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Alleviating the Adverse Effect of Salinity on Maize by the Ameliorative Effect of Salicylic Acid

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TWO EXPERIMENTS in cemented plots were conducted during 2012 and 2013 summer seasons at Soil Salinity and Alkalinity Lab., Alexandria, Egypt, to study the effect of three levels of irrigation water salinity (0.5, 2.75, 5.5 dSm^{-1}) and spraying leaves with salicylic acid (0, 100, 200 ppm) on growth, grain yield, and the components of maize grain yield. Split plot with four replicates was the experimental design. The results revealed that at mid-season, irrigation with saline water significantly decreased plant height (cm), fresh weight of plant (g), and dry weight of plant (g). However, number of leaves/plant, leaves area/plant (m^2) and leaf area index were not significantly affected. Also, at mid-season foliar spraying with salicylic acid significantly increased fresh weight of plant (g) and dry weight of plant (g). However, plant height (cm), number of leaves/plant, leaves area/plant (m^2), and leaf area index were not significantly affected. At end-season irrigation with saline water significantly decreased ear height (cm), ear weight (g), number of grains/row, 100 kernel weight (g), grain yield (g/plot), biological yield (g/plot), straw yield (g/plot) and harvest index while number of rows/ear had not been affected significantly. Also, at end-season foliar application of salicylic acid significantly increased all the studied parameters except for ear height (cm), number of rows/ear and harvest index. The interaction between salinity and salicylic acid was not significant for all the studied parameters except for grain yield meaning that every factor is acting independently from each other. In conclusion, salicylic acid could be used as an antioxidants or potential growth regulator to improve maize growth and grain yield under salinity conditions.

Keywords: Irrigation water, Salinity, Salicylic acid, Maize, Growth regulators.

Abiotic stress like salinity is known to reduce major physiological processes like photosynthesis. Khodary (2004) found a significant reduction in photosynthesis in maize due to the salinity of irrigation water. However, the degree of reduction caused by salt stress depends on leaf area, pigments, stomatal conductance (Dubey, 2005).

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Salinity stress lead to the formation of reactive oxygen species (ROS) such as hydrogen peroxide (H_2O_2) which in turn lead to the damage of chloroplasts. Plants produced many types of antioxidant compounds like salicylic acid to get rid of (ROS). Salt tolerance has been found to be associated with the antioxidant system (Mittler, 2002). So, it was suggested that salt tolerance may be enhanced by foliar application of antioxidant like salicylic acid. The phenolic compounds like salicylic acid are produced naturally in plants and play a role as growth regulator (Arberg, 1981). Spraying of salicylic acid may affect some physiologically major processes such as photosynthesis (El-Tayeb, 2005; Khan *et al*., 2003 and Khodary, 2004). Crop productivity is mainly affected by photosynthesis which takes place in green leaves where chlorophyll content is the molecule that photosynthesis depends on it. Shutting *et al.* (1997) found that higher grain yield produced by maize cultivars was maintained by high content of photosynthesis, also, these cultivars had higher transpiration rate, stomatal conductance and leaf area. Thus, the biological and grain yield can be improved by enhancing the rate of photosynthesis. Lopez (1989) stated that an increase in wheat grain yield was achieved by foliar application of salicylic acid. Rui *et al.* (1986) reported that closing of stomata was happened by abscisic acid which induced by abiotic stresses such as drought and salinity was reversed by salicylic acid.

The objective of the current study was to investigate the effect of salicylic acid as a protectant to ameliorate the adverse influence of irrigation with saline water on maize and consequently increase its salt tolerance.

Materials and Methods

Two experiments in cemented plots were conducted during the summer seasons of 2012 to 2013, Soil Salinity and Alkalinity Laboratory, Alexandria, Egypt, to investigate the effect of three levels of salicylic acid (0, 100, 200 ppm) and irrigation water salinity (0.5, 2.75, 5.5 dSm^{-1}) on growth, grain yield and the components of maize grain yield cultivar (Gemmeiza 12). The soil was analyzed according to Chapman & Pratt (1978) before sowing and had the following mechanical and chemical characters.

TABLE 1. Physical and chemical analyses of soil before sowing and analysis of tap water and well water.

Soil							
Sand %	**Silt %**	**Clay %**	**Soil texture**	**E.C. dSm^{-1}**	**pH**	**S.P. %**	**SAR**
74.0	10.4	15.6	Sandy loam	1.82	7.53	43.33	1.49

Tap water								
pH	E.C. dSm^{-1}	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	HCO_3^{-}	Cl^{-}	SO_4^{2-}
7.6	0.62	2.2	1.73	0.18	2.75	3.55	2.11	1.2
Well water								
7.8	5.44	1.8	2.4	3.9	48.0	2.9	32.0	13.9

The design of the experiment was split plot with four replicates where irrigation water salinity levels were located in the main plots which distributed in RCBD, while salicylic acid levels were located in the subplots, the experimental unit was a cemented plot with a dimension of 150 cm in long and 75 cm in wide with an area of 1.125 m^2. Every cemented plot contains four rows, the grains were sown in May and before sowing the cemented plots were prepared by adding calcium superphosphate 15.5% P_2O_5 at a rate of 100 kg/faddan (Hectare= 2.38 faddan) and potassium sulfate 48% K_2O at a rate of 50 kg/faddan, the nitrogen fertilizer was added at the rate of 125 kg N/faddan of ammonium sulfate 20.5% N at three doses, the first at sowing, the second at the first irrigation, and the third at the second irrigation. Irrigation with saline water was adopted after one month of sowing. Salicylic acid was initially dissolved in a few drops of Dimethyl sulfoxide and the final volume was reached by adding distilled water, then the pH was adjusted at 6-7 with NaOH (1.0N). A constant volume of solutions were sprayed twice on the leaves in the early morning when the plants had their fourth leaf and two weeks later.

At mid-season a sample of one plant from each plot was taken to measure the following parameters:

1. Plant height (cm)
2. Number of leaves/plant
3. Leaves area/plant (m^2/plant)
4. Leaf area index (m^2/m^2)
5. Plant fresh weight (g)
6. Plant dry weight (g)

At the end of the experiment the following characters were measured:

1- Ear height (cm)
2- Ear weight (g)
3- Number of rows/ear
4- Number of grains/row
5- 100 kernel weight (g)
6- Grain yield (g/plot)
7- Biological yield (g/plot)
8- Straw yield (g/plot)
9- Harvest index (%)

Since the trends in both seasons were similar, the test of homogeneity was carried out according to Prattle's test and the combined analysis of the data was applied according to Snedecor & Cochran (1982). After harvest, salinity of soil drain of 2.75 and 5.5 dSm^{-1} treatments were 3.5 to 4 and 6.5 to 8 dSm^{-1}, respectively**,** so**,** plots were subjected to leaching by adding excess amounts of tap water until EC of soil drain was under 2 dSm^{-1}.

Results and Discussions

The adverse effect of salinity at mid-season

Irrigation with saline water resulted in a significantly decrease in plant height, fresh weight of plant, dry weight of plant (Table 2) where irrigation with 2.75 and 5.5 dSm^{-1} lead to a decrease of 6 and 12 % in plant height, respectively. Also, a reductions of 7 and 15 % in fresh weight of plant were observed due to the irrigation with 2.75 and 5.5 dSm^{-1}, respectively, while in dry weight of plant the reduction were 12 and 15 %. However, saline water had no significant effect on number of leaves/plant, leaves area/plant and LAI.

TABLE 2. Effect of salinity and salicylic acid on maize growth at mid-season (combined analysis of 2012 and 2013 seasons).

Treatments	Plant height (cm)	No. of leaves/ plant	Leaves area/ Plant,m^2	LAI	Fresh weight/ plant (g)	Dry weight/ plant(g)
	Water salinity					
Control	186.3 a	14.5 a	0.74 a	5.3 a	521.2 a	86.4 a
2.75 dSm^{-1}	174.6 b	14.5 a	0.71 a	5.0 a	481.7 ab	75.9 ab
5.5 dSm^{-1}	164.1 b	14.2 a	0.71 a	5.0 a	442.1 b	73.7 b
	Salicylic acid					
Control	168.3 a	14.3 a	0.71 a	5.0 a	437.9 b	69.6 b
100 ppm	181.8 a	14.2 a	0.72 a	5.1 a	499.2 ab	82.3 a
200 ppm	174.8 a	14.7 a	0.72 a	5.2 a	507.9 a	84.2 a

These results are in harmony with those obtained by Khodary (2004), Hussein *et al.*(2007) and Singh *et al*.(2015), they recorded a significant reduction in plant height, fresh weight of plant, dry weight of plant, and leaves area/plant due to irrigation water salinity. Also, Desoky & Merwad (2015) reported similar results for wheat.

The adverse effect of salinity at end-season

Data in Table 3 revealed that saline irrigation water significantly decreased ear height, ear weight, number of grains/row, 100 kernel weight, grain yield, biological yield, straw yield, and harvest index. However, number of rows/ear was not significantly affected by salinity. When irrigating with 2.75 and 5.5 dSm^{-1}, respectively, the reduction in ear height were 9.2 and 9.6 %, the reduction in ear weight were 43 and 56 %, the decrease in number of grains/row were 32.6 and 38.4 %, the decrease in 100 kernel weight were 15 and 22.3 %, the decrease in grain yield were 36.6 and 58.1 %, the decrease in biological yield were 17.7 and 27.8 %, the decrease in straw yield were 14.6 and 22.8 % and finally the decrease in harvest index were 21.4 and 42.9 %. The results of the current study are in general accordance with those obtained by Khodary (2004) and Hussein *et al.* (2007) where they recorded a significant reduction in maize growth due to irrigation water salinity, however, they did not reach to end-season.

TABLE 3. Effect of salinity and salicylic acid on maize grain yield and the components of grain yield at end-season (combined analysis of 2012 and 2013 seasons).

	Ear height (cm)	Ear weight (g)	No. of rows/ ear	No. of grains/ row	100 kernel weight (g)	Grain yield/plot (g)	Biological yield/plot (g)	Straw yield/ plot (g)	HI
	Water salinity								
Control	117.5 a	151.4 a	11.4 a	36.5 a	26.9 a	460.8 a	3312.8 a	2851.9 a	0.14 a
2.75 dSm^{-1}	106.7 b	86.1 b	11.7 a	24.6 b	22.9 b	292.0 b	2727.2 b	2435.2 b	0.11 b
5.5 dSm^{-1}	106.2 b	66.6 c	11.2 a	22.5 b	20.9 c	192.9 c	2393.3 b	2200.4 b	0.08 c
	Salicylic acid								
Control	105.3 a	86.5 b	11.7 a	21.7 c	20.4 c	279.7 c	2462.8 b	2183.1 b	0.12 a
100 ppm	111.5 a	95.5 b	11.0 a	28.8 b	24.1 b	309.5 b	2802.8 ab	2493.3 ab	0.11 a
200 ppm	113.6 a	122.2 a	11.7 a	33.0 a	26.3 a	356.7 a	3167.8 a	2811.1 a	0.11 a

The ameliorative effect of salicylic acid at mid-season

Table 2 showed that foliar application of salicylic acid had no significant effect on plant height, number of leaves/plant, leaves area/plant, and leaf area index. However, both fresh weight and dry weight of plant were significantly increased by spraying salicylic acid where the concentrations of 100 and 200 ppm caused an increase of 14 and 16 % in fresh weight of plant, respectively and an increase of 18 and 21 % in dry weight of plant, respectively with no significant difference between the levels of 100 and 200 ppm of salicylic acid.

These results are in accordance with those obtained by Hussein *et al.* (2007) who stated that salicylic acid significantly increased dry weight of plant by 46 % when sprayed with 200 ppm compared to control treatment, also, they stated a non-significant increase in area of leaves. However, a contradiction with the same author was found regarding plant height and number of leaves where they stated a significant increase in those parameters.

Also, Khodary (20040 and Singh *et al.* (2015) recorded a significant increase in plant height, fresh weight of plant, dry weight of plant, leaves area/plant when plant were exposed to salicylic acid of 10^{-2} M and 0.5 mM, respectively compared to control treatment. Also, Desoky & Merwad (2015) stated similar results for wheat.

The ameliorative effect of salicylic acid at end-season

Table 3 illustrated that foliar application of salicylic acid had no significant effect on ear height, number of rows/ear, and harvest index. However, it had significantly increased ear weight, number of grains/row, 100 kernel weight, grain yield, biological yield, and straw yield where increasing the levels of salicylic acid from control to 100 and 200 ppm resulted in an increase in ear weight of 10 and 41 %, number of grains/row increased by 32 and 52 %, 100 kernel weight increased by 18 and 29 %, grain yield increased by 10 and 27 %, biological yield increased by 14 and 28 %, straw yield increased by 11 and 22 %, respectively.

The results of the current experiment agree with Amin *et al.* (2008) who recorded a significant increase in grain yield of wheat of 43 and 33 % when the plant were sprayed with 100 and 200 ppm of salicylic acid.

The effect of interaction between salinity and salicylic acid

Figure 1 showed that exogenous application of salicylic acid caused a significant increase in grain yield under all treatments of irrigation water salinity meaning that salicylic acid can play an important role as antioxidants to increase salinity tolerance of salt sensitive plants like maize.

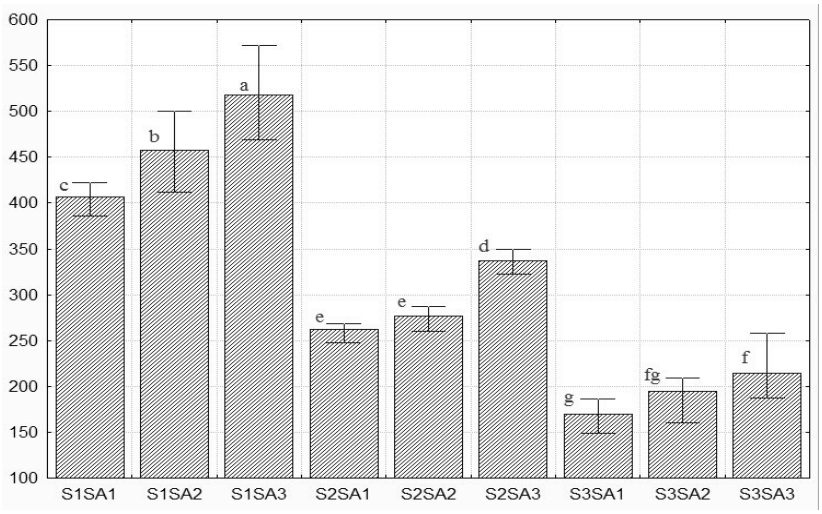

Fig. 1. Means of grain yield (g/plot) as affected by the interaction between salinity (S) and salicylic acid (SA).
$S_{1=0.5\ dSm^{-1}}$, $S_{2=2.75\ dSm^{-1}}$, $S_{3=5.5dSm^{-1}}$, $SA_{1=control}$, $SA_{2=100\ ppm}$, $SA_{3=200ppm}$

Conclusion

The ameliorative effects of salicylic acid on maize growth as well as grain yield and the components of grain yield were achieved at the level of 200 ppm which suggests that salicylic acid could be used as an antioxidants or regulator of growth to improve maize growth and grain yield under salinity conditions.

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تقليل التاثير السلبى للملوحة على الذرة بواسطة التاثير الايجابى لحمض السالسيليك

عمر مغاورى ابراهيم ، على عبد المجيد جعفر* ، بكرى احمد بكرى و محمد فاروق القرمانى****

قسم الانتاج النباتى – معهد بحوث زراعة الاراضى القاحلة – مدينة الابحاث العلمية والتطبيقات التكنولوجية ،* معمل بحوث الاراضى الملحية والقلوية – معهد بحوث الاراضى والمياه والبيئة – مركز البحوث الزراعية و **قسم بحوث المحاصيل الحقلية – المركز القومى للبحوث – القاهره – مصر.

تم اجراء تجربتان حقليتان فى احواض اسمنتية اثناء الموسمين الزراعيين الصيفيين ٢٠١٢ و ٢٠١٣ بمعمل بحوث الاراضى الملحية والقلوية بالاسكندرية لدراسة تاثير الرى بمياه مالحة (٠,٥ – ٢,٧٥ – ٥,٥ ديسيسيمنز/م) والرش الورقى بثلاث مستويات من حمض السالسيليك (٠ – ١٠٠ – ٢٠٠ جزء فى المليون) على نمو ومحصول الحبوب ومكوناته لمحصول الذرة. تم استخدام تصميم القطع المنشقة باربع مكررات. اوضحت النتائج عند منتصف الموسم ان الرى بمياه مالحة ادى الى انخفاض معنوى فى طول النبات – الوزن الطازج للنبات – الوزن الجاف للنبات. ومع ذلك لم تتاثر صفات عدد الاوراق/النبات – المساحة الورقية/النبات – دليل المساحة الورقية معنويا نتيجة الرى بمياه مالحة. فى نهاية الموسم ادى الرى بمياه مالحة الى نقص معنوى فى ارتفاع الكوز – وزن الكوز – عدد الحبوب/الصف – وزن ١٠٠ حبة – محصول الحبوب/الحوض – المحصول البيولوجى/الحوض – وزن القش/الحوض – دليل الحصاد بينما عدد الصفوف/الكوز لم تتاثر معنويا. ايضا عند نهاية الموسم ادى الرش بحمض السالسيليك الى زيادة معنوية فى كل الصفات المدروسة فيما عدا ارتفاع الكوز – عدد الصفوف/الكوز – ودليل الحصاد. كان التفاعل بين ملوحة مياه الرى والرش بحمض السالسيليك غير معنوى لكل الصفات المدروسة فيما عدا محصول الحبوب مما يعنى ان كل عامل من عوامل الدراسة مستقل عن الاخر. والخلاصة ان حمض السالسيليك يمكن ان يستخدم كمضاد اكسدة او منظم نمو لتحسين نمو محصول حبوب الذرة تحت ظروف الملوحة.