Salicylic Acid Efficacy on Resistance of Garlic Plants (*Allium sativum*, L.) to Water Salinity Stress on Growth, Yield and its Quality

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ABSTRACT

This experiment was conducted and replicated during both winter seasons of 2013/2014 and 2014/2015, respectively at Soil Salinity Laboratory, Alexandria. This research was conducted to study the effects of water salinity and the application of salicylic acid (SA) on garlic growth performance, yield and its quality. Four levels of saline irrigation water treatments were used; i.e., 435 (fresh tap water as a control), 1500, 3000 and 4500 ppm. Three levels of salicylic acid treatments were foliar applied on garlic plants at the rates of 0, 150 and 300 ppm. The spraying was applied biweekly. The results indicated that the vegetative characters, yield and yield quality were; negatively, affected with increasing saline water levels from 435 up to 4500 ppm. Spraying SA on the leaves garlic plants led to decrease the negatively effects of the saline water on the tested characters. The best results were given when salicylic acid was sprayed at the concentration of 300 pm. The interaction between saline water salinity and SA concentrations did not show any significant effects on all the studied garlic characters. Also, data appeared that spraying garlic plants with SA at the concentration of 300 ppm exhibited the highest values for bulb fresh weight (g/plant), average clove weight (g), no. of cloves per bulb, bulb diameter (cm) and nick bulb diameter (cm) with any of the tested saline water levels. Spraying garlic plants with SA resulted in relatively increasing potassium concentration in comparison to sodium content and this result might be indicated that SA application improved the performance of garlic plant to the stress of irrigation with saline water. The recommendation of this research; based on the obtained results under the conditions of this study, is spraying garlic plants with SA at the concentration of 300 ppm biweekly when having to irrigate with saline water to reduce the adverse effect of saline water on the economic characteristics of the garlic crop.

Key words: garlic, *Allium sativum,* L., salicylic acid, water salinity stress and K^+/ Na^+ ratio.

INTRODUCTION

Garlic (*Allium sativum* L.) is an important vegetable crop which belongs to the genus *Allium* and the family *Liliaceae*. It has been used since ancient times for medicinal and culinary purposes all over the world. It is propagated exclusively by vegetative means (cloves), making it inefficient to multiply and difficult to improve through conventional plant breeding (AI-Safadi and Faoury, 2004). In Egypt, garlic is considered the second cultivated bulb crop after onion and it is an important source of foreign exportation.

Salinity is one of the major environmental factors limiting plant growth and productivity. It is estimated that about one-third of world's cultivated land is affected by salinity (Kaya *et al.*, 2002). Excess salt in the soil may adversely affect plant growth either through osmotic inhibition of water uptake by roots or specific ion effects. Specific ion effects may cause direct toxicity or, alternatively, the insolubility or competitive absorption of ions may affect plant nutritional balances (Greenway and Munns, 1980).

Sodium is not considered an essential element for plants but plants accumulate Na^+ at the expense of Ca^{2+} and K^+ in saline conditions. Patel *et al.* (2010) reported that salt-tolerant species maintain high concentrations of Ca^{2+} and K^+ and low concentrations of Na^+ and Cl^-. The capacity of plants to maintain a high K^+/Na^+ ratio is likely to be one of the key determinants of plant salt tolerance (Maathuis and Amtmann, 1999). Maintenance of low Na^+/ K^+ ratios in the plant tissue is critical to the plant's ability to tolerate salinity stress. Salt stress has toxic effects on plants and lead to metabolic changes, like loss of chloroplast activity, decreased photosynthetic rate and increased photorespiration rate which then leads to an increased reactive oxygen species production (Parida and Das, 2005).

The general effect of salinity is to reduce the growth rate resulting in smaller leaves, shorter stature, and sometimes fewer leaves. Roots are also reduced in length and mass but may become thinner or thicker. Maturity rate may be delayed or advanced depending on species. Depending upon the composition of the saline solution, ion toxicities or nutritional deficiencies may arise because of a predominance of a specific ion or competition effects among cations or anions (Bernstein *et al*., 1974). The initial and primary effect of salinity, especially at low to moderate concentrations, is due to its osmotic effects (Munns and Termaat, 1986 ; Jacoby, 1994). Shannon and Grieve (1999) illustrated that the osmotic effects of salinity contribute to reduced growth rate, changes in leaf color, and developmental characteristics such as root/shoot ratio and maturity rate. Ionic effects are manifested more generally in leaf and

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meristem damage or as symptoms typical of nutritional disorders. Thus, high concentrations of Na or Cl may accumulate in leaves or portions thereof and result in "scorching" or "firing" of leaves; whereas, nutritional deficiency symptoms are generally similar to those that occur in the absence of salinity.

The degree to which growth is reduced by salinity differs greatly with species and to a lesser extent with varieties within a species. Generally the growth of plant is reduced by salinity but may vary from species to species in their tolerance (Munns and Termaat, 1986). The severity of salinity response is also mediated by environmental interactions such as relative humidity, temperature, radiation and air pollution (Shannon *et al*., 1994). In a 2-year - study; Francois (1994) found that the threshold salinity of garlic was 3.9 dS m^{-1} and at 7.4 dS m^{-1} yield was reduced by 50%. All yield components (bulb weight, diameter, and no. of plants per unit area); in addition, percent solids which are a major component of bulb quality were reduced with increasing salinity. Shoot dry weight was less sensitive to salinity increases than bulb weight, but leaf tissues accumulated significantly higher Cl^-, Na^+, and Ca^{+2} concentrations than did bulbs.

Salicylic acid (SA) is an important signal molecule modulating plant response to stress (Bideshki and Arvin, 2010). SA is a phenolic derivative, distributed in a wide range of plant species. It is a natural product of phenylpropanoid metabolism and has basal levels differing widely among plant species with up to 100-fold differences recorded (Raskin, 1992). However, SA has direct involvement in plant growth, thermogenesis, flower induction and uptake of ions. It affects ethylene biosynthesis, stomatal movement and also reverses the effects of ABA on leaf abscission. Enhancement of the level of chlorophyll and carotenoid pigments, photosynthetic rate and modifying the activity of some of the important enzymes are other roles assigned to SA (Hayat *et al*., 2007 and 2008). It has been shown that SA alleviates the adverse effect of salinity by increasing growth hormones such as IAA and cytokinins, reducing the uptake and accumulation of toxic ions and maintaining the cellular membrane integrity (Borsanio and Botella, 2001). It has also been found that SA plays a role during the plant response to abiotic stresses such as drought, chilling, heavy metal toxicity, heat, and osmotic stress. Generally, SA plays a crucial role in the regulation of physiological and biochemical processes during the entire lifespan of the plant (Rivas-San Vicente and Plasencia, 2011).

The objectives of this study were as follows: 1- studying the adverse effects of increasing irrigation water salinity on growth, yield, yield components and bulb quality of garlic plants. 2- recording the advantages of the spraying salicylic acid as an antioxidant in reducing the harmful effects of water irrigation salinity on the garlic plants.

MATERIALS AND METHODS

This experiment was carried out at Soil Salinity Laboratory, Alexandria, during the winter season of 2013/2014 and replicated in 2014/2015, to assess up the efficacy of application of Salicylic acid (SA) in alleviation the adverse effects of salt stress on growth and yield of garlic crop.

Three garlic cloves of "Sids 40" cultivar were sown directly in plastic pot of 22 cm diameter and containing 8 kg of alluvial clay loam soil collected from Behira Governorate. Some of the physical and chemical properties of the soil were measured using laboratory tests suggested by the U.S. Salinity Laboratory Staff (1954) are presented in Table (1). For saturation extract of the soil, electrical conductivity (EC) was measured by using digital electrical conductivity meter and pH by electrical pH-meter (TWT, Germany). Soluble calcium and magnesium were determined by titration with versinate. Potassium and sodium were measured by using a flame photometer (Gallenkamp flame analyser, UK). Bicarbonate was determined using 0.01N HCl titration and Chloride by using titration of silver nitrate solution and potassium chromate as indicator. Sulfate was calculated by difference between soluble cations minus anions. Soil organic matter content was determined by wet combustion with $K_2Cr_2O_7$. Cation exchange capacity (CEC) of the soil and calcium carbonate equivalent were determined. More details about the soil testing procedures can also be found in (Page *et al*., 1982). The particles size distribution of the initial soil was determined using the hydrometer method (Gee and Bauder, 1986).

After germination, the plants were thinned to only two per pot. Treatments were initiated 21 days after plantation. Four levels of saline irrigation water were used having EC of 435 (tap water as a control), 1500, 3000 and 4500 ppm which was applied as necessary according to soil field capacity (27.85%). The saline water was prepared by mixing tap water (0.68 dS/m) with sea water (46 dS/m) at certain ratios. Garlic plants were then sprayed each biweekly with different concentrations of Salicylic acid (SA) [0, 150 and 300 ppm in 0.1% Tween-20 solution] at the rate of 5 ml per plant. The pH of the sprayed solutions was maintained at 6.5 to ensure the maximum penetration into the leaf tissue and to avoid leaf injury. All the plants were fertilized with the recommended doses of N, P and K.

Table 1. Initial characteristics of the soil under the investigation

Soil property	Alluvial soil	Soluble cations	($meqL^{-1}$)
pH	8.18	Ca^{++}	5.43
EC_e, dS/m	1.87	Mg^{++}	4.11
$CaCO_3$, %	2.37	Na^+	10.40
Organic matter , %	2.51	K^+	0.28
CEC, $cmol_c$ / kg	31.80		
Particles size distribution	**(%)**	**Soluble anions**	**($meqL^{-1}$)**
Sand	38.71	HCO_3^-	8.46
Silt	21.77	Cl^-	5.66
Clay	39.52	SO_4^{--}	6.04
Soil texture	Clay Loam		

The plants received mineral fertilization; 4.0 g ammonium nitrate (33.5% N), 4.0 g calcium superphosphate (15.5% P_2O_5) and potassium sulphate (48% K_2O) monthly at a rate of 2.0 g/ pot.

The pots were arranged in a randomized complete blocks design in factorial arrangement with three replications. Each replicate had 12 treatments. Each treatment / replicate consisted of 10 pots having 20 plants. Six plants per treatment in each replicate were harvested at the end of the vegetative growth (110 days after planting) to assess vegetative characters (vegetative fresh and dry weight). The remaining 14 plants per treatment in each replicate were grown for maturity to determine yield, bulb and clove weight.

The data recorded:

Vegetative characters:

The vegetative fresh weight (g) was recorded after 110 days of planting, then the samples were dried in an oven at 70 °C for 48 h for determining the dry weight (g). The plant height (cm), number of leaves per plant, and stem diameter were measured at harvesting date (150 days from planting).

Yield and yield component characters:

The yield and its component characters were recorded at harvesting after 150 days from planting. This included the fresh weight of the bulb was recorded (g / plant), the average clove weight (g); the average number of cloves per bulb, bulb diameter (cm) and neck bulb diameter (cm) were, also, determined.

Na^+ and K^+ contents:

The cloves were oven-dried at 70°C for 48 h, weighed, ground and passed through a 2 mm mesh sieve. A 0.5 g oven-dried plant material was wet digested in 10 ml 98% H_2SO_4 and 3 ml 30% H_2O_2 for 5 h essentially as described by Skoog *et al.* (2000). The Na^+ and K^+ contents were determined using a flame photometer (Gallenkamp flame analyser).

Statistical analysis:

The obtained data were subjected to ANOVA analysis followed by Duncan's multiple range test (DMRT) at $P = 0.05$ using Costat software program.

RESULTS AND DISCUSSIONS

Effect of water salinity and salicylic acid on garlic vegetative characters:

The data presented in Table (2) showed that the vegetative characters; plant height, no. of leaves per plant, leaves fresh weight and leaves dry weight traits, significantly, affected with the water salinity treatments during the first season. In the second season, plant height and leaves dry weight characters showed highly negative effects as a result of increasing water salinity level from 435 ppm up to 4500 ppm. Number of leaves per plant and leaves fresh weight did not significantly affect by increasing irrigation water salinity from 1500 ppm up to 4500 ppm. The data recorded for the tested vegetative characters appeared in general, the best results were given when water salinity level was 435 ppm and there was gradually negative effect on the studied vegetative characters accordance with increasing the water salinity level from 435 ppm up to 4500 ppm, as shown in Table (2). The data in Table (2) showed that the growing garlic plants affected with spraying salicylic acid in different concentrations; whereas, the vegetative characters significantly affected with the differences of salicylic acid concentrations during both seasons of this study. The best results were recorded when salicylic acid was sprayed on the grown plants once every biweekly at the level of 300 ppm, followed with the treatment of 150 ppm. The lowest results were conjoined with the control treatment (sprayed with water). The interaction between water salinity levels and salicylic acid concentrations appeared to be insignificant for all the studied vegetative characters during the two seasons of this study. This result means that the salinity treatments acted uniformly with spraying salicylic on the growing garlic plants regarding to all the studied vegetative characters. It could be concluded that there were decline for the vegetative growth traits with increasing the water irrigation salinity from 435 ppm up to 4500 ppm. These results are in accordance with the obtained results by Al-Zohiri (2009). The author reported that the measured growth characteristics were gradually decreased when garlic plants were irrigated with saline water up to 6000 ppm. The author added that the relative vegetative growth was unaffected up to 1500 ppm.

The reduction in the vegetative characters were explored by Munns and Termaat (1986) and Hayat *et al*. (2008). They illustrated that this reduction could be attributed to the osmotic and a nutritional effect of salinity, which interfered with the cell membrane permeability. Plaut and Reinhold (1965) added that this situation reduces the translocation of assimilates in the plant. Bernsteim and Ayars (1965) in their study on onion crop explored that salinity also decreased the diffusion pressure gradient between the medium and the plant, which affected the water availability in the plant. Al-Safadi and Faoury (2004) explored that the harmful effects of irrigation with saline water on garlic plants might be related to the injurious effect of specific ions such as Na^+ and Cl^-, which inhibited the production of chlorophyll and carotene in leaves, high sodium concentration that induced calcium and magnesium nutritional deficiencies and influenced the respiratory pathways in roots. Munns and Termatt (1986) reported that some salts such as sodium and chloride, might interfere with the metabolism in the leaves or with plant uptake and transport of essential nutrient ions.

Effect of water salinity and salicylic acid on garlic yield and its component characters:

Table (3) clearly appeared that garlic bulb fresh weight character (yield per plant) significantly affected with water salinity levels. The bulb fresh weight was gradually decreased with increasing water salinity level from 435 ppm up to 4500 ppm, during both seasons of this study (Fig.1).

Table 2. Mean performances of the vegetative characteristics of garlic crop during both seasons of 2013/2014 and 2014/2015

seasons		2013/2014				2014/2015			
Treatments		Plant height (cm)	No. of leaves / plant	Leaves fresh weight (g)	Leaves dry weight (g)	Plant height (cm)	No. of leaves / plant	Leaves fresh weight (g)	Leaves dry weight (g)
Water salinity									
435 ppm		90.77 a	13.63 a	83.55 a	13.43a	87.67a	13.33a	82.03a	13.33a
1500 ppm		63.26 b	11.52 c	73.88 b	12.48b	60.33b	11.33b	71.52b	12.19b
3000 ppm		57.52 c	12.11 bc	72.19 d	10.69c	55.11c	11.67b	70.15b	10.50c
4500 ppm		56.33 c	12.63 b	72.87 c	10.55c	49.73d	12.22b	70.04b	10.30d
Salicylic acid conc.									
zero		64.22 b	12.00 b	74.22 c	11.59b	60.92b	11.33c	72.24c	11.44c
150 ppm		65.91 b	12.55 ab	75.49 b	11.83a	62.00b	12.25b	73.15b	11.58b
300 ppm		70.78 a	12.86 a	77.15 a	11.95a	66.71a	12.83a	74.92a	11.71a
Water salinity X Salicylic acid concentration interaction									
435 ppm	Zero	87.67	13.33	80.85	13.20	84.33	12.33	80.03	13.20
	150	89.09	13.78	83.43	13.47	85.33	13.33	81.07	13.33
	300	95.56	13.78	86.38	13.63	93.00	14.33	85.00	13.47
1500 ppm	Zero	61.56	11.67	72.49	12.23	58.67	11.00	70.43	12.03
	150	62.55	11.22	73.93	12.55	59.67	11.33	71.43	12.18
	300	65.67	11.67	75.22	12.65	62.67	11.67	72.70	12.36
3000 ppm	Zero	56.89	11.56	71.23	10.57	53.33	11.00	69.40	10.42
	150	56.67	12.00	72.11	10.77	53.67	11.67	70.07	10.52
	300	59.00	12.67	73.24	10.75	58.33	12.33	71.00	10.57
4500 ppm	Zero	50.76	11.45	72.32	10.37	47.37	11.00	69.10	10.13
	150	55.33	13.22	72.51	10.53	49.33	12.67	70.03	10.30
	300	65.89	13.22	73.77	10.75	52.50	13.00	71.00	10.45
		ns	ns	ns	ns	ns	ns	ns	ns

Means having an alphabetical letter in common, within a comparable group of means, do not significantly differ, using Duncan's multiple range test procedure at p= 0.05 level of significance.

Table 3. Mean performances of the yield and its component characteristics of garlic crop during both seasons of 2013/2014 and 2014/2015

seasons		2013/2014					2014/2015				
Treatments		Bulb fresh weight (g/plant)	Average clove weight (g)	No. of cloves /bulb	Bulb diameter (cm)	Nick diameter (cm)	Bulb fresh weight (g/plant)	Average clove weight (g)	No. of cloves /bulb	Bulb diameter (cm)	Nick diameter (cm)
Water salinity levels											
435 ppm		60.33 a	4.25 a	14.22 a	5.48 a	1.95 a	56.69a	4.82a	14.11a	5.28a	1.77a
1500 ppm		49.00 b	3.67 b	13.44 a	4.77 b	1.73 b	46.59b	3.58a	13.11ab	4.58b	1.55b
3000 ppm		45.44 c	3.67 b	12.44 b	4.53 c	1.71 b	44.20b	3.55a	12.56b	4.33c	1.54b
4500 ppm		38.11 d	3.20 c	12.00 b	3.62 d	1.69 b	35.82c	3.01b	12.00b	3.41d	1.51c
Salicylic acid concentrations											
zero		45.58 b	3.69 a	12.33 b	4.47 b	1.70 b	42.93b	3.46a	12.42b	4.26b	1.52c
150 ppm		48.92 a	3.77 a	13.00ab	4.61 a	1.78 a	46.44a	3.62a	12.92ab	4.43a	1.59b
300 ppm		50.17 a	3.62 a	13.75 a	4.72 a	1.84 a	48.11a	3.54a	13.50a	4.51a	1.66a
Water salinity X Salicylic acid concentration interaction											
435 ppm	Zero	56.33	4.13	13.67	5.32	1.92	54.00	3.96	13.67	5.14	1.73
	150	61.33	4.39	14.00	5.47	1.92	56.20	4.03	14.00	5.26	1.77
	300	63.34	4.22	15.00	5.67	2.01	59.87	4.08	14.67	5.46	1.80
1500 ppm	Zero	47.67	3.80	12.67	4.67	1.70	43.1	3.52	12.33	4.47	1.52
	150	48.33	3.73	13.00	4.80	1.74	46.67	3.73	12.67	4.67	1.54
	300	51.00	3.48	14.67	4.83	1.75	50.00	3.50	14.33	4.60	1.60
3000 ppm	Zero	41.33	3.47	12.00	4.47	1.61	39.77	3.27	12.33	4.23	1.45
	150	46.33	3.55	12.00	4.55	1.73	45.30	3.73	12.33	4.33	1.54
	300	48.67	3.66	13.33	4.60	1.80	47.4	3.65	13.00	4.43	164
4500 ppm	Zero	37.00	3.36	11.00	3.43	1.56	34.83	3.08	11.33	3.20	1.40
	150	39.68	3.10	13.00	3.63	1.73	37.47	3.00	12.67	3.47	1.53
	300	39.68	3.14	12.00	3.77	1.79	35.17	2.94	12.00	3.57	1.59
		ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

Means having an alphabetical letter in common, within a comparable group of means, do not significantly differ, using Duncan's multiple range test procedure at p= 0.05 level of significance.

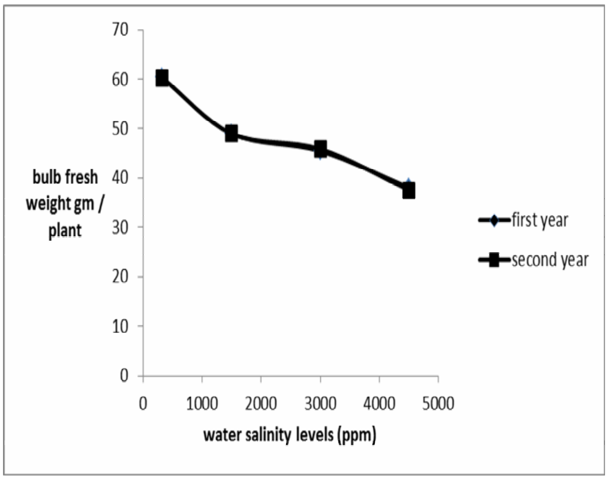

Fig 1. Effect of water salinity levels on bulb fresh weight

The only exception appeared in the second year where the data showed that there were insignificant differences between the two levels of water salinity at 1500 and 3000 ppm (Table 3). Average clove weight character was decreased with increasing water salinity level from 435 ppm up to 4500 ppm with insignificant differences between the two salinity level at 1500 and 3000 ppm (Table 3) during the first season. The data recorded in the second season showed that there were insignificant differences among the three levels of water salinity (435, 1500 and 3000 ppm) in the impact of the average clove weight trait, while this tested character was significantly decreased when water salinity level was increased up to 4500 ppm. The data of number of cloves per bulb showed, during the first year, that there were insignificant differences between the two levels of water salinity; i.e., 435 ppm and 1500 ppm. The lowest values were given when water salinity level increased up to 4500 ppm without significant differences with the treatment 3000 ppm (Table 3). The data of the second year showed that the lowest value for the number of cloves per bulb was given at water salinity level of 4500 ppm without significant differences among the two levels at 1500 and 3000 ppm (Table 3). The highest value for this tested character was given at water salinity level of 320 ppm without significant differences with the treatment 1500 ppm. The values of bulb diameter character gradually decreased with increasing water salinity levels from 435 ppm up to 4500 ppm during both years (Table 3). Nick diameter values did not significantly affect with increasing water salinity levels from 1500 ppm up to 4500 ppm during the first season, as shown in Table (3). The highest nick diameter value was recorded with the control treatment (435 ppm). On the other hand, the data of the second season appeared that nick diameter values were significantly decreased with increasing water salinity values from 435 ppm up to 4500 ppm without significant values between the two treatments 1500 ppm and 3000 ppm (Table 3).

The data of Table (3) illustrated that salicylic acid had positive effect on garlic yield and yield component traits at the concentrations of 150 and 300 ppm. The best results during both years of this study were obtained, in general, at the concentration of 300 ppm, as shown in Table (3) and Fig. (2).

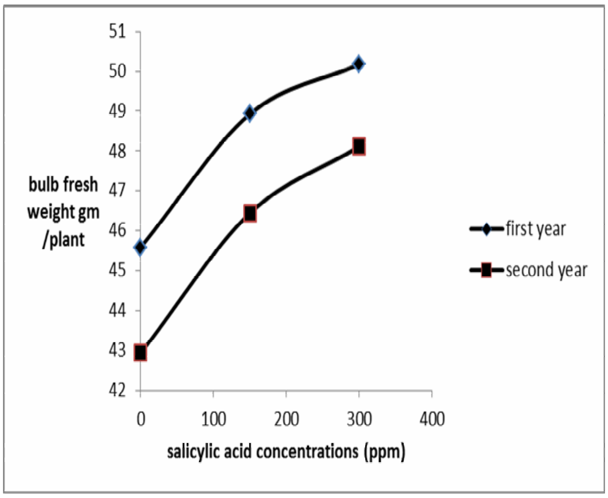

Fig 2. Effect of salicylic acid concentrations on bulb fresh weight

These results might be taken place due to the enhancing happened for the vegetative growth traits; i.e., plant height, number of leaves per plant, leaves fresh weight and leaves dry matter as a result of spraying salicylic acid once every two weeks (Table 2), which in turn reflected this increasing in yield and its component traits. The obtained result is in accordance with that obtained by Al-Zohiri (2009) on garlic crop. This author added that the increasing taken place in number of cloves per bulb did not reach the level of significant. The interaction between water salinity level and salicylic acid treatments appeared insignificant for garlic fresh weight and the component traits during the two seasons of this study (Table 3). The obtained data appeared that spraying growing garlic plants with salicylic acid at the concentration of 300 ppm exhibited the highest values for bulb fresh weight (g/plant), average clove weight (g), no. of cloves per bulb, bulb diameter (cm) and nick bulb diameter (cm) with any of the tested water saline level. The results obtained by Al-Zohiri (2009) appeared that irrigation with saline water at 1500 ppm gave the highest values for total produced yield and its components compared with 3000, 4000 and 6000 ppm during both growing seasons. There were no significant differences among the lowest salinity level used (1500 ppm) and tap water in case of number of cloves / bulb and average clove weight in the first season and total yield per plot in the second season. Al-Zohiri (2009) illustrated that the reduction happened in garlic yield and its components under saline condition may be due to reduction in vegetative growth characteristics. These results are in accordance with those results obtained by Stevens *et al*. (2006) on tomato, Arafan *et al*. (2007) on wheat and Gunes *et al*. (2007) on maize.

Effect of water salinity and salicylic acid on garlic quality characters:

Table (4) showed that the bulb dry matter percentage significantly affected with water salinity levels.

This trait was gradually decreased with increasing water salinity level from 435 ppm up to 4500 ppm, during both seasons of this research; as shown in Fig. (3). Table (4), also, showed that salicylic acid had positive effect on dry matter percentage. The best values were given with spraying salicylic acid at 300 ppm followed with 150 ppm, while non-spraying gave the lowest values during the two seasons (Fig. 4).

Table (4) indicated non-significant differences among the tested salinity levels regarding potassium content except for the treatment 1500 ppm which gave the highest values for potassium content by cloves during both seasons of this study. Sodium content in cloves was gradually increased as a result of increasing water salinity level from 435 ppm up to 4500 ppm through the two seasons (Table 4). On the other hand, sodium content was decreased with increasing the concentration of sprayed salicylic acid from zero up to 300 ppm during the first season. The data of the second season showed that there was no effect of salicylic acid treatments on the sodium content (Table 4). The interaction between water salinity levels and salicylic acid concentrations appeared to be insignificant for the quality characters and mineral contents (K^+ and Na^+) during both seasons. These results are in accordance with that obtained by Al-Zohiri (2009) and Zaki *et al.* (2009) where the authors reported that sodium content was statistically increased by increasing salinity up to the highest concentration. Al-Zohiri (2009) indicated that foliar application with salicylic acid at 100 ppm reduced the harmful effect of salts. However, application of salicylic acid was not significantly effective on Na^+ content in plant grown by the most saline water irrigation levels. The ratio between potassium and sodium contents takes attention in this research. The scored values appeared that this ratio gradually decreased by increasing water salinity level from 435 ppm up to 4500 ppm during both seasons (Table 4). As regard to the effect of salicylic acid on the ratio between potassium and sodium contents by cloves, Table (4) showed that this ratio was converged by increasing salicylic acid concentration up to 300 ppm during both seasons.

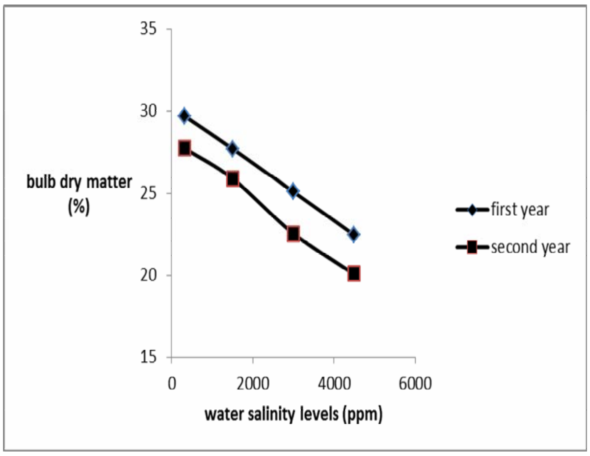

Fig 3. Effect of water salinity levels on bulb dry matter (%)

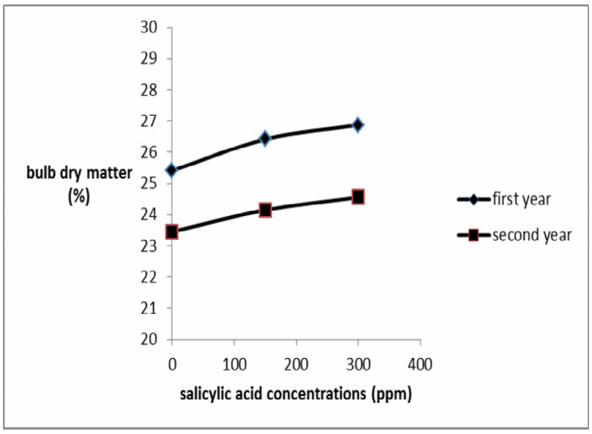

Fig 4. Effect of salicylic acid concentrations on bulb dry matter (%)

The statistical analysis illustrated that the interaction between water salinity levels x salicylic acid concentrations effect on K^+/Na^+ ratio was insignificant (Table 4).

The obtained results have been explained by many researchers who indicated that application of SA could maintain higher K^+/Na^+ ratio in garlic regardless of salinity existence by enhancing the selectivity for K^+ over Na^+ (Hussein *et al.,* 2007). With Na^+ toxicity occurring as a result of its competition with K^+ for enzyme activation and protein biosynthesis, it is likely that it is not the absolute quantity of Na^+ *per se*,

Table 4. Mean performances of the bulb dry matter and chemical constitutions of dried garlic during both seasons of 2013/2014 and 2014/2015

seasons		2013/2014				2014/2015			
Treatments		Bulb dry matter (%)	K^+ (%)	Na^+ (%)	K^+/Na^+	Bulb dry matter (%)	K^+ (%)	Na^+ (%)	K^+/Na^+
Water salinity levels									
435 ppm		29.69a	2.92b	3.07c	0.95a	27.73a	3.11b	3.10c	1.00a
1500 ppm		27.71b	4.20a	5.60b	0.75b	25.89b	4.28a	5.47b	0.78b
3000 ppm		25.08c	2.89b	6.11b	0.47c	22.53c	2.97b	6.07b	0.49c
4500 ppm		22.45d	2.96b	8.94a	0.33d	20.07d	2.98b	8.90a	0.33d
Salicylic acid concentrations									
zero		25.41b	2.60b	6.55a	0.40c	23.46c	2.82b	6.33a	0.46c
150 ppm		26.42a	2.98b	5.82ab	0.51b	24.15b	3.12b	5.84a	0.53b
300 ppm		26.87a	4.14a	5.42b	0.76a	24.56a	4.07a	5.48a	0.74a
Water salinity X Salicylic acid concentration interaction									
435 ppm	Zero	29.07	2.53	3.37	0.75	27.13	2.87	3.33	0.86
	150	29.93	2.73	2.97	0.92	27.90	2.90	3.10	0.94
	300	30.07	3.50	2.87	1.22	28.17	3.57	2.87	1.24
1500 ppm	Zero	27.23	3.20	7.00	0.46	25.37	3.50	6.73	0.52
	150	27.80	3.57	5.33	0.67	26.10	3.67	5.20	0.71
	300	28.10	5.83	4.47	1.30	26.20	5.67	4.47	1.27
3000 ppm	Zero	24.13	2.37	6.77	0.35	21.93	2.47	6.63	0.37
	150	25.20	2.63	6.07	0.43	22.53	2.80	6.10	0.46
	300	25.90	3.67	5.50	0.67	23.13	3.63	5.47	0.66
4500 ppm	Zero	21.20	2.30	9.07	0.25	19.40	2.43	8.60	0.28
	150	22.73	3.00	8.90	0.34	20.07	3.10	8.97	0.35
	300	23.43	3.57	8.67	0.41	20.73	3.40	9.13	0.37
		ns	ns	ns	ns	ns	ns	ns	ns

Means having an alphabetical letter in common, within a comparable group of means, do not significantly differ, using Duncan's multiple range test procedure at p= 0.05 level of significance.

but rather the cytosolic K^+/Na^+ ratio that determines cell metabolic competence and, ultimately, the ability of a plant to survive in saline environments (Shabala and Cuin, 2008). Different strategies commonly used by plants to improve salt stress tolerance; maintain desirable K^+/Na^+ ratio in the cytosole, regulation of K^+ uptake and prevention of Na^+ entry, efflux of Na^+ from cell or compartmentalize Na^+ into vacuole (Munis *et al*., 2010; Munns, 2002). Many researchers reported that K^+/Na^+ ratio might be considered as useful indicator for plant salinity tolerance (Khan *et al*., 2009; Munis *et al*., 2010; Saleh, 2011). One of the key features of plant salt tolerance is the ability of plant cells to maintain optimal K^+/Na^+ ratio in the cytosol (Maathuis and Amtmann, 1999; Tester and Davenport, 2003).

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الملخص العربي

فعالية حامض الساليسيليك فى مقاومة نبات الثوم لإجهاد ملوحة الماء على النمو والمحصول وجودته

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أجريت هذه الدراسة خلال الموسمين الشتويين لعـامى ٢٠١٣ -٢٠١٤/ ٢٠١٤-٢٠١٥ علـى التـوالي بمعمـل بحوث الاراضى الملحية والقلوية بالإسكندرية بهدف دراسة تأثير الرش بحامض الساليسيليك مرتين اسبوعياً بتركيزات صفر، ١٥٠ جزء فى المليون، ٣٠٠ جزء فى المليون على النمو الخضرى والمكونات الكيميائيـة وكميـة المحـصول ومكوناته لصنف الثوم سدس ٤٠ تحت ظروف الرى بميـاه البحر بتركيزات ١٥٠٠، ٣٠٠٠، ٤٥٠٠ جزء فى المليون بالاضافة الى المعاملة الكنترول (٤٣٥ جزء فى المليون).

وقد أوضحت النتائج ما يلى

١- انخفضت صفات النمو الخضرى المدروسة بشكل عـام وكذلك محصول الثوم ومكوناته خلال موسمى الزراعة بزيادة الملوحة فى مياة الرى.

٢- ادى رش نباتات الثوم بحامض الساليسيليك الى زيـادة مقاومة نباتات الثوم للتأثير الضار النـاتج عـن زيـادة ملوحة مياه الرى وقد ظهر ذلك واضـحا مـن خـلال تحسن معنوى على صفات النمو الخضرى ومحـصول الثوم ومكوناته ، وكانت أفضل النتائج بصفة عامة عند رش حامض الساليسيليك على نباتات الثوم بتركيز ٣٠٠ جزء فى المليون على مدار موسمى الزراعة.

٣- كان تأثير التداخل بين تركيزات ملوحـة ميـاه الـرى وتركيزات حامض الساليسيليك غير معنوياً علـى كـل الصفات المدروسة خلال موسمى الزراعة مما يبـرهن على ان التفاعل بين هذين العاملين كان يسير بطريقـة موحدة حيث كانت افضل النتائج للـصفات المختبـرة بصفة عامة هى الرش بحامض الساليـسيليك بتركيـز ٣٠٠ جزء فى المليون مع أى من تركيـزات الملوحـة المختبرة، يليه الرش بتركيز ١٥٠ جزء فـى المليـون، ويأتى أخيرا عدم الرش(الكنترول) الذى أعطـى أقـل النتائج.

٤- أدى الرش بحامض الساليسيليك الى تغير نسبة محتـوى الصوديوم إلى البوتاسيوم فى نبات الثـوم حيـث زادت نسبة عنصرالبوتاسيوم بالمقارنة بالزيادة فـى عنـصر الصوديوم وهذا قد يكون له تأثير إيجابى علـى تحمـل النبات للملوحة.

ويوصى البحث بناءاً على النتائج المتحصل عليها تحت ظروف هذه التجربة برش نباتات الثوم بحامض الساليسيليك بتركيز ٣٠٠ جزء فى المليـون مـرتين إسـبوعياً عنـد الاضطرارللرى بالمياه الملحية لتقليـل التـأثير الـضار لملوحة مياه الرى على الصفات الإقتصادية لمحصول الثوم.