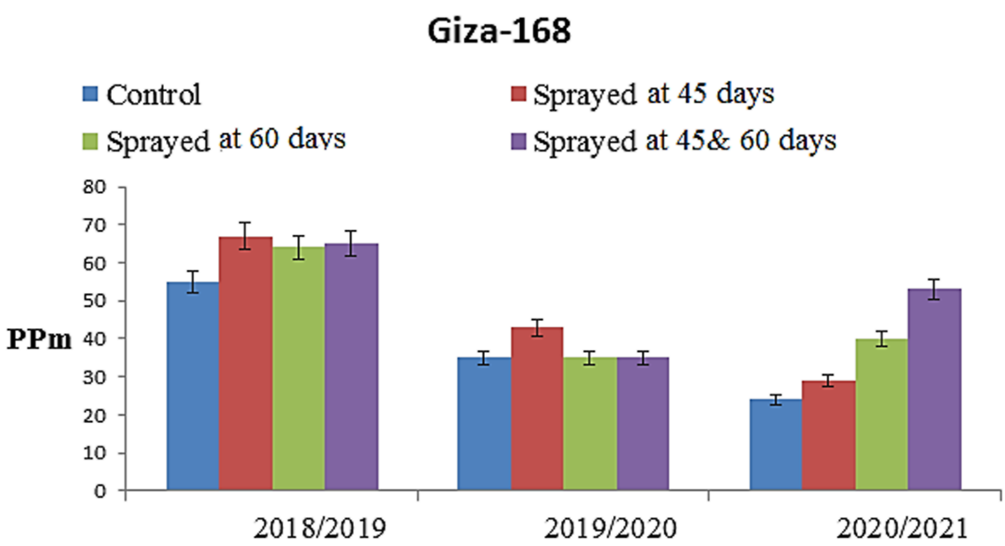

Fig. 3. Effect of zinc foliar application on Giza-168 grain zinc concentration (ppm) within three seasons

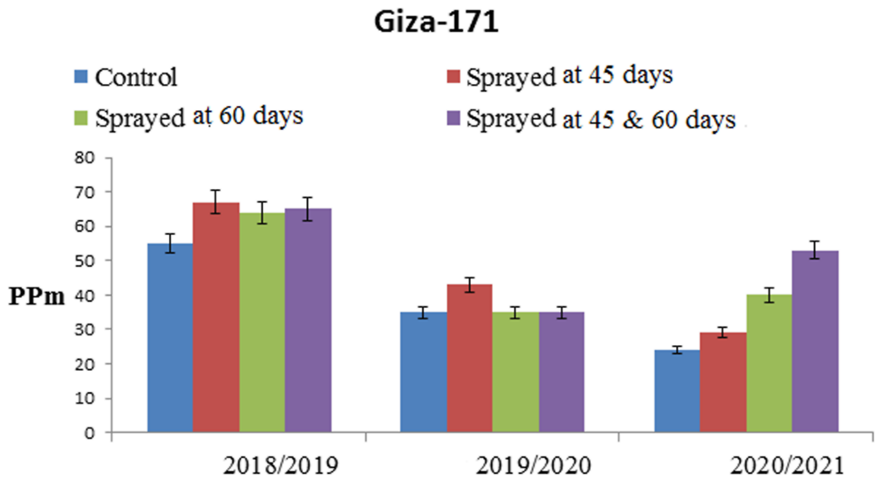

Fig. 4. Effect of zinc foliar application on Giza-171 grain zinc concentration (ppm) within three seasons

The results showed, also, that the two cultivars responded significantly concerning the biofortification of Zn in grains as reported by other authors from other regions.

Conclusion

In conclusion, it can be stated that under the conditions of this experiment, zinc in grains of both cultivars can significantly be increased through Zn foliar application, while the increase in yield was significant only in one cultivar.

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تأثيرالرش بالزنك علي المحصول ومحتوى الحبوب من الزنك في صنفين من القمح

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اجريت تجربة حقلية باستخدام صنفين من القمح (جيزة 168 وجيزة 171) خلال ثلاثة مواسم متتالية (2018/19، 2019/20 و 2020/2021) بمحطة البحوث الزراعية بوزارة الزراعة - بهتيم بمحافظة القليوبية ، مصر. يهدف البحث إلى رفع القيمة الغذائية لمحتوى الحبوب بالزنك من خلال الرش الورقي للزنك، واستكشاف استجابة الأصناف للرش بالزنك. وكانت المعاملات كالتالى: 1- رش النباتات بماء الصنبور (شاهد). 2- رش النباتات بـ $Zn\ SO_4.7H_2O$ بعد 45 يوم من الزراعة (اثناء مرحلة التفريع). 3- رش النباتات بـ $Zn\ SO_4.7H_2O$ بعد 60 يوم من الزراعة (مرحلة قبل الطرد). 4- رش النباتات بـ $Zn\ SO_4.7H_2O$ بعد 45 و 60 يوم من الزراعة. تم تحضير المحلول المرشوش باستخدام $Zn\ SO_4.7H_2O$ بمعدل 5 جم / لتر ماء حنفية / رش (250-200 لتر/ رش / فدان). أوضحت النتائج أن المحصول وبعض مكوناته لكلا الصنفين المدروسين قد أظهر زيادات في المحصول.وكانت معظم هذه الزيادات غير معنوية إحصائياً، باستثناء حالة الصنف جيزة 168 حيث كان كل من المحصول وعدد السنابل / م ^{2} فيالموسم الأول والثاني معنوياً ، على التوالي وتم تحقيق هذه الزيادات عن طريق رش نباتات القمح بالزنك بعد 45 يوماً. البذر (أثناء مرحلة التفريع). كما أشارت النتائج إلى أن رش القمح بالزنك أدى إلى زيادة معنوية في تركيز الحبوب-الزنك. وبشكل عام ، أظهر الرش الورقي مرتين بعد 45 و 60 يومًا أعلى تركيز للزنك بحبوب القمح.