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EFFECT OF SALICYLIC ACID ON PRODUCTIVITY AND CHEMICAL CONSTITUENTS OF SOME WHEAT (*Triticum aestivum* L.) VARIETIES GROWN UNDER SALINE CONDITIONS

H. M. Abdel-Lattif[1], Mohamed S. Abbas[2] and Moemen H. Taha[1]

[1]Agronomy Department, Faculty of Agriculture, Cairo University, Cairo, Egypt
[2]Department of Natural Resources, Faculty of African Postgraduate Studies, Cairo University, Egypt
[*]Corresponding author: msaelsarawy@yahoo.com

ABSTRACT

Wheat production is affected by a wide-range of abiotic factors, salinity is one of the major and increasing abiotic stress. Application of salicylic acid was used to mitigate the adverse effects of salinity and improve productivity of wheat. Two field experiments were laid out in the Desert Experimental Station, Faculty of Agriculture, Cairo University at Wadi El-Natroon, Egypt. A split-plot design was used, the main plots were allocated to salicylic acid [zero (control), 100 and 200 mg L^{-1}] and three wheat varieties, Gemmeiza7, Sakha 93 and Giza168 were devoted to sub-plot with three replications. Results showed spraying the wheat with 100mg $L^{-1}$of salicylic acid significant increased the grain yield of all varieties Gemmeiza7, Sakha 93 and Giza168 with rate of 1.07, 1.83 and 0.91 ton ha^{-1} compared with control, respectively. The interaction between the Sakha 93 and 100mg $L^{-1}$of salicylic acid gave the highest values of spike weight /plant, number of grains /plant, grain yield /plant, shoot dry weight and grain yield ha^{-1}, maximum contents of phosphors, potassium in leaves, potassium in grains and proline. It can concluded that, the exogenously applied SA increased the salinity tolerance of wheat, particularly by reducing the negative effects of salts and improve yield and its components.

Key words: Wheat; salicylic acid; yield; total soluble phenol; total sugars; minerals; plant pigment and proline

INTRODUCTION

Wheat (*Triticum aestivum* L.) is the most commonly grown crop in the world and one of the most important cereal crops in Egypt. It represents about 10% of the agricultural production in Egypt and about 20% of agricultural imports (FAO, 2015). Wheat occupies the remarkable position as source of dietary protein and calories for population of the world (FAO, 2009). It has been the basic food staple of the major societies of Europe, West Asia and North Africa (Feldman, 2001).

Salinity is one of the most serious abiotic stresses in the world. About 20% of the irrigated land and one-third of the world's arable land are influenced by salinity (Machado and Serralheiro, 2017; Qadir *et al.,* 2000). Salinity is one of the initial restrictive factors in crop production. It causes water shortage, ion toxicity, and nutrient deficiency, leading to growth and yield reduction, and even to plant death (Li *et al.* 2013). In arid and semi- arid environments, the negative influences of salinity are increased due to fertilizers application and irrigation with saline water (Villa-Astoria *et al,* 2003). Practical approaches are required to improve plant tolerance under salt conditions, Khan *et al.,* (2014) Afzal *et al.* (2006) indicated that the phyto-hormones play critical roles in plant responses to salinity as well as the foliar application of salicylic acid (SA) enhances photosynthesis activity and plant growth under salinity.

Salicylic acid is a type of small-molecule phenolic compound predominant in plants tissues that can affect many physiological processes mainly regulating plant growth, photosynthetic and development (Gallego-Giraldo *et al.,* 2011; Vicente and Plasencia, 2011; Miura and Tada, 2014 and Berkowitz *et al.,* 2016). It is also a plant endogenous signal molecule (Yan and Dong, 2014). Also, salicylic acid can alleviate several abiotic stresses e.g. salinity (Jayakannan *et al.,* 2015), drought (Saruhan *et al.,* 2012) and cold (Mutlu *et al*., 2016), toxicity of heavy-metal (Agami and Mohamed, 2013) and herbicide stress (Akbulut *et al.* 2018). Previous studies have shown that salicylic acid can alleviate growth inhibition by salinity in numerous plant species, such as strawberry (Karlidag *et al.* 2009), maize (Khodary 2004), Tomato (Shahba *et al.* 2010), olive trees (Abd-El-Rhman and Attia 2016), garlic (Abd-Elkader 2016) and onion (Nangare *et al.* 2018).

Salicylic acid at low doses seems to play a helpful role in plant metabolism. Applied 50 µM SA on wheat plants increased the growth and yield (Sahu *et al.*, 2010). Also, El-Tayeb, (2005) found that application of salicylic acid seemed to promote a pre-adaptive reaction to salt stress, leading to the encouragement of defensive responses to the photosynthetic pigments and the preservation of membrane straightness in plants, which enhances growth of plant. In this respect, salicylic acid treatment significantly increased quantities of endogenous salicylic acid, decreased concentration of lipid peroxidation, enhanced the antioxidant enzymes and contents of non-enzymatic compounds, improved the ratio of potassium to sodium and increased the plant growth resulting in the improved abiotic tolerance (He and Zhu, 2008; Chen *et al.,* 2011; Krajnc *et al.,*; 2011 Kang *et al.,* 2012 and Li *et al.,* 2013). However, Metwally *et al.* (2003) and Horváth *et al.* (2007) reported that salicylic acid has significant agronomic potential to improve plant tolerance under stress conditions and that the effect of salicylic acid is principally dependent on the concentration, application type, and plant species. Also, wheat production is affected by a wide range of abiotic and biotic factors, salinity is one of the major and increasing abiotic stress in wheat grown areas in the world as well as the growth and yield of wheat are significantly influenced by soil and/or water salinity. Therefore, exogenous application of salicylic acid was used in the peanut investigation as a regulatory factor to examine its protective effects to avoid the hazards of salinity aiming to improve growth and yield of some wheat varieties in sandy soil under drip irrigation system.

MATERIALS AND METHODS

Experimental Site: Two field experiments were laid out under drip irrigation in the Desert Experimental Station, Fac. of Agric., Cairo Univ. at Wadi El-Natroon, El-Beheira Governorate, Egypt (located at 30°32'30" and 29° 57'15" with an altitude of 45 meters) during the two successive seasons of 2015/2016 and 2016/2017(drip irrigation was used to avoid the harmful effects of salt irrigated water on wheat plants).

Soil physical analysis was conducted according to Klute (1986) and chemical was done according Page *et al.* (1982). Soil and irrigation water properties are presented in Table (1). Soil of the experimental site was sandy loam, saline and poor in nutrients and soil had available nitrogen of (6.4-8.9 mg kg^{-1}), phosphorus (1.65-2.04 mg kg^{-1}) and potassium (168-187 mg kg^{-1}) in first and second seasons respectively. Also, organic matter was low and ranged from 0.51 to 0.62% and pH from 7.43 to 7.29 in both seasons, respectively. Irrigation water was saline, the electrical conductivity (EC) of soil and irrigated water was 5.54-5.22 and 4.1-4.2 dS/m in first and second seasons, respectively. Little variances in the soil and irrigated water properties between the two seasons of the experiment.

Experimental design and treatments: Three Egyptian commercial varieties of wheat, Gemmeiza7, Sakha 93 and Giza168 were used . A split-plot design in a randomized complete block arrangement was used with three replications. The main plots were allotted to three levels of salicylic acid (SA), zero (control), 100 and 200 mg L^{-1}(equal 0, 48 and 96 g ha^{-1}respectively) sub-plots were devoted to the three varieties. Each sub-plot consists of 4 ridges of 0.70 m apart and 15.0 m in length, i.e. the experimental plot area was 42 m^2. Each main plot was surrounded with a wide ridge (2.0 m) to avoid interference of the three salicylic acid levels**.**

Cultural practices : The preceding crop was peanut (*Arachis hypogaea* L.) in both seasons. Seeds of all wheat varieties were obtained from Wheat Research Department, Field Crops Research Institute, Agricultural Research Centre, Egypt. Sowing dates were on October 15 and 19 in 2015 and 2016 seasons, respectively. Seeds were drilled by hand on both sides of the ridges at seed rate of 100kg/ha. Calcium super phosphate fertilizer (15.5% P_2O_5) at the rate of 60 kg P_2O_5 ha^{-1} was added during field preparation as basal application. Nitrogen was added at the rate of 220 kg N ha^{-1} in the form of ammonium nitrate (33.5% N). Potassium sulphate (48% K_2O) was applied at the rate of 120 kg K_2O ha^{-1}. Application of both of N and K fertilizers was started at 30 days after sowing through 12 equal doses at 7-day intervals. At 30, 45 and 60 day after sowing (DAS), SA solution was sprayed by a hand sprayer at 10.00 -12.00 AM.

The weed control was carried out during the growing season by hoeing twice at 30 and 60 day after sowing. The other cultural practices were applied as recommended by the Agricultural Research Center (ARC), Giza, Egypt.

Data collection: At harvest, plants from 0.25 m^2 area were randomly uprooted from each sub plot to determine grain yield/plant. Grain yield of the whole area of each experimental unit (sub-plot) was obtained and then adjusted into ton/ ha. The grain yield/plant and per hectare were adjusted on the basis of 14% grain moisture content. number of spikes/plant, spike weight/plant (g), number of grains/plant, plant height (cm), dry weight of root/plant (g), dry weight of shoot/plant (g), fresh weight of root/plant (g), fresh weight of shoot/plant (g) and 100-grain weight (g).

Chemical constituents: The shoots (10 days after the last dose of SA) and grains in the two seasons were chemically analyzed using 10 random plants from each plot at three replications. All analyses were done at Faculty of Agriculture Research Park, Faculty of Agriculture, Cairo University as follows:

Total soluble phenol was determined using the folin-Ciocalteau colorimetric method (Swain and Hillis 1959).

Total sugars were determined by phosphomolibdic acid method according to A.O.A.C. (1975)

Free amino acids (FAA): Total free amino acids was determined by using ninhydrin reagent (Moore and Stein, 1954).

Plant Pigments: the photosynthetic pigments (chlorophyll a, chlorophyll b and carotene) concentrations were determined in leaf fresh samples according to Nornai (1982).

Measurement of proline content: proline content was estimated colorimetrically according to the method of Trotel *et al.* (1996).

Total nitrogen (N) of the dried material was determined by using the modified- Micro-Kjeldahel method as described by Jones *et al*. (1991). Phosphorus (P) was determined sepectrophotometerically by using stannous chloride method and potassium (P) was determined by Flame-photometer (BWB1) according to A.O.A.C. (1980).

Statistical analysis: Test of normality distribution was carried out according to Shapiro and Wilk method (1965), by using SPSS v. 17.0 (2008) software package. Also, data were tested for validation of assumptions underlying the combined analysis of variance by separate analyzing of each season and then combined analysis across the two seasons was performed if homogeneity (Bartlet test) was insignificant. Estimates of LSD were calculated to test the significance of differences among means according to Snedecor and Cochran (1994).

RESULTS AND DISCUSSION

Analysis of variance: The combined analysis of variance of studied varieties and for all characters under three salicylic acid levels across seasons is presented in Tables (2, 4 and 6). Mean squares due to seasons were significant ($P\leq 0.05$ or $P\leq 0.01$) for all studied characters, except number of spikes per plant, grain index, grain yield per ha, (total sugars, N, P and K in leaves), P in grain, chlorophyll a and carotene that indicating the effect of climatic conditions on most studied characters. However, mean squares due to salicylic acid levels were significant ($P\leq 0.05$ or $P\leq 0.01$) for all characters, except number of spikes per plant, (total FAA, N, P and K in leaves) and (N, P and K in grains), suggesting that the salicylic acid had a significant effect on most studied traits. Mean squares due to varieties were significant ($P\leq 0.05$ or $P\leq 0.01$) for all characters, except number of spikes per plant, root fresh weight, chlorophyll a and chlorophyll b. Furthermore, mean squares due to salicylic acid levels x varieties were significant ($P\leq 0.05$ or $P\leq 0.01$) for all studied characters.

Effect on growth, yield and yield components

Effect of wheat varieties: Results in Table (3) showed that Sakha 93 variety gave the highest values of spike weight per plant (9.44 g), number of grains per plant (149.28), grain yield per plant (7.19 g), fresh weight of root (2.02 g) and shoot (18.92 g), dry weight of root (1.19 g), shoot (6.77 g) and grain yield ha^{-1} (5.31 ton). While, Gemmeiza7 variety gave the highest values of number of spikes per plant (3.33), 100 grain weight (5.30) without significant difference with Sakha 93 variety and plant height (97.56 cm). On the contrary, the lowest values of all studied traits of yield and its components were recorded for Giza-168 variety.

Effect of salicylic acid treatments: In general, there was a significant increase in all studied traits of yield and its components by using a foliar application of salicylic acid except number of spikes per plant. However, careful observations of results in Table (3) clearly showed that, spraying wheat plants with 100mg L^{-1}of salicylic acid gave the highest values of spike weight per plant (10.15 g), number of grains per plant (163.22), grain yield per plant (8.14 g), plant height (101.28 cm), 100 grain weight(5.29),fresh weight of shoot (14.47 g), dry weight of shoot (6.07 g) and grain yield ha^{-1} (5.30 ton). While, spraying the wheat plants with 200 mg L^{-1}of salicylic acid gave the highest value of fresh and dry weight of root (1.20 and 1.87 g), respectively, and control treatment for number of spikes per plant (3.33) but without significant difference with100 mg L^{-1}of salicylic acid treatment

Effect of interaction between wheat varieties and salicylic acid treatments: Results showed significant effect for the interaction between wheat varieties and salicylic acid treatments at the 5% level of probability. There is a positive effect for foliar application of salicylic acid on all wheat varieties compared with control treatment for studied traits except number of spikes per plant. However, results in Table (3) indicated that the interaction between Sakha 93 and 100mg L^{-1}of salicylic acid gave the highest values of spike weight per plant (12.18 g), number of grains per plant (180.83), grain yield per plant (9.48 g), dry weight of shoot (7.81 g) and grain yield ha^{-1} (6.13 ton). Also, the same variety treated with 200mg L^{-1}of salicylic acid gave the highest values of dry weight of root (1.39 g), fresh weight of root (2.40) and shoot (21.72 g). While, the interaction between Gemmeiza7variety and control, 100 and 200 mg L^{-1}of salicylic acid gave the highest value of number of spikes per plant (4), plant height (109.67 cm) and 100 grain weight (5.58 g), respectively.

In general, low dose of salicylic acid can encourage plant tolerance to adverse conditions, but high dose of salicylic acid can promote high levels of oxidative stress, resulting in a reduced tolerance to stress (Guo *et al.,* 2013; Koc *et al.,* 2013 and Yan and Dong, 2014). Application of salicylic acid seemed to promote a pre-adaptive reaction to salt stress, leading to the encouragement of defensive responses to the photosynthetic pigments and the preservation of membrane straightness in plants, which enhances growth of plant (El-Tayeb, 2005). In wheat seedlings, salicylic acid at 50 µM produced accumulation of both indole acetic acid (IAA) and abscisic acid (Shakirova *et al.,* 2003). Thus, it is well documented that SA treatment prevents decrease in IAA and cytokinin content completely, which reduce stress induced inhibition of wheat growth (Afzal *et al.* 2006).

Nemours studies have shown that salicylic acid can alleviate growth inhibition by salinity and improve the yield and its components of wheat plants, Suhaib *et al.* (2018) reported that the application of salicylic acid had a significant effect on improving the wheat growth under saline conditions. Also, Kovacs *et al*., (2014) found that the wheat productivity was enhanced by 70% through application of SA. In this concern, Karim *et al*. (2011) reported that the application of 100, 200 and 400 ppm SA increased plant height, number of tillers per plant and dry weight of shoot in wheat. While, Fariduddin *et al*. (2003) indicated that grains soaked in 5–10 M of SA gave more number of leaves and higher yield and dry matter. Also, Amin *et al*. (2008) reported that foliar application of salicylic acid (100 mg/L) resulted in the highest increase in yield and its components of wheat plants. However, Afzal *et al.* (2005) found that dry weight was decrease in wheat plants grown in salt conditions. Results of our experiments, indicated that dry weights of wheat plants were decreased due to salinity stress but plants treated with SA, showed enhanced dry weight of plants as compared to SA non treated plants. These results are in line with many other researchers, El-Tayeb *et al.* (2005) and Khodary *et al.* (2004) reported that SA pre-treatment increased dry weight in the stressed barley seedlings and maize plants, respectively. Salicylic acid induces salinity tolerance by increasing yield of wheat seedlings (Arfan *et al*., 2007). Similar results under heat stress were reported by Chouhan, *et al*., (2017) who found that SA 150 ppm of spray application alleviated the negative effect of heat stress on yield and yield components in wheat. On other hand. Ibrahim *et al.,* (2014) indicated that a high wheat yield might be gotten by treatment of 100 kg/fed. of nitrogen and spraying of salicylic acid with dose of 100 ppm.

Effect on chemical constituents

Effect of wheat varieties: Results in Tables (5) and (7) indicated that Sakha 93 variety gave the maximum values of total sugars (48.18 mg/g) and phosphorus content (3.81 mg/g) in leaves, total soluble phenol (2.12 mg/g) and total sugars (32.16) mg/g in grains, chlorophyll a (1.330 mg/g) and chlorophyll b (1.083 mg/g). While, Gemmeiza7variety gave the maximum value of total soluble phenol (9.78 mg/g), potassium contents in leaves (29.28 mg/g) and in grains (5.11 mg/g), carotene (0.714 mg/g) and proline content (6.23 mg/g). Whereas, total free amino acids and nitrogen contents in leaves (6.14 and 24.31 mg/g, respectively) and grains (2.58 and 20.65 mg/g, respectively), and phosphors contents in grains (2.82 mg/g) were recorded in plants of Giza-168 variety.

Effect of salicylic acid treatments: Tables (5) and (7) show that exogenous application of SA at dose of 100 mgL^{-1} significantly increased all studied traits in terms of total soluble phenol, total sugars, total free amino acids, minerals content (N, P and K) in leaves and grains. Also, plant pigment (chlorophyll a, chlorophyll b and carotene) and proline content.

Effect of interaction between wheat varieties and salicylic acid treatments: Foliar application of SA improved the performance of all wheat varieties under salinity conditions. However, careful observations of results in Tables (5 and 7) clearly showed that, wheat plants of Sakha 93 variety treated with zero salicylic acid (control) had the maximum contents of chlorophyll b (1.166 mg/g), carotene (0.577 mg/g), at dose of 100 mg L^{-1} gave the maximum contents of phosphors (5.31 mg/g), potassium (31.02 mg/g)in leaves, potassium (6.3 mg/g) in grains and proline (6.78 mg/g) while, at dose 200 mg L^{-1} gave the maximum contents of chlorophyll a (1.384 mg/g). Whereas, spraying the wheat plants of Gemmeiza7variety with 100 and 200 mg $L^{-1}$of salicylic acid gave the maximum contents of total sugars (39.06 mg/g) in grains and total soluble phenol (11.16 mg/g) in leaves, respectively. While, the interaction between Giza-168 variety and 100 mg $L^{-1}$of salicylic acid gave the maximum contents of total sugars (55.44 mg/g), total free amino acids (7.43 mg/g), nitrogen (30.92 mg/g) in leaves, nitrogen (25.32 mg/g) and phosphors (3.64 mg/g) in grains.

Our results indicated that the total free amino acids, total sugars and total soluble phenol improved in all wheat varieties under salt conditions. Amino acids have an osmo-protective role in different tissues exposed to salt toxicity (Mohamedin *et al.,* 2006). However, El-Basseouny and Bakheta (2005) reported that salinity increased the total amino acid content in Gemmaza 9 while in Giza 168 wheat variety war decreased. In this respect, Noreen *et al* (2017) reported that total free amino acids increased in wheat under drought stress. Also, Chandra *et al*. (2007) reported that free amino acids was increased in many of crops in reaction to drought stress. Form our study, wheat plants of Sakha 93 variety treated with 100 mg L^{-1} salicylic acid gave the highest value of proline content, proline is increased quickly under different a biotic stresses (Gadallah, 1999). Moreover, proline increased in maize plants when using SA application and under salt stress (Hussein, *et al*., 2007). On other hand, Ghafiyehsanj *et al.* (2013) reported that application of SA on wheat plants significantly reduced soluble sugar content of cowpea plants.

The salt stress depressed the absorption of K^+ ion in wheat. On the other hands, the treatment of salicylic acid increased the uptake of K^+ ion that may be has a positive effect of growth and productivity of wheat plants under salt stress. These results were harmony with findings obtained by Noreen *et al.* (2017) who found that the translocation of K^+ from roots to shoots caused enhancement in the growth and development of wheat.

Application of salicylic acid reduces the salinity harmful effect by increasing chlorophyll a and b as well as carotene contents. These results are consistent with those obtained by Yildirim *et al.* (2008) who indicated that chlorophyll content is one of the significant signs of salt tolerance in crops. However, Sweify and Abdel Wahid (2008) reported that applied salicylic acid increased chlorophyll a, b and caroteniod contents in *Syngonium podphyllum* plants. Sing and Usha, (2003) and Khodary (2004) found increasing in pigment contents and photosynthetic rate of wheat and maize plants, respectively by exogenous application of SA. Also, Karim and Khursheed (2010) reported application of SA a significantly improved chlorophyll and carotenoid contents in wheat plants.

Table 1. Soil and irrigation water properties at the experimental site in 2015/2016 and 2016/2017 seasons.

Soil analysis	2015/2016	2016/2017
Physical properties		
Sand (%)	94.15	92.27
Silt (%)	4.35	5.20
Clay (%)	1.50	2.53
Texture class	Sandy	Sandy
Chemical properties		
pH $_{(1:1)}$	7.43	7.29
EC$_{(1:1)}$ **(dS** m^{-1}**)**	5.54	5.22
Organic matter (%)	0.51	0.62
Total $CaCO_3$ **(%)**	3.74	5.91
Available N (mg kg^{-1} **)**	6.4	8.9
Available P (mg kg^{-1} **)**	1.65	2.04
Available K (mg kg^{-1} **)**	168	187
Irrigation system	Drip irrigation	Drip irrigation

Chemical properties of irrigation water										
		EC				**Ions concentration meq** L^{-1}				
Season	**pH**	**ds** m^{-1}	**Ppm**	HCO_3^-	CL^-	SO_4^-	Ca^{++}	Mg^{++}	Na^+	K^+
2016	7.7	4.1	2624	2.8	30.5	9.0	3.9	4.3	33.3	0.64
2017	7.5	4.2	2688	3.2	29.1	7.9	5.3	4.6	32.5	0.55

Table 2. Mean squares from combined analysis of variance of split plot design for three wheat varieties evaluated under three salicylic acid treatments across 2015/2016 and 2016/2017 seasons.

S. O. V	Df	No. of spikes /plant	Spike weight /plant	No. of grains /plant	Grain yield /plant	Plant height	100 grain weight
Season (S)	1	0.29	39.42**	7210.6**	22.34**	308.16**	0.009
Reps/(S)	4	0.37	0.39	420.1	0.45	31.04	0.112
Varieties (A)	2	0.67	17.13**	5592**	8.84**	210.35*	0.703*
SA	2	1.85*	10.87**	3668**	5.56**	140.05*	0.307
Error	8	0.23	0.54	131.4	0.30	24.59	0.146
Salicylic acid (B)	2	0.22	73.11**	3327**	58.82**	1405**	0.428*
S×B	2	1.185	5.11**	1667.5*	3.65**	12.17	0.163
A×B	4	1.56*	23.77**	2371**	8.01**	90.46**	0.386*
S×A×B	4	0.4	0.99	150.6	0.74	52.88*	0.064
Error	24	0.41	0.56	378.6	0.43	18.07	0.099

S. O. V	df	Plant dry weight		Plant fresh weight		Grain yield/ha
		Root	Shoot	Root	Shoot	
Season (S)	1	0.685*	36.40**	2.82**	110.7**	0.249
Reps/(S)	4	0.132	0.55	0.08	3.49	0.162
Varieties (A)	2	0.467*	25.57**	3.06**	516.3**	5.70**
SA	2	0.05	5.63**	0.39	59.98**	0.248

Error	8	0.07	0.55	0.18	2.32	0.052
Salicylic acid (B)	2	0.575*	17.49**	0.53	91.48**	7.79**
S×B	2	0.118	3.81*	0.30	0.73	0.016
A×B	4	0.151*	4.90**	0.73*	39.93**	0.45**
S×A×B	4	0.096	2.23	0.26	1.36	0.163*
Error	24	0.148	0.82	0.23	2.62	0.052

*and** indicate significant at 0.05 and 0.01 levels of probability respectively.

Table 3. Means of yield and its components for varieties, treatments and their interaction across 2015/2016 and 2016/2017 seasons.

Varieties	Treatments	No. of spikes /plant	Spike weight/plant	No. of grains /plant	Grain yield (g/p)	Plant height (cm)	100 grain weight (g)
Gemmeiza7		3.33	7.90	117.72	6.15	97.56	5.30
Sakha 93		3.30	9.44	149.28	7.19	93.39	5.17
Giza 168		3.00	7.63	119.89	5.85	90.78	4.91
$LSD_{0.05}$		0.37	0.56	8.79	0.41	3.77	0.29
	Control	3.33	6.16	91.44	4.53	84.11	4.98
	Salicylic acid 100mg L^{-1}	3.22	10.15	163.22	8.14	101.28	5.29
	Salicylic acid 200mg L^{-1}	3.11	8.66	132.22	6.52	96.33	5.11
$LSD_{0.05}$		0.44	0.51	13.38	0.45	2.92	0.22
Gemmeiza7	Control	4.00	6.48	88.67	4.75	83.83	5.08
	Salicylic acid 100mg L^{-1}	3.33	7.18	130.83	6.41	109.67	5.23
	Salicylic acid 200mg L^{-1}	2.67	10.04	133.67	7.29	99.17	5.58
Sakha 93	Control	3.33	7.05	111.33	5.06	84.67	5.14
	Salicylic acid 100mg L^{-1}	3.17	12.18	180.83	9.48	98.67	5.48
	Salicylic acid 200mg L^{-1}	3.50	9.10	155.67	7.02	96.83	4.90
Giza 168	Control	2.67	4.97	74.33	3.79	83.83	4.72
	Salicylic acid 100mg L^{-1}	3.17	11.10	178.00	8.53	95.50	5.16
	Salicylic acid 200mg L^{-1}	3.17	6.84	107.33	5.24	93.00	4.85
$LSD_{0.05}$		0.77	0.89	23.17	0.78	5.06	0.37

Varieties	Treatments	Plant dry weight (g)		Plant fresh weight (g)		Grain yield (ton/ha)
		Root	Shoot	Root	Shoot	
Gemmeiza7		1.02	5.08	1.85	10.19	4.31
Sakha 93		1.19	6.77	2.02	18.92	5.31
Giza 168		0.87	4.46	1.23	9.18	4.49
$LSD_{0.05}$		0.20	0.57	0.33	1.17	0.24
	Control	0.85	4.30	1.53	10.21	4.03
	Salicylic acid 100mg L^{-1}	1.04	6.07	1.70	14.47	5.30
	Salicylic acid 200mg L^{-1}	1.20	5.94	1.87	13.62	4.79
$LSD_{0.05}$		0.27	0.62	0.30	1.11	0.18
Gemmeiza7	Control	0.78	3.66	1.85	7.05	3.70
	Salicylic acid 100mg L^{-1}	0.94	5.09	1.56	11.74	4.77
	Salicylic acid 200mg L^{-1}	1.36	6.49	2.15	11.79	4.46
Sakha 93	Control	0.94	5.15	1.51	13.99	4.30
	Salicylic acid 100mg L^{-1}	1.24	7.81	2.14	21.05	6.13
	Salicylic acid 200mg L^{-1}	1.39	7.34	2.40	21.72	5.51
Giza 168	Control	0.82	4.09	1.23	9.58	4.08
	Salicylic acid 100mg L^{-1}	0.92	5.31	1.42	10.62	4.99
	Salicylic acid 200mg L^{-1}	0.86	3.99	1.06	7.34	4.40
$LSD_{0.05}$		0.47	1.08	0.57	1.92	0.27

Table 4. Mean squares from combined analysis of variance of split plot design for three varieties evaluated under three salicylic acid treatments across 2015/2016 and 2016/2017 seasons.

S. O. V	df	Leaves					
		Total soluble phenol	Total sugars	Total FAA	N	P	K
Season (S)	1	32.50**	20.48	9.01**	34.21	0.47	9.13
Reps/(S)	4	4.39	3.02	1.64**	1.57	0.20	5.46
Varieties (A)	2	21.67**	114.3**	0.22	16.79	0.65	0.10
SA	2	0.20	4.83	0.18	0.53	0.66	11.13
Error	8	1.46	5.86	0.18	19.72	0.81	5.42
Salicylic acid (B)	2	3.66*	848.5**	13.53**	467.9**	35.36**	17.42*
S×B	2	0.38	1.21	0.10	1.43	0.20	0.11
A×B	4	8.31**	123.1**	0.36*	9.83*	1.17*	3.78*
S×A×B	4	0.16	1.03	0.18	0.44	0.34	0.13
Error	24	1.10	0.95	0.61	7.29	0.42	5.51
S. O. V	df	Grains					
		Total soluble phenol	Total sugars	Total FAA	N	P	K
Season (S)	1	0.51**	19.12**	1.24*	20.16**	0.54	6.20*
Reps/(S)	4	0.02*	1.16	0.01	2.51	0.04	4.79**
Varieties (A)	2	0.52**	10.11**	0.89*	2.59	0.10	1.59
SA	2	0.01*	0.12	0.03	0.87	0.06	0.35
Error	8	0.00	0.86	0.14	1.56	0.16	0.61
Salicylic acid (B)	2	0.59**	563.1**	2.46**	478.1**	7.93**	16.30**
S×B	2	0.02**	0.43	0.03	2.66	0.01	0.19
A×B	4	0.31**	30.31**	0.46**	2.85*	0.39*	0.17*
S×A×B	4	0.01	0.51	0.02	0.36	0.07	0.15
Error	24	0.01	2.24	0.07	1.00	0.15	0.84

*and** indicate significant at 0.05 and 0.01 levels of probability respectively.

Table 5. Means of some chemical constituents of varieties, salicylic acid treatments and their interaction across 2015/2016 and 2016/2017 seasons*

Varieties	Treatments	Leaves (mg/g)					
		Total soluble phenol	Total sugars	Total FAA	N	P	K
Gemmeiza 7		9.78	45.41	5.94	22.64	3.63	29.28
Sakha 93		8.73	48.18	6.13	22.63	3.81	29.14
Giza 168		7.59	43.15	6.14	24.31	3.43	29.24
$LSD_{0.05}$		0.93	1.86	0.32	3.41	0.69	1.79
	Control	8.30	39.78	5.41	18.86	2.22	28.33
	Salicylic acid 100mg L^{-1}	9.19	53.16	7.05	28.81	5.02	30.27
	Salicylic acid 200mg L^{-1}	8.61	43.80	5.75	21.91	3.63	29.05
$LSD_{0.05}$		0.72	0.67	0.54	1.86	0.44	1.61
Gemmeiza 7	Control	8.46	37.52	5.36	18.93	2.80	28.26
	Salicylic acid 100mg L^{-1}	9.72	51.75	6.87	28.48	4.81	30.31
	Salicylic acid 200mg L^{-1}	11.16	46.95	5.61	20.52	3.28	29.27
Sakha 93	Control	9.15	46.75	5.60	19.09	2.04	28.25
	Salicylic acid 100mg L^{-1}	9.08	52.30	6.87	27.03	5.31	31.02
	Salicylic acid 200mg L^{-1}	7.96	45.51	5.91	21.77	4.08	28.14
Giza 168	Control	7.28	35.08	5.28	18.57	1.82	28.47
	Salicylic acid 100mg L^{-1}	8.76	55.44	7.43	30.92	4.95	29.50
	Salicylic acid 200mg L^{-1}	6.72	38.93	5.72	23.44	3.52	29.74
$LSD_{0.05}$		1.25	1.16	0.93	3.21	0.75	2.78

Varieties	Treatments	Grains (mg/g)					
		Total soluble phenol	Total sugars	Total FAA	N	P	K
Gemmeiza7		1.79	31.05	2.14	20.12	2.67	5.11
Sakha 93		2.12	32.16	2.34	19.92	2.74	5.03
Giza 168		1.86	30.73	2.58	20.65	2.82	4.56
$LSD_{0.05}$		0.05	0.71	0.29	0.98	0.30	0.59
	Control	1.79	25.54	2.73	14.69	2.16	4.07
	Salicylic acid 100mg L^{-1}	2.13	36.71	2.35	24.89	3.47	5.94
	Salicylic acid 200mg L^{-1}	1.85	31.69	1.99	21.11	2.61	4.69
$LSD_{0.05}$		0.04	1.02	0.18	0.69	0.26	0.62
Gemmeiza7	Control	1.48	23.67	2.25	15.17	2.25	4.16
	Salicylic acid 100mg L^{-1}	2.07	39.06	2.18	24.04	3.23	6.04
	Salicylic acid 200mg L^{-1}	1.83	30.41	1.99	21.13	2.54	5.12
Sakha 93	Control	2.28	26.51	2.66	14.12	2.30	4.22
	Salicylic acid 100mg L^{-1}	2.17	35.69	2.33	25.30	3.53	6.13
	Salicylic acid 200mg L^{-1}	1.90	34.27	2.04	20.35	2.39	4.75
Giza 168	Control	1.60	26.44	3.27	14.79	1.94	3.82
	Salicylic acid 100mg L^{-1}	2.15	35.37	2.55	25.32	3.64	5.64
	Salicylic acid 200mg L^{-1}	1.83	30.39	1.93	21.86	2.89	4.21
$LSD_{0.05}$		0.07	1.77	0.32	1.19	0.45	1.02

Table 6. Mean squares from combined analysis of variance of split plot design for three varieties evaluated under three salicylic acid treatments across 2015/2016 and 2016/2017 seasons.

S. O. V	Df	Leaves			
		Ch a	Ch b	Carotene	Proline
Season (S)	1	0.169	0.87**	0.099	17.9**
Reps/(S)	4	0.022	0.006	0.008	0.13
Varieties (A)	2	1.22**	0.87**	0.43**	1.42**
SA	2	0.016	0.02	0	0.10
Error	8	0.049	0.015	0.02	0.03
Salicylic acid (B)	2	0.016	0.004	0.008*	8.10**
S×B	2	0.01	0.002	0.003	0.02
A×B	4	0.03*	0.05**	0.05**	0.47*
S×A×B	4	0.013	0.035*	0.001	0.01
Error	24	0.011	0.012	0.002	0.13

*and** indicate significant at 0.05 and 0.01 levels of probability respectively.

Table 7. Means of plant pigments (chlorophyll a, chlorophyll b and carotene) and proline of wheat varieties, salicylic acid treatments and their interaction across 2015/2016 and 2016/2017 seasons.

Varieties	Treatments	Leaves (mg/g)			
		Ch a	Ch b	Carotene	Proline
Gemmeiza7		1.009	0.820	0.714	6.23
Sakha 93		1.330	1.083	0.581	5.97
Giza 168		0.815	0.646	0.404	5.66
$LSD_{0.05}$		0.170	0.090	0.110	0.13
	Control	1.082	0.849	0.546	5.31
	Salicylic acid 100mg L^{-1}	1.051	0.866	0.589	6.65
	Salicylic acid 200mg L^{-1}	1.022	0.835	0.564	5.91
$LSD_{0.05}$		0.072	0.075	0.030	0.25
Gemmeiza7	Control	1.104	0.702	0.595	5.66

	Salicylic acid 100mg L^{-1}	1.003	0.853	0.826	6.63
	Salicylic acid 200mg L^{-1}	0.921	0.905	0.720	6.39
Sakha 93	Control	1.301	1.166	0.577	5.47
	Salicylic acid 100mg L^{-1}	1.306	1.061	0.569	6.78
	Salicylic acid 200mg L^{-1}	1.384	1.023	0.597	5.67
Giza 168	Control	0.841	0.679	0.466	4.79
	Salicylic acid 100mg L^{-1}	0.843	0.684	0.371	6.54
	Salicylic acid 200mg L^{-1}	0.760	0.575	0.373	5.65
$LSD_{0.05}$		0.125	0.131	0.053	0.43

Conclusions: The exogenously applied salicylic acid increased the salinity tolerance of all wheat varieties, particularly by reducing the negative effects of salts. These results showed that spraying the wheat (*Triticum aestivum* L.) plants with salicylic acid in both concentrations (100 and 200 mg L^{-1}) improved plant growth, yield components and yield.

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