Egypt. J. Agron. **Vol. 43**, No. 3, pp. 417-430 (2021)

Egyptian Journal of Agronomy

http://agro.journals.ekb.eg/

Role of Zinc on Drought Tolerance in Some Wheat (*Triticum aestivum* L.) Cultivars under Reduced Soil Water

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DROUGHT is a serious abiotic stress affects crop production in Egypt and worldwide. Two experiments were carried out under drought stress and normal irrigation during the seasons of 2018/19 and 2019/20 to study the effect of foliar application of Zn to alleviate drought stress. The soil texture is clay. The genetic materials were three Egyptian cultivars; Sakha 69, Giza 68 and Gemmieza 11. The levels of foliar spray of zinc oxide were 500ppm, 250 ppm, water and control (no treatment), sprayed two weeks before and at anthesis. Mean squares of the combined data was significant ($P \leq 0.01$) for Zn levels and for yield traits except for spike length. The differences among cultivars were significant ($P \leq 0.01$) except for yield under irrigation. This confirms the concept of "selection for yield under stress is better than under favorable environment". The traits plant height (PH), number of spikes/plant (NS/P), biological yield/plant (BY/P), grain yield/plant (GY/P) and 100GW showed the best performance at the higher Zn level 500ppm. Water deficit exerted negative effects on RWC% and chlorophyll. The reduction % (the difference between irrigation and drought stress relative to irrigation performance) in all traits was the lowest at 500ppm of Zn and increased ascendingly by decreasing the Zn level. Sakha 69 significantly showed the best performance for PH, NS/P and BY/P under both, drought stress and normal irrigation. It could be concluded that Zn foliar application alleviated drought stress, and Sakha 69 was the most stable cultivar in GY/P and gave the best performance under drought stress.

Keywords: Chlorophyll, Drought stress, RWC%, *T. aestivum* L., Zn foliar application.

Introduction

Drought is one of the main limiting abiotic factors of wheat production in arid and semiarid environments. Drought affects growth and plant development as considered a challenge for agricultural researchers and plant breeders (Mahpara et al., 2015; Nezhadahmadi et al., 2013). Therefore, drought should be highly preferred in the future wheat improvement programs. Raising productivity of a crop depends on the availability of nutrients during its life cycle. Zinc deficiencies cause agronomic problems, particularly in cereals (Moreno-Lora & Delgado, 2020). Zinc is a precursor of plant growth hormones (auxin), proteins and is required in sugar consumption. Root development, carbohydrate and chlorophyll formation are also dependent on zinc. Zn is a regulatory co-factor and structural constituent in proteins and enzymes involved in many biochemical pathways (Alloway, 2009; Cakmak et al., 2017). The presence of some micronutrients needed for plant growth may alleviate the effect of dehydration. Interestingly Zn, B, and Mn applications raise the resistance of plants to drought stress (Khan et al., 2004; Movahhedy-Dehnavy et al., 2009). Otherwise, drought stress has exerted a negative effect on relative water content of leaves (RWC), and durum wheat under water stress loses much more water than the bread wheat. Larbi et al. (2004), Akram (2011) and Keyvan (2010) indicated that increase in the intensity of drought stress decreased RWC, total chlorophyll and increased proline content. Also, Tale & Haddad (2011) stated that drought stress closes stomata, inhibits photosynthesis and damages the chlorophyll contents. Furthermore, Almeselmani et al. (2012) recorded reduction in all physiological traits, yield and yield component in

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Received 09/11/2021; Accepted 10/1/2022
DOI : 10.21608/agro.2022.105221.1291

the drought susceptible varieties compared to other varieties.

Foliar application of Zn, B, and Mn at booting to anthesis reduced the harmful effects of drought stress in winter wheat, and increased the rate of photosynthesis and chlorophyll content as measured by SPAD instrument, pollen viability, number of fertile spikes, number of grains per spike (Hassan et al., 2005; Karim et al., 2012; Tavallali et al., 2009). The sensitivity to Zn deficiency stress increased when plants were drought-stressed, and irrigation maximized grain yield with adequate supply of Zn. Under drought stress the growth, yield, biochemical and antioxidant enzymes of the wheat plant were reduced (Bagci et al., 2007). However, application of salicylic acid or zinc has beneficial effects on growth and chemical constituents as well as yield quality under different levels of irrigation interval (Sofy, 2015). The foliar application of Zn alleviated the negative effects of drought stress (Hera et al., 2018; Yavas & Unay, 2016) and improved yield and yield components (Sultana et al., 2016). Under salinity stress, it was found that foliar spraying with either K or Zn significantly increased yield and yield components (El-Dahshouri et al., 2017; Manal et al., 2016; Zafar et al., 2016). Likewise, foliar application of Zn increased SPAD and improved plant photosynthetic characteristics under water stress (Abid et al., 2018; Ma et al., 2017). Taran et al. (2017) showed that Cu and Zn-nanoparticles alleviated the negative effect of drought action upon plants of winter wheat. In calcareous soil, Ru et al. (2018) indicated that Fe and Zn applications, either as soil or foliar application improved the grain yield, protein, and gluten content of wheat in calcareous soil. The aim of this work was to study the ability of foliar application of Zn to bread wheat to alleviate the effects of water stress and increase yield and yield components.

Materials and Methods

Two experiments were carried out during the two seasons; 2018/19 and 2019/20 at Faculty of Agriculture Experimental farm, Assiut University, Egypt (Longitude: 31.125° Latitude: 27.25° E, Elevation: 45m/148 Feet). The soil texture is clay (Table 1). The first experiment was under drought stress, and the second one under normal irrigation with a stripe of six-meter width in between to prevent water seepage. The experimental design was split-plot in a randomized complete block design with three replications. The treatments of the whole plots were foliar spray of zinc oxide; 500ppm, 250ppm, water, and control (no treatment). The three cultivars were assigned to the split plots. The plot size was two rows, three m in long and 30cm apart. Date of planting was November 28th in the first and November 27th in the second season. After full emergence the seedlings were adjusted to 30 seedlings per row. The two experiments were foliar sprayed two weeks before and at anthesis.

The genetic materials

The genetic materials were three spring wheat (*Triticum aestivum* L) Egyptian cultivars; Sakha 69, Giza 68 and Gemmieza 11.

Irrigation

The experiment under normal irrigation received planting irrigation and four surface irrigations throughout the growing season. However, the experiment under drought stress received planting irrigation and only one irrigation three weeks later.

TABLE 1. Some physical and chemical properties of representative soil samples in the experimental sites before sowing (30cm depth)

Sand (%)	**Silt (%)**	**Clay (%)**	**Texture grade**	**EC (1:1 extract) dSm^{-1}**	**pH**	**$CaCO_3$ (%)**	**Organic matter (%)**	**$NaHCO_3$-extractable P ($mg\ kg^{-1}$)**
27.4	24.3	48.3	Clay	0.47	8.2	3.4	1.75	4.36
Total nitrogen (%)	KCl-extractable N ($mg\ kg^{-1}$)	Fe Mg/kg	Mn Mg/kg	Cu Mg/kg	Zn Mg/kg	Soil moisture at F.Capacity.	Soil moisture at wilting point.	NH_4OAC-extractable K ($mg\ kg^{-1}$)
0.72	41.23	13.21	5.152	1.31	2.12	46%	28%	49.24

* Each value represents the mean of three replications.

Fe, Mn, Cu and Zn were determined by inductively coupled plasma emission spectrometer (iCAP 6200) in the Central Lab of the Fac. of Agriculture.

Fertilization

Super phosphate (P_2O_5, 15.5%) was added during land preparation at a rate of 357.14kg/ha. Nitrogen fertilization in the form of ammonium nitrate (33.5% N) was added to both experiments at a rate of 190.5kg N/ha in one dose before the first irrigation.

The soil moisture percentage (Table 2) at 30cm depth in the drought stress experiment before anthesis was 23.86% in the first year and 18.52% in the second year, and was less than the wilting point (28%) (Table 1). This indicates that the plants in the drought experiment were subjected to severe drought starting before anthesis to harvest.

To determine relative water content (RWC%) five flag leaves were sampled at 0900 h in the morning at anthesis three days after the second spray of Zn. The leaves were placed in polyethene bags and transferred to the laboratory as quickly as possible to minimize water losses. Fresh weight was determined one hour after excision. The turgid weight was obtained after soaking and incubating the leaves for 24 h in distilled water at 20°C. After soaking, leaves were quickly and carefully blotted dry with tissue paper prior to the determination of turgid weight. Dry weight was obtained after oven-drying the leaf samples for 72h at 70°C. The relative water content was calculated from the equation: RWC%= (fresh weight – dry weight)/(turgid weight – dry weight) x100 (Larbi et al., 2004). A portable leaf chlorophyll meter (SPAD-502; Konica Minolta Sensing, Inc., Japan) (The Soil Plant Analysis Development (SPAD) chlorophyll meter) was used to measure the leaf greenness of the plants 10 days before (75 days from sowing) and after anthesis (95 days from sowing) on 20 flag leaves from each plot. The strong relationship between readings of the portable SPAD-502 chlorophyll meter and leaf chlorophyll content has been demonstrated by several authors (Markwell et al., 1995; Marquard & Tipton , 1987; Yadava, 1986).

At maturity, the plot (60 plants) was harvested, number of spikes/plant (NS/P), biological yield (BY/P, g), grain yield (GY/P, g) and 100 grain weight, g (GW, g) were recorded. Plant height (PH, cm) and spike length (SL, cm) were recorded on ten individual plants.

Statistical analysis

Statistical analysis was performed using Excel (Microsoft office 2016) on plot mean basis, and mean separation using LSD test according to Steel & Torrie (1980).

Results and Discussion

The soil texture of the experimental site is clay, and the pH is 8.2 which could cause unavailability of Zn required for plant growth (Table 1). Zinc deficiency is most seen on alkaline and sandy soil. High levels of phosphorus and copper, and low level of nitrogen in the soil increase the probability of zinc deficiency. The availability of zinc to the plant decreases as pH increases (McKenzie, 2015; Wade, 2019). As pH rises, micronutrients precipitate as insoluble minerals, which cannot be taken up by plants.

Mean squares of Zn levels was significant ($P \leq 0.05$ or 0.01) in both years and their combined under both environments for PH, NS/P, BY/P, GY/P, RWC and chlorophyll at 75 and 95 days from sowing indicates the effects of Zn levels on all traits except SL (Tables 3 and 4). These results agree with those reported by Abid et al. (2018), Ma et al. (2017).

The effect of years under drought stress was significant ($P \leq 0.01$) for PH, GY/P and GW. The differences among cultivars were significant ($P \leq 0.01$) either under drought or irrigated environment in all cases, except for yield under irrigation. This confirms the concept of selection for yield under stress is better than under favorable environment.

TABLE 2. The soil moisture percentage at 30cm depth

Seasons / Time	Season 2018/19		Season 2019/20	
	Drought stress experiment	Normal Irrig. experiment	Drought stress experiment	Normal Irrig. experiment
Before 2nd irrigation	37.84	39.84	38.56	37.12
Before 4th irrigation	23.86	33.72	22.81	36.89
At anthesis	17.15	38.17	18.52	37.55

TABLE 3. Mean squares of yield traits in separate and combined analyses under drought stress and irrigation

Trait	S.V.	Years (Y)	Reps	Reps/ years	A	A*Y	Error a	B	B*Y	A*B	A*B*Y	Error b
	d.f.	1	2	4	3	3	$6^s,12^c$	2	2	6	6	$16^s,32^c$
PH Stress	Year 1		52.31		101.19**		10.41	18.25**		10.66		14.15
	Year 2		28.45		127.52**		4.18	633.45**		3.63		17.34
	Comb.	1132.12**		40.38	224.58**	4.13	7.31	2264.19**	194.34**	2.54	11.77	15.74
PH Irrigation	Year 1		21.03		122.35**		7.7	444.56		20.08		15.35
	Year 2		8.34		145.38**		9.26	358.34**		0.93		18.4
	Comb.	32		14.69	256.54**	11.21	8.47	615.81**	187.06	10.07		16.88
SL Stress	Year 1		1.9		0.36		1.64	12.00**		0.41		0.82
	Year 2		0.36		1.36*		0.25	19.53**		0.19		0.53
	Comb.	1		1.13	1.45	0.27	0.94	30.26**	1.26	0.15	0.45	0.67
SL Irrigation	Year 1		3.56		0.77		0.55	25.75**		0.24		0.82
	Year 2		0.86		0.99		0.6	38.53		0.05		0.62
	Comb.	5.56		2.21	1.09	0.67	0.58	37.10**	27.18**	0.2	0.08	0.72
NS/P Stress	Year 1		0.08		3.73**		0.24	5.25**		0.17		0.3
	Year 2		1.52		1.05*		0.2	9.44**		0.48		0.36
	Comb.	2.04		0.8	4.36**	0.41	0.22	14.33**	0.36	0.24	0.41	0.33
NS/P Irrigation	Year 1		0.2		2.02**		0.27	25.45**		0.48		0.81
	Year 2		0.34		4.89*		0.53	10.98**		0.18		0.41
	Comb.	3.79*		0.27	6.48**	0.44	0.4	14.28**	22.13**	0.36	0.29	0.61

TABLE 3. Cont.

Trait	S.V.	Years (Y)	Reps	Reps/ years	A	A*Y	Error a	B	B*Y	A*B	A*B*Y	Error b
BY/P Stress	Year 1		19.13		270.99**		4.58	94.81**		19.18*		5.68
	Year 2		2.32		11.88		9.83	162.78**		2.59		5.77
	Comb.	1.39		10.72	193.35**	89.51**	7.21	250.39**	7.19	8.72	13.05	5.72
BY/P Irrigation	Year 1		65.68		236.67**		15.72	75.30*	1	12.45		13.68
	Year 2		2.09		51.61**		1.56	93.95**		5.28		5.24
	Comb.	2579.06*		33.88	251.50**	36.78*	8.64	16.61	152.65**	7.51	10.21	9.46
GY/P Stress	Year 1		1.36		27.7**		1.1	7.94**		1.66		1.11
	Year 2		0.17		5.63**		0.32	2.49*		0.9		0.57
	Comb.	87.66**		0.76	28.99**	4.34**	0.71	8.04**	2.39	0.63	1.93	0.84
GY/P Irrigation	Year 1		3.11		15.77**		1.34	1.72		2.64		3.18
	Year 2		0.74		20.34**		1.14	0.88		0.7		0.66
	Comb.	503.13**		1.392	35.28**	0.84	1.24	2.53	0.08	0.98	2.36	1.92
100GW Stress	Year 1		0.05		0.39*		0.08	2.17		0.01		0.08
	Year 2		0.01		0.11		0.04	3.12**		0.02		0.04
	Comb.	18.67**		0.03	0.45**	4.19**	0.06	5.19**	0.11	0.02	0.003	0.06
100GW Irrigation	Year 1		0.13		0.23*		0.04	3.42**		0.02		0.11
	Year 2		0.14		0.42		0.1	1.13**		0.05		0.17
	Comb.	22.81**		0.13	0.64**	0.64**	0.07	1.52**	3.03**	0.05	0.02	0.14

*, **: Significant at 0.05 and 0.01% levels of probability, respectively.

PH= Plant height, SL= Spike length, NS/P= Number of spikes/plant, BY/P= Biological yield/plant, GY/P= Grain yield/plant, s and c= Error variance for separate and combined analyses, respectively.

TABLE 4. Mean squares of separate and combined analyses of RWC% and chlorophyll under drought stress and irrigation

Trait	S.V.`	Years (Y)	Reps	Reps/ years	A	A*Y	Error a	B	B*Y	A*B	A*B*Y	Error b
	d.f.	1	2	4	3	3	$6^s,12^c$	2	2	6	6	$16^s,32^c$
RWC% Stress	Year 1		1.06		13.77**		1.04	58.31**		1.39		0.71
	Year 2		7.52		27.48**		4.43	13.33**		1.11		2.11
	Comb.	393.87**		4.3	39.02**	3.23	2.73	63.69**	7.97**	2.12	0.39	1.41
RWC% Irrigation	Year 1		0.73		13.42**		1.35	58.27**		1.54		0.63
	Year 2		12.28		38.56**		6.66	85.47**		0.84		7.69
	Comb.	122.44**		6.5	47.21**	4.77	4.02	142.34**	1.41	1.14	1.24	5.16
Chlorophyll75 Stress	Year 1		0.94		12.13**		0.54	75.26**		1.1		0.58
	Year 2		0.27		23.22**		1.34	148.46**		0.73		1.09
	Comb.	11.58*		0.51	33.28**	2.07	0.94	28.70**	195.02**	0.66	1.17	0.84
Chlorophyll75 Irrigation	Year 1		0.52		4.30*		0.67	20.80**		0.26		0.47
	Year 2		1.26		2.91*		0.61	124.67**		0.28		0.73
	Comb.	169.81**		0.89	6.84**	0.4	0.64	123.59**	21.88**	0.25	0.29	0.6
Chlorophyll95 Stress	Year 1		1.84		25.52**		1.15	51.73		5.53		1.55
	Year 2		3.4		3.88*		0.57	183.31**		1.96		0.66
	Comb.	86.09**		2.62	23.82**	5.59**	0.86	48.48**	186.57**	2.32	5.17**	1.1
Chlorophyll95 Irrigation	Year 1		0.17		5.25**		0.57	33.97**		0.49		0.33
	Year 2		3.52		4.25*		0.63	78.61**		0.08		0.55
	Comb.	14.30*		1.84	9.47**	0.03	0.6	105.52**	7.05**	0.32	0.26	0.44

*, **: Significant at 0.05 and 0.01 levels of probability, respectively.

RWC%= Leaf relative water content, chlorophyll 75 and 95= Chlorophyll content after 75 and 95 days from sowing, s and c= Error variance for separate and combined analyses, respectively.

Mean squares of RWC% and chlorophyll before and at anthesis (Table 4) indicates the significant effect of years (P≤ 0.05 - P≤ 0.01). Furthermore, mean square of years for RWC% and chlorophyll at anthesis (95 days) was larger under stress than under normal irrigation. The differences among Zn levels and among cultivars were significant (P≤ 0.01). The interaction of cultivars and years is significant except for RWC% under normal irrigation, and mean squares of RWC% and chlorophyll at anthesis was larger under drought stress than under normal irrigation. This preliminary study clarifies that selection among genotypes under drought stress for yield, RWC% and chlorophyll content could be better than under normal irrigation.

Means of PH, NS/P, BY/P, GY/P and 100gw were the best at the higher Zn level 500ppm in both years and their combined (Table 5, Fig.1 to 6), while SL was not affected.

Water deficit exerted negative effects on RWC% and chlorophyll at 75 and 95 days from planting in both years and their combined**.** The means decreased in descending order from 500ppm, 250ppm, water and control (Fig.7 to 9). The combined mean of plant height under drought stress decreased from 88.22cm to 79.86cm at, and from 100.69 to 91.81cm at 500ppm Zn level to control treatment under normal irrigation and control treatment, respectively. The reduction % in all traits (Table 5, Fig. 10) was the lowest at 500ppm foliar application of Zn and increased in ascending order as level of Zn decreased. This indicates the ability of Zn foliar application to alleviate drought stress confirming the results of many researchers (Khan et al., 2004; Movahhedy-Dehnavy et al., 2009; Keyvan, 2010; Akram, 2011; Yavas & Unay, 2016; Hera et al., 2018).

The combined means of the cultivars (Table 6) show that Sakha 69 significantly performed the best for NS/P and BY/P under both of drought stress and normal irrigation. Giza 168 showed the best performance in spike length, RWC% and chlorophyll, and Gemmieza 11 was the best in GW under both environments. Respect GY/P Sakha 69 exceeded (P≤ 0.05) the others under drought stress, however Gemmieza 11 was the best under normal irrigation in both years and combined. The reduction % which reflects stability of the cultivars varied from trait to another, Sakha 69 showed the lowest Red% (stable) in PH, BY/P, GY/P, RWC and chlorophyll before and at anthesis (Fig. 11). Gemmieza 11gave the lowest Red% for SL. It could be concluded that Sakha 69 was the most stable cultivar in GY/P and out yielded the others under drought stress.

Conclusion

The availability of zinc to the plant decreases as pH increases. As pH rises, micronutrients precipitate as insoluble minerals, which cannot be taken up by plants. The pH of the experimental site was 8.2. Results indicated that mean squares of Zn levels was significant (P≤ 0.05 or 0.01) in both years and their combined under both environments for PH, NS/P, BY/P, GY/P, RWC and chlorophyll at 75 and 95 days from sowing indicating the effects of Zn levels on all traits except SL. The differences among cultivars were significant (P≤ 0.01) either under drought or irrigation environment in all cases except yield under irrigation. This confirms the concept of selection for yield under stress is better than under favorable environment. Means of PH, NS/P, BY/P, GY/P and 100gw were the best at the high Zn level 500ppm in both years and their combined, while SL was not affected. The means decreased in descending order from 500ppm, 250ppm, water and control. The reduction % in all traits was the lowest at 500ppm foliar application of Zn and increased in ascending order as level of Zn decreased. This indicates the ability of Zn foliar application to alleviate drought stress. It could be concluded that Sakha 69 was the most stable cultivar in GY/P and out yielded the others under drought stress.

TABLE 5. Means of yield traits, RWC% and chlorophyll in both seasons and their combined under drought stress and irrigation.

Zn levels	PH ,cm (stress)			PH, cm (irrigation)				SL, cm (stress)			SL, cm (irrigation)			
	Year 1	Year 2	Comb.	Year 1	Year 2	Comb.	RED%	Year 1	Year 2	Comb.	Year 1	Year 2	Comb.	RED%
500ppm	83.67a	92.78a	88.22a	99.17a	102.22a	100.69a	12.39	11.94a	12.44a	12.19a	12.56a	13.67a	13.11a	6.99
250ppm	81.89a	89.67a	85.78b	97.89a	98.89a	98.39b	12.82	11.83a	12.22a	12.03a	13.00a	13.44a	13.22a	9.03
water	80.44a	87.22b	83.83c	96.78a	96.11b	96.44bc	13.08	11.89a	11.89b	11.89a	13.00a	13.22a	13.11a	9.32
None	75.83b	83.89c	79.86d	90.83b	92.78c	91.80d	13.01	11.5a	11.56b	11.53a	12.44a	12.89a	12.67a	8.99
	NS/P (stress)			NS/P (irrigation)				BY/P, g (stress)			BY/P ,g (irrigation)			
	Year 1	Year 2	Comb.	Year 1	Year 2	Comb.	RED%	Year 1	Year 2	Comb.	Year 1	Year 2	Comb.	RED%
500ppm	5.78a	5.77a	5.78a	7.67a	7.47a	7.57a	23.68	31.30a	27.04a	29.17a	54.83a	40.52a	47.68a	38.81
250ppm	5.22a	5.48a	5.35b	7.18a	6.74a	6.96b	23.10	26.37b	25.20a	25.79b	52.73a	38.37b	45.55b	43.39
water	4.98ab	5.34ab	5.16b	6.83b	6.54a	6.68b	22.85	24.77b	24.96a	24.86b	48.07b	37.44b	42.76c	41.84
None	4.23b	4.95b	4.59c	6.58b	5.67b	6.12c	25.06	15.93c	24.38a	20.15c	43.32c	34.74d	39.03d	48.37
	GY/P,g (stress)			GY/P, g (irrigation)				100GW,g (stress)			100GW,g (irrigation)			
	Year 1	Year 2	Comb.	Year 1	Year 2	Comb.	RED%	Year 1	Year 2	Comb.	Year 1	Year 2	Comb.	RED%
500ppm	9.72a	6.60a	8.16a	17.78a	12.98a	15.38a	46.93	4.69a	5.58a	5.14a	5.13a	6.31a	5.72a	10.18
250ppm	8.78a	5.89a	7.33b	17.09a	11.71b	14.39b	49.06	4.47ab	5.08b	4.78b	4.93ab	6.08ab	5.51b	13.31
water	7.12b	5.29ab	6.21c	16.15ab	10.32c	13.23c	53.10	4.34b	4.75c	4.54c	4.84ab	5.96ab	5.40b	13.89
None	5.76c	4.77b	5.26d	14.72b	9.59d	12.16d	56.68	4.21b	4.80c	4.51c	4.76ab	5.80b	5.28c	14.59
	RWC% (stress)			RWC% (irrigation)				Chlorophyll 75(Stress)			Chlorophyll75(irrigation)			
	Year 1	Year 2	Comb.	Year 1	Year 2	Comb.	RED%	Year 1	Year 2	Comb.	Year 1	Year 2	Comb.	Red%
500ppm	91.85a	88.38a	90.11a	95.66a	93.78a	94.72a	4.87	51.46a	48.48a	49.97a	51.74a	51.27a	51.50a	2.97
250ppm	89.76bc	86.07ab	87.92b	94.02b	91.73a	92.88a	5.34	50.82a	47.98a	49.40a	51.34a	50.71a	51.02a	3.19
water	88.75c	85.77b	87.26b	93.32b	91.19ab	92.26ab	5.41	49.30b	47.71ab	48.50b	51.93a	49.11b	50.52ab	3.99
None	87.9c	82.83c	85.37c	92.88c	88.75b	90.82b	6.00	47.44c	46.40b	46.92c	51.55a	48.43b	49.99b	6.15
	Chlorophyll.95 (stress)			Chlorophyll.95 (irrigation)										
	Year 1	Year 2	Comb.	Year 1	Year 2	Comb.	RED%							
500ppm	53.08a	50.06a	51.57a	53.24a	52.25a	52.74a	2.23							
250ppm	52.41a	48.92b	50.66b	52.41a	52.28ab	52.34ab	3.21							
water	51.34a	48.10bc	49.72c	51.51b	52.06ab	51.79bc	4.00							
None	49.18b	47.82c	48.50d	51.41b	51.41b	51.41c	5.66							

Means followed by the same alphabetical letter are not significant at 0.05 level of probability.

Red%= (Combined mean at irrigation-at drought/ combined mean at irrigation)*100, PH=Plant height, SL=Spike length, NS/P= Number of spikes/plant, BY/P= Biological yield/plant, GY/P= Grain yield/plant, GW= 100 grain weight, RWC= Relative water content, chlorophyll 75 and 95= Chlorophyll content after 75 and 95 days from sowing.

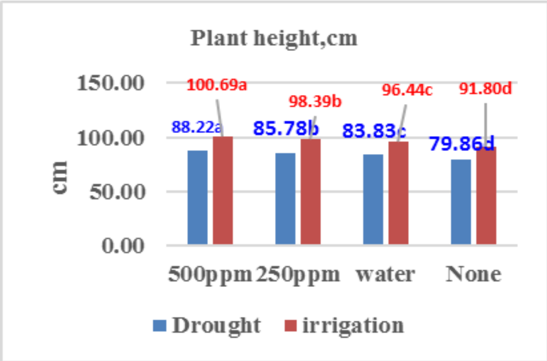

Fig. 1. Effect of zinc on PH (plant height, cm) based on combined means under drought and irrigation conditions [a, b means followed by the same letter are not significant under drought and irrigation separately]

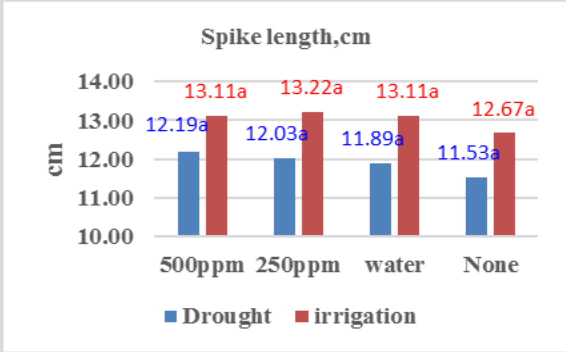

Fig. 2. Effect of zinc on spike length based on combined means under drought and irrigation conditions [a, b means followed by the same letter are not significant under drought and irrigation separately]

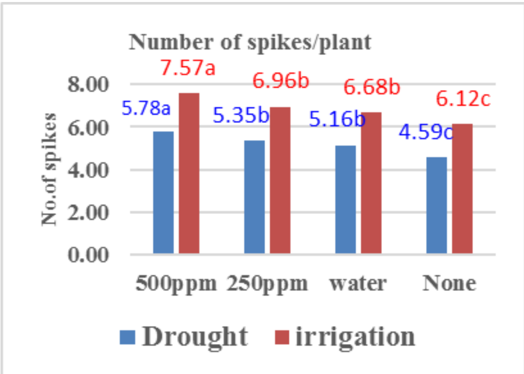

Fig. 3. Effect of zinc on NS/P based on combined means under drought and irrigation conditions [a, b means followed by the same letter are not significant under drought and irrigation separately]

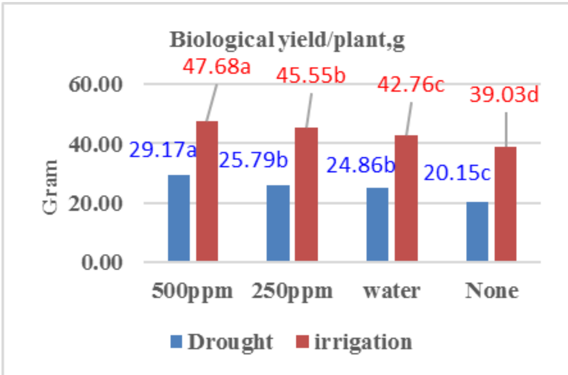

Fig. 4. Effect of zinc on BY/P based on combined means under drought and irrigation conditions [a, b means followed by the same letter are not significant under drought and irrigation separately]

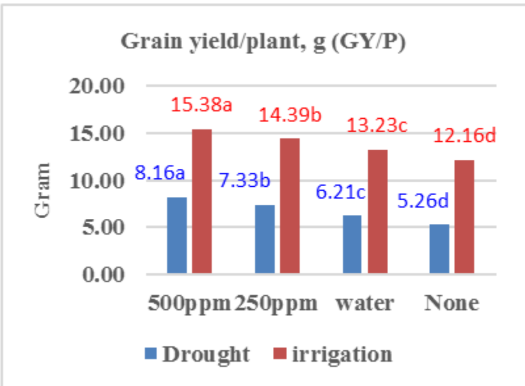

Fig. 5. Effect of zinc on GY/P based on combined means under drought and irrigation conditions [a, b means followed by the same letter are not significant under drought and irrigation separately]

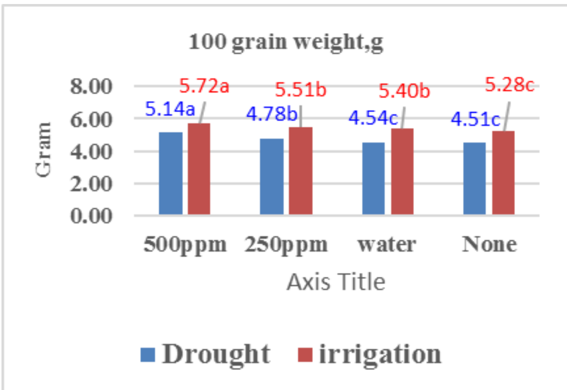

Fig. 6. Effect of zinc on 100 grain weight (g) based on combined means under drought and irrigation conditions [a, b means followed by the same letter are not significant under drought and irrigation separately]

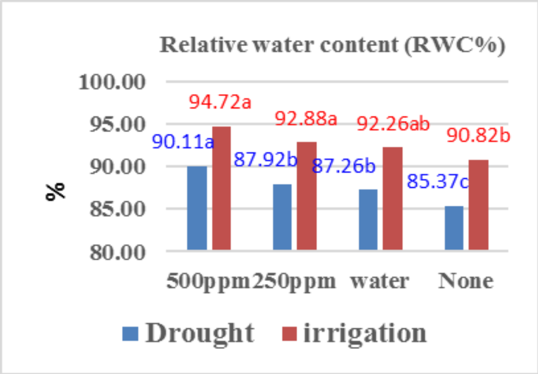

Fig. 7. Effect of RWC% on PH based on combined means under drought and irrigation conditions [a, b means followed by the same letter are not significant under drought and irrigation separately]

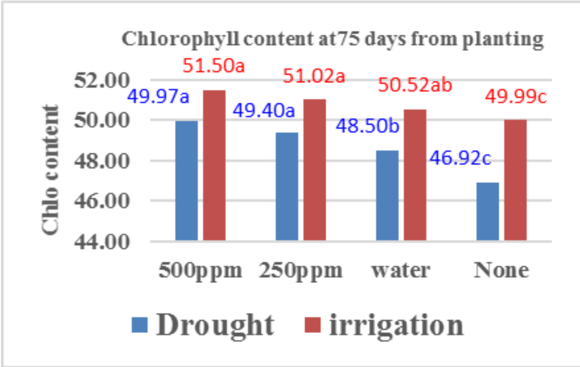

Fig. 8. Effect of zinc on (Chl.) chlorophyll 75d based on combined means under drought and irrigation conditions [a, b means followed by the same letter are not significant under drought and irrigation separately]

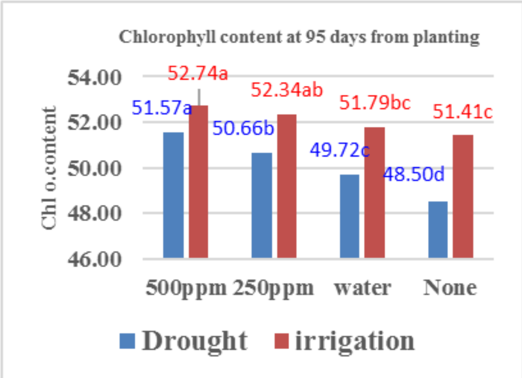

Fig. 9. Effect of zinc on (Chl.) chlorophyll 95d based on combined means under drought and irrigation conditions [a, b means followed by the same letter are not significant under drought and irrigation separately]

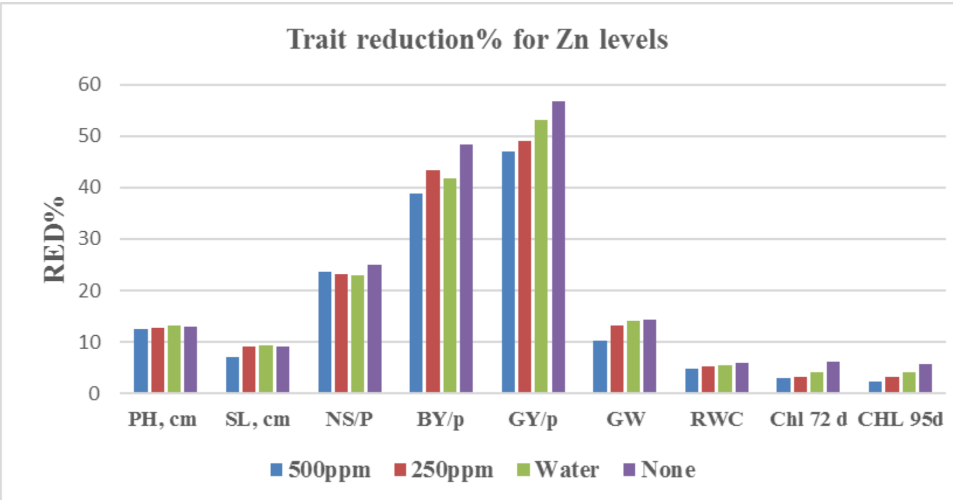

Fig. 10. Combined means of reduction % in the studied traits over the two years for the Zn levels [Red%= (Combined mean at irrigation-at drought/ combined mean at irrigation)*100, PH= Plant height, SL= Spike length, NS/P= Number of spikes/plant, BY/P= Biological yield/plant, GY/P= Grain yield/plant, GW= 100 grain weight, RWC= Relative water content, chlorophyll 75 and 95= Chlorophyll content after 75 and 95 days from sowing]

TABLE 6. Means of the studied traits for the three cultivars in both seasons and their combined under drought stress and irrigation.

	PH, cm (stress)			PH, cm (irrigation)				SL, cm (stress)			SL, cm (irrigation)			
Cultivars	Year 1	Year 2	Comb.	Year 1	Year 2	Comb.	RED%	Year 1	Year 2	Comb.	Year 1	Year 2	Comb.	RED%
Sakha 69	84.12b	92.67a	88.39b	96.79b	92.50c	94.64b	6.59	10.79c	10.58c	10.69c	11.08b	13.33b	12.21b	12.46
G168	90.54a	92.50a	91.52a	101.92a	103.33a	102.62a	10.79	12.79a	13.00a	12.90a	13.83a	15.08a	14.46a	10.79
Gemm.11	66.71c	80.00b	73.35c	89.79c	96.67b	93.23b	21.35	11.79b	12.50b	12.14b	13.33a	11.50c	12.42b	2.18
	NS/P (stress)			NS/P (irrigation)				BY/P,g (stress)			BY/P,g (irrigation)			
	Year 1	Year 2	Comb.	Year 1	Year 2	Comb.	RED%	Year 1	Year 2	Comb.	Year 1	Year 2	Comb.	RED%
Sakha 69	5.69a	6.18a	5.93a	8.74a	6.36b	7.55a	21.42	27.07a	27.21a	27.14a	51.88a	34.56b	43.22a	37.38
G168	5.09b	5.56b	5.32b	6.24b	5.80b	6.02c	11.57	24.82b	27.82a	26.32a	46.99b	39.67a	43.33a	39.64
Gemm.11	4.37c	4.43c	4.39c	6.21b	7.66a	6.94b	36.61	21.89c	21.16b	21.53b	50.34a	39.08a	44.71a	51.95
	GY/P ,g (stress)			GY/P, g (irrigation)				100GW,g (stress)			100GW,g (irrigation)			
	Year 1	Year 2	Comb.	Year 1	Year 2	Comb.	RED%	Year 1	Year 2	Comb.	Year 1	Year 2	Comb.	RED%
Sakha 69	8.75a	5.85a	7.30a	15.99a	10.84a	13.42a	45.78	4.07b	5.11b	4.59c	4.31b	6.24a	5.28b	186.95
G168	7.61b	5.95a	6.78ab	16.64a	11.26a	13.95a	51.82	4.31b	5.18b	4.74b	5.09a	5.69b	5.39b	188.02
Gemm.11	7.18b	5.12b	6.15b	16.67a	11.34a	14.01a	56.37	4.89a	6.03a	5.46a	5.33a	6.19a	5.76a	194.80
	RWC% (stress)			RWC% (irrigation)				Chlorophyll 75 (Stress)			Chlorophyll 75 (irrigation)			
	Year 1	Year 2	Comb.	Year 1	Year 2	Comb.	RED%	Year 1	Year 2	Comb.	Year 1	Year 2	Comb.	Red%
Sakha 69	88.78c	85.27b	87.03c	91.78c	88.78c	90.28c	3.60	48.7b	47.35b	48.02b	48.97c	47.86c	48.41c	0.81
G168	93.19a	87.38a	90.28a	96.19a	94.11a	95.15a	5.12	48.79b	51.16a	49.98a	53.48a	52.23a	52.86a	5.44
Gemm.11	90.91b	86.20ab	88.55b	93.95b	91.19b	92.57b	4.34	51.78a	44.39c	48.08b	52.48b	49.55b	51.01b	5.75
	Chlorophyll 95 (stress)			Chlorophyll 95 (irrigation)										
	Year 1	Year 2	Comb.	Year 1	Year 2	Comb.	RED%							
Sakha 69	49.42c	48.91	49.17b	50.08c	50.24c	50.16c	1.99							
G168	51.56b	52.36	51.96a	53.98a	53.37a	53.67a	3.20							
Gemm.11	53.51a	44.89	49.20b	52.36b	52.39b	52.38b	6.07							

Means followed by the same alphabetical letter are not significant at 0.05 level of probability.

Red%= (Combined mean at irrigation-at drought/ combined mean at irrigation)*100, PH= Plant height, SL= Spike length, NS/P= Number of spikes/plant, BY/P= Biological yield/plant, GY/P= Grain yield/plant, GW= 100 grain weight, RWC= Relative water content, chlorophyll 75 and 95= Chlorophyll content after 75 and 95 days from sowing.

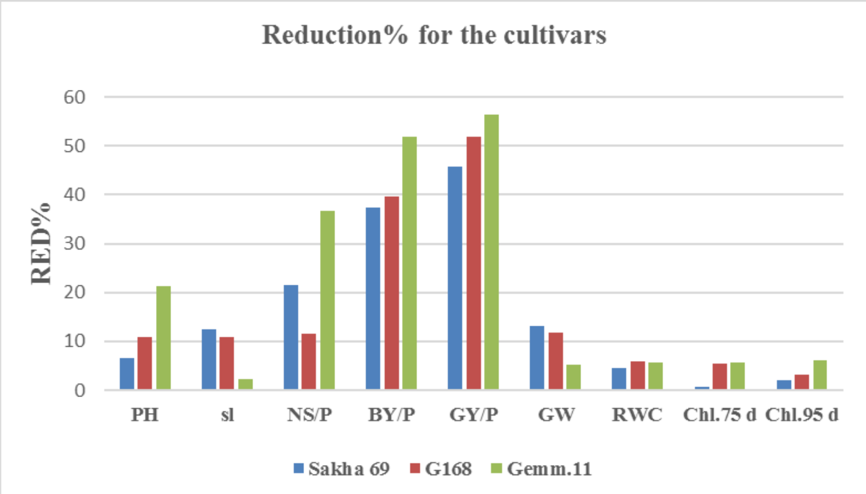

Fig. 11. Combined means of reduction% in the studied traits over the two years for the three cultivars [Red%= (Combined mean at irrigation-at drought/ combined mean at irrigation)*100, PH= Plant height, SL= Spike length, NS/P= Number of spikes/plant, BY/P= Biological yield/plant, GY/P= Grain yield/plant, GW= 100 grain weight, RWC= Relative water content, chlorophyll 75 and 95= Chlorophyll content after 75 and 95 days from sowing]

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دور الزنك فى تحمل الجفاف في القمح (تريتيكم استفم) تحت ظروف نقص الماء فى التربه

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يؤثر الجفاف تأثيرا خطيرا على انتاجيه المحاصيل في مصر والعالم. أجريت تجربتين تحت ظروف الجفاف والري العادي موسمي 2018/2019 و2019/2020 لدراسة تأثير الرش الورقي بالزنك في تقليل تأثير الجفاف وذلك في التربة الطينية. كانت مواد البحث ثلاثة أصناف مصرية من قمح الخبز وهي سخا 69، جيزة 68، جميزه 11. وكانت مستويات الزنك هي 500 جزء في المليون، 250 جزء في المليون، والرش بالماء ومعامله الكونترول (بدون رش). أجري الرش مرتين قبل وبعد انتثار حبوب اللقاح بأسبوعين. وكان تأثير الرش معنويا جدا على كل الصفات عدا طول السنبلة. وكانت الفروق بين الأصناف معنويه جدا لكل الصفات عدا محصول الحبوب تحت ظروف الري. وهذا يؤكد مفهوم افضليه الانتخاب للمحصول تحت ظروف الجفاف عنه تحت الظروف المثلى. واظهرت صفات طول النبات، وعدد السنابل للنبات، والمحصول البيولوجي ومحصول الحبوب ووزن 100 حبه أعلى القيم عند الرش بالزنك 500جزء في المليون. وكان تأثير الجفاف سلبيا على الكلوروفيل ونسبه المحتوى الورقي للماء. وكانت نسبه النقص الناتج عن الجفاف (المتوسط عند الري-المتوسط عند الجاف منسوبا الى المتوسط عند الري) في كل الصفات اقل ما يمكن عند الرش بالمستوى الأعلى من الزنك (500 جزء في المليون) ويزيد النقص في الصفات بنقص مستوى الزنك. وأظهر الصنف سخا 69 أفضل الأداء في طول النبات وعدد السابل للنبات والمحصول البيولوجي تحت ظروف الجفاف والري. ويمكن ان نستخلص من هذه الدراسة ان الرش الورقي بالزنك قلل من تأثير الجفاف على كل صفات النبات وان الصنف سخا 69 كان أكثر الأصناف ثباتا بالنسبة لمحصول الحبوب للنبات وأفضلهم أداءا تحت ظروف الجفاف.