Egypt. J. Agron. **Vol. 43**, No.1, pp. 45-54 (2021)

Egyptian Journal of Agronomy
http://agro.journals.ekb.eg/

Effect of Ascorbic Acid and Zinc on the Productivity of Sunflower (*Helianthus annuus* L.) under Saline Stress Conditions

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SALTINESS is the most restricting factor for agriculture in arid and semi-arid regions, addition to zinc is deposited in forms not accessible to plants in calcareous soils. During the 2018 and 2019 seasons, two field experiments were conducted at the Desert Research Center, Agriculture Experimental Station at Ras-Sudr, South Sinai Governorate, Egypt. The impact of seed priming by soaking seeds in ascorbic acid at 0, 100, 200, and 300mg ASC/L and the soil application of zinc at the rates of 0, 3, 6, 12, and 24kg zinc sulfate/ha ($ZnSO_4$) on sunflower yields and its attributes were studied. The results reported that plant height, head diameter, number of seeds/head, seed weight/head, seed index, biological, seed and oil yields, and seed oil content responded considerably to ascorbic acid (ASC) in both seasons. In this connection, sunflower seeds soaked in 200mg ASC/L was the potency practice compared to other treatments in both years. $ZnSO_4$ significantly affected all the aforementioned traits in both seasons. In this regard, adding 12kg $ZnSO_4$ ha^{-1} gave the highest values for all the studied parameters, except for plant height, which recorded the highest value of 143.2 and 131.2 cm at 24kg $ZnSO_4$ ha^{-1}, respectively as compared to non-$ZnSO_4$ application in both seasons. The outcomes of this study suggest that soaking sunflower seeds in 200mg/L ASC alongside $ZnSO_4$ fertilization at a rate of 12kg/ha could be used to alleviate the harmful effects of salinity stress and increase the sunflower yields.

Keywords: Ascorbic acid, Salinity, Sunflower, Yield, and its components, Zinc.

Introduction

Sunflower is the fourth annual seed oil crop in the world with high performance under a wide range of environmental conditions (Hatami, 2017) due to its short growing season and adaptability to a wide range of climatic and soil conditions (Thavaprakash et al., 2003). Sunflower produces high-quality oil for human consumption, the oil is also used in the chemical and food industries (El-Bially et al., 2018). In attempting to close the gap between oil production and consumption in Egypt, great attention must be paid to such a crop. However, crops in nature are continuously exposed to various biotic and abiotic stresses. Salinity is the main abiotic stress beside the other stresses such as drought and low and high temperature that negatively influences the productivity of biomass, economic yields, and in the end survival of food crops up to the two-third, therefore they are a real threat to global food security (Thakur et al., 2010; Nawaz et al., 2020). Agricultural losses caused by soil salinity stress have been estimated by almost approximately 6% of cultivated land worldwide and 20% of all irrigated land, which greatly reduces food production (Hasanuzzaman et al., 2013; Aslam et al., 2017). Furthermore, soil salinity is the principal cause of arable land degradation, worryingly, the extent of salinity of soils affected by salt and continued spread is alarming in densely populated countries (Vashev et al., 2010), mostly in arid and semi-arid regions (Hasanuzzaman et al., 2014). Besides, saline groundwater is an essential resource for irrigating soils in arid and semi-arid regions with water scarcity, as the current study area of the Ras-Sudr at the South Sinai Governorate (Reiad et al., 2014). Salt stress causes a series of changes in the

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Received 28/11/2020; Accepted 2/2/2021
DOI: 10.21608/agro.2021.51398.1240

metabolism of plants. These changes may include ionic toxicity, osmotic stress, and the production of reactive oxygen species (ROS) (Mittler, 2002). Salt induced-osmotic stress, as well as sodium toxicity, trigger the formation of ROSs such as superoxide (O_2•-), hydrogen peroxide (H_2O_2), hydroxyl radical (OH•) and oxygen singlet ($^1O_2$), which can damage mitochondria and chloroplasts by altering cell structure (Mittler, 2002). Also, high levels of ROS lead to protein inactivation and inhibit the activity of multiple enzymes involved in metabolic pathways and cause oxidation of other macromolecules, including lipids and DNA (Hossain et al., 2014).

Ascorbic acid biochemical functions include its roles as an important antioxidant to environmental stress, such as salinity, electron transport, and an enzymatic cofactor (Prasad & Upadhyay, 2011). Also, synthesis of stress-responsive proteins and the production of specific chemical defense compounds (Khan et al., 2011), ascorbic acid application relieves ROS (Dolatabadian et al., 2009) and promotes the tolerance of plants to oxidative stress (Smirnoff, 1995). Moreover, ascorbic acid (vitamin C) is an essential metabolite involved in many cellular processes, including cell division (De Gara et al., 2003), especially during the initial stages of germination (Stasolla & Yeung, 2001). Fatemi (2014) mentioned that application of ASC enhanced sunflower productivity, also at the germination stage of the sunflower, seeds primed in different concentrations of ascorbic acid showed a better salinity tolerance as compared to non-treated seeds. In another study, Abou-Leila et al. (2012) noticed that treatments with ascorbic acid under saline conditions have an increasing effect on certain selected ions such as Mg^{++} and a decreasing effect on Na^+ at the high salinity levels. Moreover, ascorbic acid had a positive impact on sunflower seed and oil yields under both water-deficit and sufficient water supply conditions (El-Bially et al., 2018).

Plant zinc-nutritional status is important for increased crop productivity. Its deficiency is regarded as the most restricting factor for plant growth under conditions each of salinity stress (Khoshgoftar et al., 2004) and calcareous soils in arid and semi-arid areas (Bityutskii et al., 2017; Noulas et al., 2018; Chen et al., 2019). The presence of $CaCO_3$ directly or indirectly influences the availability of N, P, K, Mg, Fe, Mn, and Zn (Obreza et al., 1993). However, the limited availability of Zn in arid and semi-arid regions is particularly common on calcareous and alkaline soils (Alloway, 2006) due to their high $CaCO_3$ content and the lack of organic matter (Bityutskii et al., 2017; Kumari et al., 2018). Zinc decreases the harmful effect of salts and reduces the activity of NADPH-bound membrane oxidase, which may result in a reduction in the production of ROS (Waraich et al., 2011). Also, zinc may be a vital micronutrient for the correct growth of plants and human health (Noulas et al., 2018), and as a co-factor in the enzymatic activity of more than 300 enzymes (Marschner, 1995). Gitte et al. (2005) found that adding 5.25kg Zn/ha to the soil gave the maximum sunflower seed yield, 1000 seed weight, and oil percentage. Therefore, the current investigation aims: (a) to mitigate the adverse impact of salinity, and (b) to improve the productivity of sunflower, using seed priming technique in ASC with the application of Zn under saline stress conditions.

Materials and Methods

Site description

During the seasons of 2018 and 2019, sunflower plants were cultivated at the Desert Research Center Experimental Farm, Ras-Sudr, South Sinai Governorate, Egypt (30˚34\ N and 31˚34\ E). The soil of the experimental site is highly calcareous with a sandy loam texture. According to the methods of Jackson (1973) and Chapman & Pratt (1961), the mechanical, physical, and chemical analyses were done (Table 1). Moreover, the physical and chemical properties of the irrigation water at the site are shown in Table 2. Barley was the previous cultivated crop in both seasons.

The climate of the study area

Egypt is one of the driest countries in the world, with an extremely low rainfall average per year (Mean annual rainfall ranges between 100 and 150mm during the winter). Climatic condition data of the study area (Ras-Sudr), which is characterized by a hyper-arid, there is no rainfall during the summer. The average minimum temperature ranges from 24.6–29.9˚C, while the mean maximum temperature ranges between 34.1–39.4˚C during the growing seasons of sunflower plants from May to August. On the other side, the average relative humidity fluctuates between 30.2 to 55.0%, and the mean wind speed varied from 12.6 to 21.0km/h for the same period (climatic data were collected from the meteorological station of Ras-Sudr in Egypt).

TABLE 1. The mechanical, physical and chemical properties of the soil experimental at Ras Sudr station

Parameter	Units	Value
Mechanical property		
Sand	%	79.43
Silt	%	10.49
Clay	%	10.08
Textural class	Sandy loam	
pH	-	7.8
EC	dS m^{-1}	8.3
$CaCO_3$	%	56.4
Chemical property		
Cations		
Ca^{++}	mg/100g	24.80
Mg^{++}	mg/100g	5.50
Na^{+}	mg/100g	57.45
Anions		
$CO_3^{=}$	mg/100g	0.0
HCO_3^{-}	mg/100g	6.10
Cl^{-}	mg/100g	61.61
$SO_4^{=}$	mg/100g	26.32
Available nutrients		
N	mg kg^{-1}	26.13
P	mg kg^{-1}	5.15
K	mg kg^{-1}	51.49
Zn	mg kg^{-1}	0.78

TABLE 2. Physical and chemical analysis of the irrigation water

Parameter	Units	value
pH	-	7.9
EC	dS m^{-1}	9.8
Soluble cations		
Ca^{++}	meq L^{-1}	17.73
Mg^{++}	meq L^{-1}	16.03
Na^{+}	meq L^{-1}	39.12
K^{+}	meq L^{-1}	0.47
Soluble anions		
$CO_3^{=}$	meq L^{-1}	0.00
HCO_3^{-}	meq L^{-1}	2.12
Cl^{-}	meq L^{-1}	51.81
$SO_4^{=}$	meq L^{-1}	17.59

Treatments and experimental management

Four ascorbic acids (ASC) levels, i.e., 0, 100, 200, and 300mg/L, as seed priming treatment were examined. Seeds were soaked for 8 hrs. and then air-dried before sowing. The second treatment was the soil application of zinc in five quantities, i.e., nil Zn, 0.684, 1.368, 2.736, and 5.472kg Zn ha^{-1}, which equal 0.0, 3.0, 6.0, 12.0, and 24.0kg $ZnSO_4$/ha ($ZnSO_4.7H_2O$), respectively, and applied at planting time. Zinc sulfate ($ZnSO_4.7H_2O$) containing 22.8% zinc. Treatments were arranged in a split-plot design in three replicates, where ascorbic acid levels were arranged in the main plots and zinc rates were distributed in the subplots. The net area of each plot was 10.5m^2 containing five ridges (3.5m length and 0.6m width).

On May 12^{th} and 16^{th} in the 2018 and 2019 seasons, respectively, sunflsower Sakha 53 cultivar seeds were sown in hills (3-4 seeds/hill), 20cm apart at a rate of 12.0 kg/ha. At 21 days after sowing, plants were thinned to obtain one plant per hill. Nitrogen fertilizer was added at the rate of 191kg N/ha in the form of ammonium sulfate (20.5% N) at three equal doses: After thinning, and before the second and the third irrigations. Phosphorus fertilizer (calcium superphosphate, 15.5% P_2O_5) at a rate of 107kg P_2O_5/ha and organic manure at a rate of 48 m^3/ha were added during soil preparation. Potassium fertilizer was applied in the form of potassium sulfate (48% K_2O) at a rate of 179kg K_2O/ha at 50 days after sowing. Ground water was the source of irrigation applied through the gated pipe irrigation system. All other recommended agricultural practices and proper agronomic management for sunflower plants were adopted throughout the two growing seasons.

Sampling and assessments

Yield traits

At harvest (92 and 96 days after sowing in 2018 and 2019 seasons, respectively), ten guarded plants were chosen randomly from each plot to estimate plant height, head diameter, number of seeds per head, seed weight/head, and seed index. Moreover, whole plants of the plot were harvested to estimate biological and seed yields per hectare.

Seed oil content

Oil percentage of seeds was measured by extraction using Soxhlet Apparatus with hexane as a solvent, according to AOAC (2005). The oil yield ton/ha was computed, as seed yield (ton/ha) × oil percentage.

Data analysis

The obtained data of each season were separately subjected to analysis of variance (ANOVA) according to Gomez & Gomez (1984), using MSTAT–C software program (MSTATC, Michigan State Univ., 1992). Means were compared by using the least significant difference (LSD) test at $P \leq 0.05$.

Results

Effect of ascorbic acid (ASC)

Plant height, head diameter, seeds number/head, seeds weight/head, and seed index, in addition to biological, seed and oil yields and oil content of sunflower plants were varied considerably among ascorbic acid treatments. Each increase in ASC up to 200mg/L led to a marked increment in the above-mentioned traits. Whilst, the excessive concentration of ascorbic acid (300mg/L) tended to reduce all the aforementioned traits, except plant height in the first and second seasons (Table 3). Soaking sunflower seeds in 200mg ASC/L was the superior treatment, and caused increases of 31.8, 40.9, 34.4, 44.5, 30.8, 40.1, 52.3 and 8.8% in the first season, and 24.1, 44.8, 34.9, 49.3, 38.7, 42.8, 52.1 and 6.7% in the second one for head diameter, seeds number/head, seeds weight/head, seed index as well as biological, seed and oil yields and oil content, respectively. However, plant height recorded the highest values at 300mg ASC/L treatment with an increase of 22.1 and 26.2%, in the first and second seasons, respectively, as compared to non-ASC (Table 3).

Effect of zinc ($ZnSO_4$)

As shown in Table 3, all the agronomic characters, i.e., Plant height, head diameter, number of seeds/head, seeds weight/head, seed index, as well as biological, seed, and oil yields and oil content significantly responded to zinc application in the two seasons. Applying 12kg $ZnSO_4$ ha^{-1} gave the highest values for all the studied traits, except plant height, which recorded its highest values at 24kg $ZnSO_4$ ha^{-1} in both seasons (Table 3). The superior treatment of 12 kg $ZnSO_4$ ha^{-1} improved head diameter by 29.3 and 35.6%, number seeds/head by 24.5 and 24.7%, seeds weight/head by 25.6 and 27.9%, and seed index by 18.8 and 22.3%, respectively as compared to no zinc application in 2018 and 2019 seasons. Moreover, the same potency treatment (12kg $ZnSO_4$ ha^{-1}) increased biological yield by 17.9 and 22.2%, seed yield by 25.8 and 25.2%, oil content by 8.0 and 7.7%, and oil yield by 34.5 and 33.7%, respectively compared with no Zn applied in both growing seasons. While adding 24kg $ZnSO_4$ ha^{-1} produced the tallest plants with an increase of 21.9 and 22.8%, respectively compared to without Zn application, in both seasons (Table 3).

Effect of interaction

Results in Tables 4 and 5 demonstrated the positive impact of the combination between ASC and Zn treatments on sunflower yields and its components in both seasons, except seed oil content in the first season only, and head diameter, seed weight/head, and seed index in both seasons. Seeds soaked in 200mg ASC/L combined with applying 12kg $ZnSO_4$ ha^{-1} as fertilization recorded the highest values of plant height in the first season and oil content in the second season, as well as the number of seeds/head, biological, seed and oil yields in both seasons. While the treatment of 200mg ASC/L as seed priming combined with 24kg $ZnSO_4$ ha^{-1} as fertilization produced the highest value of plant height in the second season only. The minimum values for oil content in the second season and plant height, number of seeds/head as well as biological, seed, and oil yields in 2018 and 2019 were recorded with the combination of sunflower seed primed with no ASC × no $ZnSO_4$ application (Tables 4 and 5).

Discussion

Agricultural areas that have calcareous soil, e.g. arid lands, are considered limited crop productivity. Under such conditions, cultivated plants are suffering from more than one stress type due to the abundance of calcium carbonate ($CaCO_3$), in addition to salinity. In the current study, since plants faced the hazard impact of salinity in non-ASC treatment, minimal values of all yield traits were observed (Table 3). This may be due to that salinity stress caused reduction in photosynthetic capacity, photosynthetic pigments, stomata, and non-stomata factors that affect CO_2 assimilation and later cause a decline in plant growth (Dubey, 2005). Also, the presence of poisonous ions in the root zone (Panda et al., 2008) inhibits seedling growth by changing the water potential, increasing the ion toxicity, inhibiting the cell division and cellular expansion, or causing ion imbalance (Arshi et al., 2005). Moreover, salt stress enhances the production of ROS lead to progressive oxidative damage and ultimately cell death and growth suppression (Ruiz-Lozano et al., 2012). Khan et al. (2013) found that accumulation of ROS as a result of salinity stress causes loss of sunflower crop productivity.

Contrariwise, the results of the current study supported the hypothesis that the use of ASC as seed priming could increase the productivity of sunflower under salinity stress conditions. The ASC treatments increased the plant height, head diameter, seeds number/head, seeds weight/head, seed index, oil %, in addition to biological, seed, and oil yields in the 2018 and 2019 seasons over the control (Table 3). Similar results that emphasized the positive and synergistic effect of ASC on sunflower yields and its attributes were reported by Salem & Shoman (2018), El-Bially et al. (2018), Abdel-Hafeez et al. (2019). In this connection, the potency of sunflower seeds soaked to produce high values of yield and its components with 200mg ASC/L treatment (Table 3) may be due to the role of ASC regulation in photosynthetic capacity, flowering, and senescence (Davey et al., 2000). Also, the main role of ASC as coenzymes, independent roles in the processes of biochemical for sunflower plants, produced a significant increase in N, P, K, Fe, Mn, and Zn of sunflower compared to non-ASC and the vital role in repairing the harmful effects of unfavorable conditions (Abdel-Hafeez et al., 2019). Moreover, seeds primed with different concentrations of ascorbic acid are successful in providing salt tolerance in the sunflower germination stage, significantly reduced the harmful effects of salinity stress, accelerated seedling emergence, and improved seedling vigor (Fatemi, 2014). In addition to ASC can scavenge the ROS, which might be highly damaging to the growth of sunflower plants (Osman et al., 2014; Abdel-Hafeez et al., 2019). The highest plant height of sunflower plants was obtained from seeds primed with 300mg ASC/L in both seasons, and this is may be due to that ascorbic acid could accelerate cell division and cell enlargement of treated plants (Athar et al., 2008). On the other side, the higher concentration than 200mg/L of ASC (300mg/L) resulted in a decrease in all the previously mentioned parameters, except plant height in both seasons as shown in Table 3. This may be because the excessive amount of ASC may cause certain phytotoxic effects on chlorophyll function and decrease the chlorophyll content (Ebrahimian & Bybordi, 2012), which resulted in a decrease in sunflower plant biomass, thereby reducing the yield and its components.

TABLE 3. Effect of ascorbic acid and zinc on sunflower yields, its components, and seed oil percentage (2018 and 2019 seasons)

Treatments	Plant height (cm)	Head			Seed index (g)	Yield (ton/ha)		Oil	
		Diameter (cm)	Seeds number	Seed weight (g)		Biological	Seed	%	Yield (ton/ha)
2018 season									
Ascorbic acid (mg/L)									
0	116.33	14.87	587.93	26.00	34.80	4.45	1.47	36.53	0.539
100	130.73	16.93	656.13	29.00	40.07	5.36	1.80	38.00	0.689
200	141.60	19.60	828.20	34.93	50.27	5.82	2.06	39.73	0.821
300	142.07	19.20	819.67	34.47	49.60	5.80	2.04	39.40	0.806
LSD ($P_{0.05}$)	0.74	0.36	1.22	0.48	0.48	0.01	0.01	0.37	0.01
$ZnSO_4$ (kg ha^{-1})									
0	117.42	15.08	637.83	27.33	39.58	4.85	1.59	36.50	0.588
3	127.75	16.92	682.75	29.25	41.92	5.15	1.76	38.33	0.679
6	132.83	17.92	717.17	31.42	43.75	5.39	1.89	38.75	0.736
12	142.25	19.50	794.17	34.33	47.00	5.72	2.00	39.42	0.791
24	143.17	18.83	783.00	33.17	46.17	5.68	1.97	39.08	0.774
LSD ($P_{0.05}$)	0.79	0.47	2.93	0.51	0.78	0.01	0.01	0.39	0.01
2019 season									
Ascorbic acid (mg/L)									
0	105.40	14.40	526.33	24.27	30.27	3.85	1.31	35.93	0.472
100	114.47	15.80	599.93	27.40	34.93	4.77	1.72	37.40	0.646
200	130.60	17.87	762.00	32.73	45.20	5.34	1.87	38.33	0.718
300	133.00	17.07	761.87	32.20	44.47	5.33	1.85	38.27	0.709
LSD ($P_{0.05}$)	0.42	0.33	1.42	0.39	0.32	0.004	0.01	0.27	0.01
$ZnSO_4$ (kg ha^{-1})									
0	106.83	13.33	585.67	25.33	34.42	4.28	1.47	35.83	0.531
3	116.08	15.50	622.33	27.58	37.00	4.59	1.61	37.25	0.603
6	120.25	16.75	651.92	29.25	38.92	4.82	1.70	37.83	0.647
12	130.00	18.08	730.50	32.42	42.08	5.23	1.84	38.58	0.710
24	131.17	17.75	722.25	31.17	41.17	5.20	1.81	37.92	0.689
LSD ($P_{0.05}$)	0.79	0.42	2.18	0.65	0.76	0.02	0.01	0.41	0.01

* LSD ($P_{0.05}$) is Least significant difference ($P \leq 0.05$).

TABLE 4. Effect of ascorbic acid and zinc interaction on sunflower yields, its components, and seed oil percentage (2018 season)

Treatments		Plant	Head			Seed index (g)	Yield (ton/ha)		Oil	
ASC (mg/L)	$ZnSO_4$ (kg ha^{-1})	height (cm)	Diameter (cm)	Seeds number	Seed weight (g)		Biological	Seed	%	Yield (ton/ha)
0	0	101.67	12.00	507.33	23.00	30.33	3.91	1.21	34.33	0.415
	3	110.67	14.00	552.33	24.33	33.00	4.24	1.37	36.33	0.498
	6	116.33	15.33	583.33	26.33	34.33	4.46	1.47	37.00	0.544
	12	125.67	17.00	654.67	29.00	38.33	4.82	1.67	37.67	0.628
	24	127.33	16.00	642.00	27.33	38.00	4.81	1.63	37.33	0.609
100	0	111.33	14.00	571.33	25.33	36.00	4.82	1.51	36.00	0.553
	3	125.00	16.33	624.00	27.33	37.67	5.16	1.70	38.00	0.646
	6	131.00	17.33	653.00	29.00	40.00	5.37	1.83	38.33	0.701
	12	142.33	18.67	722.00	32.33	43.67	5.78	2.01	39.00	0.785
	24	144.00	18.33	710.33	31.00	43.00	5.68	1.96	38.67	0.758
200	0	126.00	17.32	721.33	30.67	47.00	5.34	1.84	38.00	0.699
	3	138.00	19.00	772.67	33.00	49.00	5.59	2.00	39.67	0.792
	6	143.00	19.67	829.33	35.33	50.67	5.89	2.15	40.00	0.859
	12	150.67	21.33	915.00	38.33	53.00	6.17	2.17	40.67	0.881
	24	150.33	20.67	902.67	37.33	51.67	6.12	2.16	40.33	0.871
300	0	130.67	17.00	751.33	30.33	45.00	5.31	1.82	37.67	0.684
	3	137.33	18.33	782.00	32.32	48.00	5.60	1.99	39.33	0.781
	6	141.00	19.33	803.00	35.00	50.00	5.86	2.12	39.67	0.841
	12	150.33	21.00	885.00	37.67	52.98	6.12	2.15	40.33	0.867
	24	151.00	20.33	877.00	37.00	52.00	6.11	2.14	40.00	0.857
LSD ($P_{0.05}$)		1.58	NS	5.85	NS	NS	0.03	0.03	NS	0.02

- LSD ($P_{0.05}$) is Least significant difference ($P\leq 0.05$); NS means non-significant at 0.05 level of significance.

TABLE 5. Effect of ascorbic acid and zinc interaction on sunflower yields, its components, and seed oil percentage (2019 season)

Treatments		Plant	Head			Seed index (g)	Yield (ton/ha)		Oil	
ASC (mg/L)	$ZnSO_4$ (kg ha^{-1})	height (cm)	Diameter (cm)	Seeds number	Seed weight (g)		Biological	Seed	%	Yield (ton/ha)
0	0	91.00	11.33	451.33	20.00	26.00	3.31	1.03	34.00	0.350
	3	99.67	13.33	493.33	23.00	28.33	3.63	1.17	35.33	0.414
	6	105.00	15.00	513.67	24.33	30.00	3.87	1.29	36.00	0.464
	12	114.67	16.33	592.00	27.67	34.00	4.23	1.52	37.33	0.567
	24	116.67	16.00	581.33	26.33	33.00	4.22	1.52	37.00	0.562
100	0	99.00	12.00	521.33	24.00	30.00	4.22	1.42	35.00	0.497
	3	109.00	15.00	562.00	26.00	32.67	4.53	1.59	37.33	0.595
	6	113.33	16.67	593.33	27.00	35.00	4.74	1.73	38.33	0.663
	12	124.67	18.00	663.00	31.00	39.00	5.19	1.94	38.67	0.751
	24	126.33	17.32	660.00	29.00	38.00	5.15	1.91	37.67	0.721
200	0	116.67	15.33	677.33	28.97	41.00	4.77	1.72	37.33	0.642
	3	125.67	17.33	718.00	31.00	44.00	5.10	1.85	38.00	0.702
	6	129.00	18.00	753.67	32.67	46.00	5.32	1.91	38.67	0.737
	12	140.67	19.33	836.00	36.00	48.00	5.77	1.98	39.33	0.773
	24	141.00	19.32	825.00	35.00	47.00	5.72	1.92	38.33	0.735
300	0	120.67	14.67	692.67	28.33	40.67	4.81	1.71	37.00	0.633
	3	130.00	16.32	716.00	30.33	43.00	5.11	1.83	38.32	0.700
	6	133.67	17.33	747.00	33.00	44.67	5.33	1.89	38.33	0.723
	12	140.00	18.67	831.00	35.00	47.33	5.74	1.92	39.00	0.749
	24	140.66	18.33	822.67	34.33	46.67	5.71	1.91	38.67	0.737
LSD ($P_{0.05}$)		1.57	NS	4.36	NS	NS	0.03	0.03	0.82	0.02

- LSD ($P_{0.05}$) is Least significant difference ($P\leq 0.05$); NS means non-significant at 0.05 level of significance.

Concerning, the impact of $ZnSO_4$, data in Table 3 demonstrated that zinc application has a beneficial effect under salinity stress in improving sunflower yield, yield components, and oil content. In this concern, plant height, head diameter, seeds number/head, seeds weight/head, seed index, oil % as well as biological, seed, and oil yields significantly responded to Zn application rates in the 2018 and 2019 seasons (Table 3). These results are close to the results of Mirzapour & Khoshgoftar (2006), Akladious & Mohamed (2017). The good performance of plants with progressive increase the rate of $ZnSO_4$ up to 12kg/ha, may be attributed to the potential role of Zn in promoting salt tolerance in plants with a decreased Na^+ and Cl^- ion uptake (Tavallali et al., 2009; Nadeem et al., 2020). Also, Zn improves salt tolerance in plants and helps the roots absorb more water (Mehrizi et al., 2011). Moreover, zinc can act as a ROS scavenger and protect the cells (Jan et al., 2019), Zn accelerates the growth of seedlings because of multiplied photosynthesis (Li et al., 2013). Zn considerably improves the activity of antioxidant enzymes such as SOD, APX, and GR in sunflower plants compared with control (Akladious & Mohamed, 2017). Zn applications induce pollen longevity, leading to elevate its fertility and produce more seeds/head (Baniabbasishahri et al., 2012). However, the higher concentrations of Zn (24kg $ZnSO_4$/ha) had adverse effects and resulted in a decrease in the values of all the studied traits, except for plant height in 2018 and 2019 years (Table 3). This may be due to the excessive rates of Zn that caused a toxicity level and was most inhibitory to plant growth (Ozdener & Aydin, 2010; Dong et al., 2014), which reflected on yield and its attributes. These results are in harmony with Sanaullah et al. (2014), Akladious & Mohamed (2017).

These improvements in sunflower yield and its parameters in the treatment (seeds soaked with 200mg ASC/L with adding 12kg $ZnSO_4$/ha) may be due to the favorable and synergistic effect of ASC and Zn application on saline stress alleviation for sunflower plants, especially during the stage of germination and seedling, on one hand, and improved availability of both micro and macronutrients in the soil, on the other hand, and the efficient transition of these nutrients to the plants from the soil, which reflected in the increase of the productivity (Tables 4 and 5).

Conclusion

Sunflower seeds soaked in ascorbic acid have gained considerable attention as an effective technique to mitigate the unfavorable effects of high salinity. As well, adding zinc as a soil application was sufficient to compensate for the unavailability of Zn in calcareous saline soils. So, it could be recommended to soak sunflower seeds in 200mg ASC/L in combination with applying 12kg $ZnSO_4$/ha as a promising practice for improving sunflower productivity under saline conditions. Accordingly, farmers are advised to exploit the complementary effect of ascorbic acid and Zn supply to obtain the maximum returns gained from the cultivation of sunflower in salt-affected soils.

Acknowledgments: The author would like to acknowledge the technical support providing by the Desert Research Center, Egypt.

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تأثير حامض الأسكوربيك والزنك على إنتاجية دوار الشمس تحت ظروف الإجهاد الملحى

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تعتبر الملوحة العامل الأكثر تقييدا للزراعة في المناطق القاحلة وشبه القاحلة، بالإضافة للزنك الذى يترسب في صور لا تمكن النباتات الاستفادة منه فى الأراضى الجيرية. أجريت تجربتان حقليتين خلال موسمي 2018 و 2019، بمركز بحوث الصحراء، محطة التجارب الزراعية برأس سدر، محافظة جنوب سيناء، مصر. درس تأثير أربعة معاملات لنقع البذور (نقع البذور فى ماء فقط، 100، 200، 300 ملجم حامض الأسكوربيك/لتر) وخمسة معدلات من التسميد الأرضى بالزنك (بدون، 3، 6، 12، 24 كجم كبريتات زنك/هكتار) على محصول دوار الشمس وصفاته. أشارت النتائج أن صفات ارتفاع النبات، قطر القرص، عدد البذور/القرص، ووزن البذور/القرص، ودليل البذور، والمحصول البيولوجى، ومحصول البذور ومحصول الزيت، ومحتوى زيت البذور استجابت بشكل كبير لحامض الأسكوربيك في كلا الموسمين. في هذا الصدد، نقع بذور دوار الشمس في 200 ملجم حامض الأسكوربيك/لتر هي الممارسة الفعالة مقارنة بالمعاملات الأخرى في كلا الموسمين. معاملات كبريتات الزنك أثرت معنويا على جميع الصفات المذكورة أعلاه في كلا الموسمين. وفي هذا الشأن، إضافة 12 كجم كبريتات زنك/هكتار أعطت أعلى القيم لجميع الصفات المدروسة، باستثناء صفة ارتفاع النبات، التى سجلت أعلى قيمة 143.2 و 131.2 سم عند إضافة 24 كجم كبريتات زنك/هكتارعلى التوالي مقارنة بمعاملة الكنترول (بدون إضافة كبريتات الزنك) في كلا الموسمين. تقترح نتائج هذه الدراسة أن نقع بذور دوار الشمس فى 200 ملجم حامض الأسكوربيك/لتر جنبا إلى جنب مع التسميد بمعدل 12 كجم كبريتات زنك/هكتار هى الممارسة الفعالة للتخفيف من الأثار الضارة لإجهاد الملوحة وزيادة محصول دوار الشمس.