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Effect of Foliar Application by some Antioxidants on Growth and Productivity of Maize under Saline Soil Conditions

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ABSTRACT

This research investigates the physiological effect of exogenous antioxidants application at different rates on growth and productivity of maize crop grown under saline soils condition. A field trail was conducted at a field located in South Port Said, Egypt, during the two successive summer seasons 2016 and 2017 on yellow maize three cross hybrid 352 grown under saline soil condition to study the effect of exogenous antioxidants, i.e., ascorbic, citric and salicylic acids at 100 and 200 ppm concentration for each one as well as mixture of 100 ppm for the three antioxidant under study. Results could be summarized as follows: The foliar application with 100 ppm of antioxidant mixture increased plant height, leaf area index (LAI), crop growth rate (CGR), net assimilation rate (NAR), photosynthetic pigments, soluble sugars, antioxidant enzymes [catalase (CAT), polyphenol oxidase (PPO), peroxidase (POD), phenylalanine ammonia lyase (PAL) and tyrosine ammonia lyase (TAL)], potassium content, ear length, grain weight/ear, 100- grain weight, grain and straw yields, followed by foliar application with 200 ppm of ascorbic acid (AA). However, proline, sodium contents and sodium/potassium ratio in leaves were decreased as compared with control.

Keywords: Maize, salt stress, antioxidants, growth, yield.

INTRODUCTION

Maize (*Zea mays* L.) is considered the third important cereal crops come after wheat and rice. Maize used in human consumption, animal feeding, starch industry and oil production as well as raw materials of biofulels and industry in Egypt and the world, it known as "King of grain crops" (Nuss and Tanumihardjo, 2010).

Salinity is one of the environmental abiotic stress that lowers growth and reduce productivity of maize crop that is moderately sensitive to soil salinity (Farooq *et al.*, 2015). The influences of salinity stress on plants are sodium ion toxicity, nutritional imbalance, physiological water deficit, metabolic disorder, oxidative damage, photoinhibation and the alteration of major cytosolic enzyme activities (Abreu *et al.,* 2013; Shabala *et al*., 2014 and Tang *et al.,* 2015). Salinity stress causes ionic imbalance, induces generation and accumulation of reactive oxygen species (ROS) in plant cells resulting damage of lipids membrane, proteins and nucleic acids (Gill and Tuteja, 2010 and Chawla *et al.,* 2013). Plants under salinity stress conditions have developed an antioxidant defence system to overcome oxidative stress.

However, most crop plants tolerance to salinity is associated with a high antioxidant system efficiency that enhanced by both enzymatic and non-enzymatic systems.

The non-enzymatic antioxidative system consists of compounds as ascorbic acid (vitamin C), salicylic acid, ά-tocopherol, carotenoids, and flavonoids, whereas the enzymatic antioxidative system consists superoxide dismutase (SOD), ascorbate peroxidase (APX), glutathione reductase (GR), catalase (CAT), peroxidase (POD) and polyphenol oxidase (PPO), etc. Scavenge the reactive oxygen species (ROS) produced in plant cells during oxidative stress in the main role of antioxidant system and thus help the plants to overcome such stress conditions (Mandal *et al*., 2009).

Ascorbic acid considered one of the universal non-enzymatic antioxidants molecule that play a role in detoxification of ROS and intermediating a number of important functions in plant both under stress and normal conditions. However, its physiologically active form is ascorbate that known as a vital water-soluble antioxidant molecule in biological system (Qian *et al*., 2014 and Akram *et al*., 2017). Exogenous foliar application of ascorbic acid is also effective against lipids and proteins protection under abiotic stresses-induced oxidative adversaries (Naz *et al*., 2016).

Citric acid (CA), carboxylic acid, is considered as non-enzymatic antioxidant and acts under stress to eliminate free radicals produced in plants. However, defense mechanisms in plant cells induced by citric acid that increase the antioxidant enzymes activities (Sun and Hong, 2011). Citric acid is participating in the physiological oxidation of fats, proteins and carbohydrates to CO_2 and water. It is an important substrate in Krebs cycle and have an essential role in activating biosynthesis processes (Abd El-Al, 2009).

Salicylic acid (SA) is known as a phenolic compound produced in the regulation of plant growth and improvement and its response to biotic and abiotic stress factors (Miura and Tada, 2014). SA is participating in the regulation of most plant biological processes like photosynthesis, proline metabolism, nitrogen metabolism, antioxidant defense system and provides protection against abiotic stresses (Khan *et al*., 2015). Application of SA as foliar spraying on maize to overcome effects of abiotic stresses were investigated and many studies reported that salicylic acid induced increases in the resistance to abiotic stresses (Tuna *et al*., 2007 and Rajeshwari and Bhuvaneshwari, 2017).

The present work aimed to mitigate the effect of salinity stress by foliar application of non-enzymatic antioxidants i.e. ascorbic, citric and salicylic acids at different rates in maize plants grown under saline soil conditions.

MATERIALS AND METHODS

The present work was carried out at South Port Said, Egypt (31° 08′ 20″ N 32° 17′ 29″ E) during the two successive summer seasons of 2016 and 2017 to study the physiological impact of three antioxidants (ascorbic, citric and salicylic acids) on growth, biochemical constituents, yield and yield components of maize plants grown in saline soil conditions.

The experiment was laid out in randomized complete block design (RCBD) with four replicates. The treatments under study were applied at 30 & 45 days after sowing (DAS) as follows:

1- Spray with water (Control).
2- Spray with 100 ppm ascorbic acid.
3- Spray with 200 ppm ascorbic acid.
4- Spray with 100 ppm citric acid.
5- Spray with 200 ppm citric acid.
6- Spray with 100 ppm salicylic acid.
7- Spray with 200 ppm salicylic acid.
8- Spray with 100 ppm ascorbic, citric and salicylic acids for each one.

Soil samples before planting were obtained from each replicate (from surface at 20 cm depth) to check the chemical state of the experimental site. Soil analyses were done according to the methods cited by Richards (1954). Physical and chemical properties of the experimental site during 2016 and 2017 seasons are presented in the Table 1.

Table 1. Mean of some physiochemical analysis of the experimental soil during the studied period.

Season	EC dSm^{-1}	pH (1:2.5)	Texture	Cations (ml equevlant/L)				Anions (ml equevlant/L)			
				Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{-}	HCO_3^{-}	Cl^{-}	SO_4^{-}
2016	4.6	8.15	clay	8.26	8.78	26.11	1.98	-	1.40	24.26	19.48
2017	4.2	8.04	clay	8.10	7.96	25.81	1.13	-	1.08	22.41	16.51

Yellow maize hybrid TC 352 was hand sown on 15 May 2016 and 18 May 2017 in hills spaced 25 cm on 5 ridges 3 m long and 0.70 m apart, each plot was 10.5 m^2 (3 x 3.5 m). Plants were thinned to one plant/hill at 21 DAS. 15 kg P_2O_5/fad was applied as calcium super phosphate (15.5% P_2O_5) through soil preparation. 120 kg N/fad in the form of urea (46% N) was applied in three equal doses before irrigation.

Other, cultural practices were done according to the methods being adopted for growing maize crop in the locality.

To calculate growth traits, five plants were randomly taken from each plot at 55, 70 and 85 days after sowing (DAS). Other plants were taken and dried at 70 °C in ventilated oven to a constant weight. According to Hunt (1990) formulas, the following traits were determined:

- Plant height (cm)
- **Leaf area index (LAI)= leaf area per plant (cm^2)/ground area occupied by plant (cm^2)**
- Net assimilation rate in (g/m^2/day), was determined as described by Radford (1967).

$$\mathbf{NAR = (W_2-W_1)\ (\log_e A_2-\log_e A_1)/(A_2-A_1)(t_2-t_1).}$$

- Crop growth rate in (g/day/m^2), was determined as described by Radford (1967).

$$\mathbf{CGR = (W_2-W_1)/\ (t_2-t_1).}$$

Where:

A_2-A_1= differences in leaf area between two successive samples in cm^2.
W_2-W_1= differences in dry matter accumulation of whole plants between two successive samples in (g).
t_2-t_1= Number of days between two successive samples (day).
Log_e = Natural logarithm.

At 70 days after sowing, the following traits were determined:

- Photosynthetic pigments (chl a, chl b and carotenoides) in mg/g fresh weight according to Metzener *et al.* (1965).
- Soluble sugars using modifications of the procedures by Yemm and Willis (1954).
- Catalase, polyphenol oxidase and peroxidase activities according to Kar and Mishra (1976).
- Phenylalanine ammonia lyase and tyrosine ammonia lyase activities according to the method adopted by Beaudoin-Egan and Thorpe (1985).
- Leaf proline concentration, in µg/g fresh weight, according to Bates *et al.* (1973).
- Potassium, sodium contents and Na^+/K^+ ratio in leaves of maize plant in mmole/kg dry weight, according to Allen *et al.* (1974).

At harvest time (7 September, 2016 and 11 September, 2017), ear length (cm), grains weight/ear (g), 100-grain weight (g), grain and straw yields (t/fad) were determined.

Data of the two seasons were subjected to statistical analysis of variance according to Steel and Torrie (1980). The treatments average was compared using LSD test at 0.05 level of probability.

RESULTS AND DISCUSSION

1- Growth and growth analysis:

Plant height and crop growth rate of maize plants as influenced by foliar application with ascorbic, citric and salicylic acids at different rates under saline soil conditions are presented in Table 2.

Table 2. Plant height and crop growth rate (CGR) of maize as affected by foliar application with antioxidants at various rates during 2016 and 2017 seasons.

Foliar treatments	Plant height (cm)						CGR (g /day/m^2)			
	55 day		70 day		85 day		(55-70 day)		(70-85 day)	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Water (control)	138.8	140.5	210.0	212.8	269.3	271.8	28.62	29.02	29.88	30.11
100 ppm AA	139.8	141.8	217.8	220.3	280.8	283.0	29.89	30.31	31.14	31.37
200 ppm AA	141.3	143.0	222.5	225.0	286.3	289.3	30.62	31.00	31.93	32.19
100 ppm CA	139.0	140.3	214.3	217.5	277.8	279.8	29.17	29.49	30.33	30.59
200 ppm CA	141.0	142.5	218.5	222.5	282.8	285.3	29.95	30.32	31.10	31.57
100 ppm SA	140.0	142.3	216.5	219.5	279.8	282.3	29.59	29.96	30.74	31.00
200 ppm SA	142.5	144.5	221.8	224.0	283.0	286.3	30.07	30.45	31.21	31.47
100 ppm AA +CA+SA	145.0	147.3	227.3	230.5	292.3	295.3	31.13	31.50	32.40	32.67
LSD (0.05)	ns	ns	ns	ns	13.8	11.6	0.29	0.30	0.28	0.21

AA; ascorbic acid CA; citric acid SA; salicylic acid

The plant height of maize at 55, 70 and 85 DAS recorded an increase as a result of antioxidant application. The highest values were obtained when the antioxidants mixture applied at 100 ppm for each one in the two seasons followed by spraying 200 ppm of AA at 70 and 85 DAS. While, crop growth rate (CGR) of maize at the two periods of 55-70 and 70-85 DAS were recorded significant affect, when plants sprayed by any antioxidant treatments as compared to control in the two seasons. The antioxidants stimulated growth improvement as observed for the maize plant during the present study which might be due to increase of growth and this may be the participation of antioxidants in regulation of cell growth and cell division by enhancement of the cell development cycle (Smirnoff and Wheeler, 2000). These findings are in accordance with that reported by Ali *et al.* (2015), Abo-Marzoka *et al.* (2016), Baddour et al. (2017) and Billah *et al.* (2017).

Leaf area index (LAI) and net assimilation rate (NAR) of maize plants treated with foliar application with some antioxidants at different rates are shown in Table 3.

LAI at 55, 70 and 85 DAS as well as NAR at the two periods (55-70) & (70-85) DAS were recorded significant affect in the two seasons under study. The highest values of LAI and NAR were achieved when plants sprayed by 100 ppm of antioxidants mixture, followed by application of 200 ppm AA. This enhancement increases in maize growth parameters as a result to foliar spray by antioxidants might be due to the increasing of cell division within the meristemic cells of maize plants roots which resulted in increasing plant growth (Sakhabutdinova *et al*., 2003), however, the role of antioxidants is to improve plant performance through stimulating growth of maize (Chattha *et al.,* 2015), improves germination (Hayat *et al.,* 2010) and plant growth enhancement (Mahdi *et al*., 2013). Our results are in agreement with those of Tuna *et al*. (2013) and Billah *et al.* (2017).

Table 3. Leaf area index (LAI) and net assimilation rate (NAR) of maize as affected by foliar application with antioxidants at various rates during 2016 and 2017 seasons.

Foliar treatments	LAI						NAR (g/m^2/day)			
	55 day		70 day		85 day		(55-70 day)		(70-85 day)	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Water (control)	3.78	3.89	4.20	4.31	4.93	5.04	11.16	11.29	11.88	11.99
100 ppm AA	3.92	4.03	4.58	4.70	5.42	5.52	11.66	11.79	12.32	12.43
200 ppm AA	4.10	4.21	4.73	4.85	5.66	5.78	11.92	12.07	12.68	12.78
100 ppm CA	3.86	3.97	4.49	4.59	5.21	5.32	11.41	11.52	12.18	12.30
200 ppm CA	3.99	4.10	4.62	4.72	5.39	5.50	11.58	11.67	12.33	12.43
100 ppm SA	3.89	3.98	4.53	4.64	5.38	5.49	11.52	11.63	12.28	12.37
200 ppm SA	4.00	4.12	4.67	4.78	5.60	5.71	11.68	11.80	12.59	12.70
100 ppm AA +CA+SA	4.20	4.31	4.83	4.96	5.82	5.94	12.20	12.32	12.91	13.01
LSD (0.05)	0.19	0.19	0.19	0.20	0.19	0.20	0.20	0.20	0.19	0.19

AA; ascorbic acid CA; citric acid SA; salicylic acid

Photosynthetic pigments

The photosynthetic pigments (chlorophyll a, chlorophyll b and carotenoids) contents at 70 DAS in maize plants leaves treated with foliar application by some antioxidants at different rates are shown in Table 4. The values of chlorophyll a, chlorophyll b and carotenoids at 70 DAS were significantly increase when plants sprayed by any antioxidant treatments in the two seasons under study.

Table 4. Photosynthetic pigments in maize plants leaves at 70 DAS as affected by foliar application with antioxidants at various rates during 2016 and 2017 seasons.

Foliar treatments	Photosynthetic pigments					
	Chlorophyll a (mg/g FW)		Chlorophyll b (mg/g FW)		Carotenoids (mg/g FW)	
	2016	2017	2016	2017	2016	2017
Water (control)	1.098	1.116	0.598	0.614	0.109	0.120
100 ppm AA	1.160	1.181	0.631	0.645	0.132	0.141
200 ppm AA	1.193	1.216	0.666	0.681	0.145	0.156
100 ppm CA	1.140	1.160	0.619	0.632	0.121	0.130
200 ppm CA	1.161	1.180	0.640	0.656	0.134	0.145
100 ppm SA	1.155	1.175	0.625	0.640	0.125	0.134
200 ppm SA	1.187	1.201	0.646	0.661	0.141	0.152
100 ppm AA +CA+SA	1.215	1.236	0.695	0.711	0.156	0.167
LSD (0.05)	0.06	0.04	0.009	0.011	0.009	0.01

AA; ascorbic acid CA; citric acid SA; salicylic acid

The highest values of chlorophyll a, chlorophyll b and carotenoids were achieved when plants sprayed by 100 ppm of antioxidants mixture in two seasons, followed by application of 200 ppm AA. However, under saline soil conditions as observed in control treatment chlorophyll a and b as well as carotenoid contents decreased in maize plants leaves, such decrease in chlorophyll content might be due to the degradation of chlorophyll pigment that resulted from of proteolytic enzymes chlorophyllase stimulation (Zhao *et al*., 2006). Under abiotic stresses, the protocol efficiency of chloroplast senescence is mainly the investigation of chlorophyll degradation. However, chlorophyll degradation and loss is observed to be due to considerable rapid accumulation of H_2O_2, a potential reactive oxygen species (ROS). Furthermore, salinity stress is reported to induce the chlorophyll pigment degradative enzyme, chlorophyllase, activity and at the same time adversely influence the biochemical synthesis of proteins, especially those which aggregate and bind chlorophyll molecules (Jaleel *et al*., 2007). However, in many studies an enhancement of photosynthetic pigments has been observed due to the foliar antioxidants application (Ismail, 2013 and Tuna *et al*., 2013).

-Soluble sugars and antioxidant enzymes

Soluble sugars and antioxidant enzymes [catalase (CAT), polyphenol oxidase (PPO), peroxidase (POD), phenylalanine ammonia lyase (PAL) and tyrosine ammonia lyase (TAL)] activities contents in maize plants leaves treated with foliar application with some antioxidants at different rates are shown in Table 5. The soluble sugars and antioxidants enzymes activities contents in maize plants leaves were significantly increased as a result of foliar AA, CA and SA application, especially with AA, in the two seasons as compared with control treatment. The highest values of soluble sugars, CAT, PPO, POD, PAL and TAL activities were achieved when plants sprayed by 100 ppm of antioxidants mixture in two seasons, followed by application of 200 ppm AA. Exposure plants to saline soil conditions reduced soluble sugars contents of maize leaves. The change in soluble sugars contents under salinity stress has already been investigated for a lot of plant species (Khattab, 2007 and Hassanein *et al.*, 2009). In this present investigation application of antioxidants induce the soluble sugars accumulation as compared with control plants. Under saline soils conditions, antioxidants might be assumed to inhibit polysaccharide hydrolyzing enzyme system and/or accelerate the formation of polysaccharides from soluble sugars (Khodary, 2004). ROS scavenging enzymes and antioxidant molecules in plants prevent or alleviate the damage from $O_2^{\bullet-}$ and H_2O_2, and $O_2^{\bullet-}$ can be dismutated into H_2O_2 by superoxide dismutase in chloroplasts, mitochondria, the cytoplasm and peroxisomes (Bowler et al., 1992). CAT, PPO, POD, PAL and TAL are reported to scavenge H_2O_2 into water in plant species (Gill and Tujeta, 2010; Miller *et al*., 2010). Our obtained data on enzymatic antioxidants activities, following antioxidants application clearly demonstrated an unambiguous role of ascorbic, citric and salicylic acids in scavenging maize plants from salinity stress oxidative damage and those results are in harmony with results of (Ahmad *et al.* 2018; Pirasteh-Anosheh and Emam 2018; Tahjib-UI-Arif *et al*., 2018), and clearly demonstrated that the protective role of exogenous antioxidants in oxidative protection through the stimulation of antioxidant capacity that might increase the photosynthetic process and lower the toxic effects of salinity stress on maize plants.

Table 5. Soluble sugars and antioxidant enzymes activities in maize plants leaves at 70 DAS as affected by foliar application with antioxidants at various rates during 2016 and 2017 seasons.

Foliar treatments	Soluble sugars (mg glucose equivelant /g dry tissue)		Catalase activity (µmole H_2O_2 min^{-1})		Polyphenol oxidase activity (mg protein min^{-1})		Peroxidase activity (mg protein min^{-1})		PAL activity (mg t-cinnamic acid produced/g FW/h)		TAL activity (mg p-coumaric acid produced/g FW/h)	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Water (control)	31.5	31.9	15.4	15.8	35.4	35.7	85.5	86.3	4.45	4.63	2.99	3.12
100 ppm AA	32.1	32.5	16.4	16.8	36.7	37.0	95.9	96.7	5.21	5.58	3.66	3.92
200 ppm AA	33.1	33.5	17.9	18.3	37.5	37.9	102.5	103.4	6.11	6.48	4.01	4.37
100 ppm CA	31.9	32.3	15.9	16.2	36.0	36.3	90.0	90.8	4.87	5.17	3.28	3.50
200 ppm CA	32.5	32.9	16.4	16.8	36.7	36.9	96.3	96.7	5.23	5.58	3.56	3.89
100 ppm SA	32.0	32.4	16.0	16.4	36.4	36.7	91.4	92.1	5.13	5.42	3.51	3.79
200 ppm SA	32.7	33.1	16.9	17.3	37.0	37.3	98.0	98.7	5.58	5.81	3.79	4.05
100 ppm AA +CA+SA	33.9	34.3	18.1	18.4	38.9	39.3	108.1	108.8	6.54	6.90	4.33	4.70
LSD (0.05)	0.28	0.24	0.28	0.34	0.27	0.32	0.52	0.40	0.26	0.23	0.24	0.21

AA; ascorbic acid CA; citric acid SA; salicylic acid

-Proline, sodium, potassium concentrations and Na^+/K^+ ratio

Proline, Na^+, K^+ contents and Na^+/K^+ ratio in maize plants leaves treated with foliar application of some antioxidants at different rates are show in Table 6. Proline, Na^+ and Na^+/K^+ ratio in leaves of maize plants were significantly decreased as a result of AA, CA and SA application as compared with untreated plants (control).

The lowest values of proline, Na^+ and Na^+/K^+ ratio were achieved when plants sprayed by 100 ppm of antioxidants mixture in two seasons, followed by application of 200 ppm AA. On the other hand, K^+ content in maize leaves were increased as a results of foliar antioxidants application. The highest values of potassium content were achieved when plants sprayed by 100 ppm of antioxidants mixture in two seasons, followed by application of 200 ppm AA. The foliar application of ascorbic acid reduced the proline content more starkly as compared to other antioxidants under study. When plants are grown in excess salinity stress, some plants tolerate this stress by induction and accumulation of organic substances in the cytoplasm to decrease the osmotic potential. One of these organic solutes is proline that act as an osmoregulation compound for adjusting plant cell cytoplasmic osmotic potential (Ashraf and Foolad, 2007). Furthermore, proline have a role in radical detoxification and enzyme protection (Gadallah, 1999). Moreover, Al-Hakimi and Hamada (2001) stated that soaking wheat grain in antioxidants like ascorbic acid and sodium salicylate could overcome the unsuitable effects of salinity stress on wheat seedlings induced accumulation of proline that suppress stress. However, in this study, foliar non-enzymatic antioxidants application decreased accumulation of proline in maize plants as compared to the salt stressed plants (control). It is well established that proline content, which makes the highest percent of the total amino acid pool, increases up to 100 times the normal level in many plants when exposure to abiotic stress conditions (Dolatabadian *et al.,* 2009). In this present study, it's observed that saline soil conditions induced the accumulation proline in maize plants leaves, that might have participated in osmotic adjustment and allowed plants to maintain turgor pressure by enhancing them to adapt to saline soil conditions. It is possible that application of antioxidants eliminated ROS and decrease proline synthesis. Ascorbic, citric and salicylic acids were reported as an effectiveness compounds in increasing the potassium content and decreasing sodium accumulation in the salt stressed maize plants leaves. According to Athar *et al.* (2009), potassium content in the leaves of wheat plants reduced significantly due to salinity stress. Moreover, foliar applied ascorbic acid induced the accumulation of potassium ion in the salt stressed plants leaves. Also, exogenously foliar applied antioxidants resulted in highly decreasing of Na^+/K^+ ratio in maize and barley plants leaves (Tuna *et al.,* 2013 and Fayez and Bazaid, 2014).

Table 6. Proline, sodium, potassium concentrations and Na^+/K^+ ratio of maize leaves at 70 DAS as affected by foliar application with antioxidants at various rates during 2016 and 2017 seasons.

Foliar treatments	Proline (µg /g FW)		Na^+ Leaf content (mmole/kg)		K^+ Leaf content (mmole/kg)		Na+/K+ ratio	
	2016	2017	2016	2017	2016	2017	2016	2017
Water (control)	70.71	69.55	331	310	468	487	0.71	0.64
100 ppm AA	65.67	64.71	308	281	491	510	0.63	0.55
200 ppm AA	62.44	61.32	275	248	509	522	0.54	0.48
100 ppm CA	67.47	66.76	318	298	478	497	0.67	0.60
200 ppm CA	65.54	64.64	288	268	495	506	0.58	0.53
100 ppm SA	66.56	65.65	315	289	482	499	0.65	0.58
200 ppm SA	63.14	62.26	280	259	499	518	0.56	0.50
100 ppm AA +CA+SA	59.76	58.68	246	215	531	543	0.46	0.40
LSD 0.05	0.46	0.40	22.7	19.4	19.1	18.1	0.05	0.04

AA; ascorbic acid CA; citric acid SA; salicylic acid

Yield and yield components

Yield and yield components of maize plants treated with foliar antioxidants application are show in Table 7.

Ear length, grain weight/ear, 100-grain weight, grain yield, straw yield and harvest index of maize crop were significantly increased with foliar application of AA, CA and SA as compared with untreated plants (control) in the two seasons. The highest values of ear length, grain weight/ear, 100-grain weight, grain yield and harvest index were achieved when plants sprayed by 100 ppm of antioxidants mixture in two seasons, followed by application of 200 ppm AA, whereas, straw yield obtained the maximum values when plants sprayed by 100 ppm AA followed by spraying 100 ppm SA and 100 ppm antioxidants mixture, respectively.

Table 7. Yield and yield components of maize as affected by foliar application with antioxidants at various rates during 2016 and 2017 seasons.

Foliar treatments	Ear length (cm)		Grains weight/ear (g)		100-grain weight (g)		Grain yield (t/fad)		Straw yield (t/fad)		Harvest index	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Water (control)	21.25	21.50	209	220	37.85	38.74	2.09	2.20	3.06	3.10	41	41
100 ppm AA	23.13	23.50	230	243	40.55	41.25	2.21	2.32	3.07	3.14	42	43
200 ppm AA	25.38	25.88	242	255	42.93	43.59	2.37	2.46	3.07	3.05	44	45
100 ppm CA	22.00	22.25	220	231	38.98	39.27	2.14	2.24	3.03	3.08	41	42
200 ppm CA	24.38	24.75	229	243	40.40	41.26	2.21	2.31	2.98	2.96	43	44
100 ppm SA	22.50	22.63	223	238	39.62	40.44	2.17	2.27	2.99	2.99	42	43
200 ppm SA	24.88	25.28	239	251	41.58	42.79	2.28	2.37	2.95	2.95	44	45
100 ppm AA +CA+SA	26.75	27.13	253	265	44.41	44.94	2.41	2.50	2.99	2.99	45	46
LSD 0.05	0.71	0.55	17.6	17.8	0.42	0.35	0.15	0.14	ns	0.12	0.8	1.3

AA; ascorbic acid CA; citric acid SA; salicylic acid

Foliar applied AA, CA and SA enhanced growth parameters and subsequently enhanced increase in the ear length, grain weight/ear, 100-grain weight, grain and straw yield as well as harvest index. However, the increase in growth and yield in response to non-enzymatic antioxidants under saline soil conditions may be due to protective role of antioxidants on cell membranes that might be responsible for increasing plant salt tolerance (Babar *et al*., 2014). However, many authors concluded the antioxidants role in the salt stress response regulating of maize plant and suggested that antioxidants could be used as essential growth regulator to improve plant growth and nutrient uptake to overcome salinity stress (Gunes *et al.,* 2007).

CONCLUSION

According to aforementioned results, it can be concluded that the superiority of foliar spray by 100 ppm ascorbic, citric and salicylic acids at 30 & 45 DAS, followed by application of 200 ppm ascorbic acid, for enhancing maize growth and productivity under salt stress conditions in East Delta Region in Egypt.

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تأثير الرش الورقى ببعض مضادات الأكسدة على نمو وانتاجية الذرة الشامية تحت ظروف الأراضى الملحية

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أجريت تجربة حقلية جنوب بورسعيد، خلال موسمى 2016، 2017 لدراسة تأثير الرش الورقى بأحماض الأسكوربيك والستريك والسلسيلك على النمو والمحصول ومكوناته لهجين الذرة الصفراء الثلاثى 352 تحت ظروف الأراضى الملحية وكانت المعاملات: الرش بتركيز 100 و 200 جزء فى المليون لكل حامض ، خليط من 100 جزء فى المليون من الثلاثة أحماض، معاملة المقارنة (رش بالماء)، أوضحت النتائج أن الرش بمضادات الأكسده أدى الى زيادة معنوية فى صفات إرتفاع النبات، دليل مساحة الأوراق (LAI) عند 55، 70، 85 يوم من الزراعة، معدل نمو المحصول (CGR) عند فترتى (55-70) و (70-85) يوم من الزراعة، صافى معدل التمثيل الضوئي (NAR) عند فترتى (55-70) و (70-85) يوم من الزراعة، محتوى الأوراق من كلوروفيل A ، B والكاروتينويد والسكريات الذائبة ونشاط إنزيمات مضادات الأكسدة (الكاتليز والبولى فينول بيروكسيديز والبيروكسيديز) وأيون البوتاسيوم ووزن ال 100 حبة و محصولي الحبوب والقش للفدان ودليل الحصاد لمحصول الذرة في كلا الموسمين وخاصة مع الخليط بتركيز 100 جزء فى المليون من مضادات الأكسده مقارنة بمعاملة الرش بالماء. وكان هناك إنخفاض معنوى في محتوى الأوراق من البرولين والصوديوم وكذلك نسبة عنصر الصوديوم الى البوتاسيوم عند رش النباتات بمضادات الأكسده في كلا الموسمين مقارنة بمعاملة الرش بالماء (معاملة الكنترول).