

IMPROVING TOLERANCE OF *CORTADERIA SELLOANA* PLANTS TO IRRIGATION WATER SALINITY THROUGH SALICYLIC ACID APPLICATION

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ABSTRACT: In order to improve the ability of the *Cortaderia selloana* (pampas grass) seedlings to withstand the salinity of irrigation water, a pot experiment was conducted at the Experimental Farm of Ornamental Plants and Landscape Gardening, Res. Dept., Hort. Res. Inst., ARC, Giza, Egypt during 2017/2018 and 2018/2019 seasons. Seedlings were irrigated with a saline water containing NaCl at concentrations of 0, 6000, 8000 and 10000 ppm and sprayed with salicylic acid (SA) at concentrations of 0, 50, 100 and 150 ppm. The results showed that irrigation with saline water led to a remarkable gradual decrease in all vegetative, flowering and root characteristics as well as the contents of total carbohydrates and chlorophylls with increasing salinity levels, this was accompanied with more accumulation of proline, sodium and chlorine in leaves. Regarding foliar spraying with SA, there was an increment in vegetative, floral and root characteristics due to increasing SA concentrations until reaching the maximum growth rate at a concentration of 150 ppm, and it also increased the leaf content of total carbohydrates, total chlorophylls and proline. On the other hand, SA reduced the accumulation of sodium and chlorine in the leaves. The interaction between SA and saline water treatments cleared that SA application ameliorated the adverse effects of salinity on shoots, flowers and root growth. The best results were obtained with SA at 150 ppm for plants under a salinity of 6000 ppm, where this interaction achieved the best vegetative and floral growth equal or better than control in most cases. Accordingly, it may be recommended to spray *Cortaderia selloana* with a solution of SA at a rate of 150 ppm once every three weeks to obtain good growth under salinity stress of water up to 6000 ppm conditions.

Key words: *Cortaderia selloana*, pampas grass, NaCl, saline water, salicylic acid.

INTRODUCTION

Cortaderia selloana (Schult. & Schult.f.) Asch. & Graebn. (Fam: Poaceae) is an evergreen plant native to South America and New Zealand, large, densely tufted, perennial grass, the common name is pampas grass, forming large clumps, 1.8-3.7 m high, the lower internodes is short and the upper one is very long. Foliage medium to glaucous green, medium in texture,

mostly crowded at the base of the culm; upper leaves 0.3-2.5 m long, Staminate inflorescence are branched, oblong, panicle 60-70 cm long, about 20-30 cm wide, the branches is erect or ascending and spreading, bearing spikelets nearly to the base, the inflorescence is usually white, beige or off-white. Flowering and fruiting occur from early June until frost in the native area. *Cortaderia selloana* can used in lawns, in

rock and water gardens, and around swimming pools and patios; it acts as a screen along driveways and property lines. *Cortaderia selloana* is excellent sources of cut flowers when the inflorescence has attained its maximum size and brilliance in color and the mature panicles are useful in dried arrangements (Oakes, 1990).

Salinity causes flowering delay and leaf chlorosis, a reduction in shoot and root growth; and bulb production. This was documented by El-Fouly *et al.* (2015) on *Iris tingitana* cv. Wedgewood, Oliveira *et al.* (2017) on *Catharanthus roseus*, *Allamanda cathartica*, *Ixora coccinea* and *Duranta erecta*; in addition to Bian and Pan (2018) on *Narcissus tazetta* var. *chinensis*, Hassan and Abd El-Azeim (2019) on *Polianthes tuberosa* and Hoang *et al.* (2020) on *Amaranthus tricolor*.

Under salt stress, plants produce some signaling molecules, which can reduce deleterious effects. One of these signaling compounds, salicylic acid (SA) is known to improve plant adaptations to stressful conditions (Dempsey and Klessig, 2017 and Kudla, 2018). SA as a phytohormone, affects plant growth processes, from seed germination to yield (Dempsey and Klessig, 2017), and improves a plant's tolerance against both biotic and abiotic stresses, including salinity (Tissa *et al.*, 2000 and Al-Whaibi *et al.*, 2012). Exogenous applied SA has been reported to improve salinity tolerance by enhancing membrane stability and photosynthetic rates in barley (El-Tayeb, 2005; Al-Whaibi *et al.*, 2012).

This study was conducted to evaluate the effect of irrigation water salinity on growth, plant chemical constituents and quality of *Cortaderia selloana* as a garden plants and to increase the ability of the plant to withstand high levels of saline water by applying

different levels of salicylic acid.

MATERIALS AND METHODS

A trial was performed under open field conditions at the Experimental Farm of Ornamental Plants and Landscape Gardening, Res. Dept., Hort. Res. Inst., ARC, Giza, Egypt through 2017/2018 and 2018/2019 seasons to investigate the effect of salicylic acid on the performance of *Cortaderia selloana* under saline water irrigation.

Transplants of *Cortaderia selloana* (one tiller, 90-100 cm height with 16-18 leaves) were obtained from local nursery in Al-Qanatir Al-Khayriyyah, Qalyubia Governorate.

The transplants were immediately planted on July 15th in both seasons in 30-cm diameter plastic pots filled with about 5.5 kg/pot of the loamy soil. Physical and chemical properties of the field soil are shown in Table (a).

Treatments:

The seedlings were irrigated with fresh water once every three days for 30 days till mid of August, then they were received the following treatments:

1. Saline water treatments: pure NaCl salt was used to prepare artificial saline water at concentrations of 0, 6000, 8000, and 10000 ppm. The seedlings were irrigated with the previous saline water every three days until the experiment was terminated 14 months later (on October 15th).
2. Salicylic acid was applied as foliar spraying at 0, 50, 100 and 150 ppm every 3 weeks.
3. These salicylic acid treatments were combined with those of saline water to create 16 interaction treatments.

Table a. The physical and chemical analyses of the used soil.

Soil type	Particle size distribution (%)			S.P.	E.C. (dS/m)	pH	Cations (meq/l)				Anions (meq/l)		
	Sand	Silt	Clay				Ca ⁺⁺	Mg ⁺⁺	Na ⁺	K ⁺	HCO ₃	Cl ⁻	SO ₄ ⁻
Loamy	48.0	35.5	16.5	44.0	1.36	8.28	3.5	2.5	6.63	0.65	0.5	7.5	5.28

A factorial experiment based on a complete randomized block design, replicated thrice with 4 plants per replicate was accomplished in both seasons according to Gomez and Gomez (1984).

The plants under various treatments were fertilized every two weeks with 2 g/pot of commercial chemical fertilizer “Flowering Spring” produced by Agrico International Co., containing 20 N : 20 P : 20 K + micronutrients and the other agricultural practices were undertaken whenever needed, as usually grower did.

Data recorded:

1. Vegetative growth parameters:

Plant height (cm) (average length of tillers), average number of leaves/tiller, number of tillers/plant, vegetative fresh and dry weights (average tillers fresh and dry weights), roots fresh and dry weights and foliar salt damage and plant growth. A Reference scale (visual score) from 0 to 5 according to Sun *et al.* (2015).

2. Flowering specifications:

Number of days till flowering, number of inflorescences/plant, spike length (from pot surface to end of the inflorescence (m), spike weight (g) and diameter of the inflorescence (cm) at 15 cm from the base of the inflorescence.

3. Chemical composition:

At the end of the second season, chemical composition analysis was carried out as following:

1. Total carbohydrates (% in dry matter) according to Dubois *et al.* (1956).
2. Photosynthetic pigments (total chlorophylls (a + b); mg/g f.w.): fresh leaves were collected from all plots to determine total chlorophyll content, according to the method described by Wellburn and Lichtenthaler (1984).
3. Sodium and chloride contents (mg/g d.w.) were determined using the methods of Jackson (1973). Free proline content was

colorimetrically evaluated in dry leaf samples according to Bates *et al.* (1973).

Statistical analysis:

All obtained data were statistically analyzed according to the technique of analysis of variance (ANOVA) for a complete randomized block design in a factorial experiment as published by Gomez and Gomez (1984) by using “MSTAT-C” computer software package (MSTAT Development Team, 1989). Means of treatments were compared using Duncan’s multiple range tests at 5% level of probability as described by Duncan (1955).

RESULTS

Effect of salinity levels, salicylic acid (SA) rates and their interactions on:

1. Vegetative growth parameters:

Concerning the effect of salinity of irrigation water, data in Table (1) show that treated plants were affected significantly by salinity of irrigation water. Increasing saline doses led to a gradual decrease in all characteristics of plant growth, as Plant height, number of tillers/plant and number of leaves/tiller were decreased progressively with increasing the salinity level. The least values occurred at the highest level (10000 ppm), compared to plants irrigated with non-saline water (2.66 and 2.50 m for plant height, 17.87 and 16.91 for number of tillers/plant and 35.17 and 35.63 for number of leaves/tiller, in both seasons, respectively).

As for the effect of SA application, the same data in Table (1) indicated that increasing in all data to the maximum values as a result of increasing SA dose to by the highest dose (150 ppm), the highest values were (2.22 and 2.10 m for plant height, 15.91 and 14.85 for number of tillers and 29.0 and 30.53 for number of leaves/tiller in the 1st and 2nd seasons respectively).

The interactions between salinity of irrigation water and SA treatments also exerted a marked effect, where the plants received SA at either 50, 100 or 150 ppm

Table 1. Effect of saline water, salicylic acid and their interaction on plant height, number of tillers/plant and number of leaves/tiller of *Cortaderia selloana* plants during 2017/2018 and 2018/2019 seasons.

Water salinity levels (ppm)	Salicylic acid (ppm)									
	Control (0)	50	100	150	Mean (A)	Control (0)	50	100	150	Mean (A)
	2017/2018					2018/2019				
	Plant height (m)									
Control (0)	2.59 c	2.57 c	2.73 b	2.76 a	2.66 a	2.36 d	2.40 c	2.59 b	2.65 a	2.50a
6000	2.02 g	2.17 f	2.34 e	2.52 d	2.26 b	1.92 g	2.00 f	2.18 e	2.40 c	2.13 b
8000	1.79 j	1.86 i	1.91h	1.89 h	1.86 c	1.50 k	1.60 j	1.75 h	1.75 h	1.65 c
10000	1.64 m	1.61 l	1.70 k	1.70 k	1.67 d	1.44 l	1.43 l	1.64 i	1.58 j	1.53 d
Mean (B)	2.01 d	2.05 c	2.17 b	2.22 a		1.81 d	1.86 c	2.04 b	2.10 a	
	Number of tillers/plant									
Control (0)	17.67 a	16.33 bc	18.63 a	18.83 a	17.87 a	15.33 cd	15.83 bc	17.13 b	19.33 a	16.91 a
6000	12.87 f	12.97 ef	14.43 de	17.83 a	14.53 b	13.17 e	13.43 e	14.20 de	15.37 cd	14.04 b
8000	9.43 hi	10.53 gh	11.67 fg	14.87 cd	11.63 c	8.20 g	11.63 f	10.77 f	13.83 e	11.11 c
10000	6.43 j	5.87 j	8.20 i	12.10 f	8.15 d	5.53 h	6.00 h	7.50 g	10.87 f	7.48 d
Mean (B)	11.6 c	11.42 c	13.23 b	15.91 a		10.56 d	11.73 c	12.4 b	14.85 a	
	Number of leaves/tiller									
Control (0)	35.33 ab	34.33 c	35.00 ab	36.00 a	35.17 a	35.00 bc	34.67 c	35.33 bc	37.50 a	35.63 a
6000	27.33 d	25.33 e	26.67 d	35.17 ab	28.63 b	24.00 gh	25.00 ef	26.17 d	35.61 b	27.70 b
8000	21.00 h	21.00 h	22.33 g	23.67 f	22.00 c	20.00 j	22.17 i	24.50 fg	25.33 e	23.00 c
10000	20.00 i	20.67 hi	20.67 hi	21.33 h	20.67 d	17.67 k	20.33 j	22.67 i	23.67 h	21.08 d
Mean (B)	25.92b	25.33 c	26.17 b	29.00 a		24.17 d	25.54 c	27.17 b	30.53 a	

Means having the same letter are not significantly differed at 0.05 level of probability according to Duncan's Multiple Range Test (Duncan, 1955).

and irrigated with non-saline water recorded, the utmost high values in the two seasons, with the superiority of the combined treatment of fresh water + SA at 150 ppm, as it gave the highest records (2.76 and 2.65 m for plant height, 18.83 and 19.33 for number of tillers/plant and 36.0 and 37.5 for number of leaves/tiller in the 1st and 2nd seasons, respectively). Generally, the gradual increment in salinity of irrigation water was accompanied by a progressive suppress in all measurements and this impact which was improved by the gradual increase in SA dose.

Data in Table (2) show that treating plants with high levels of salinity showed marked decrease in fresh and dry weights of shoot and root growth. The best values were (197.8 and 209.5 g for vegetative fresh weight, 58.7 and 60.9 g for vegetative dry weight, 1.353 and 1.418 kg for root fresh weight and 0.476 and 0.500 kg for root dry

fresh weight in both seasons, respectively) for the plants irrigated with tap water (control).

Concerning the effect of SA application (Table, 2) it was found that treating plants with higher levels of SA showed increases in the fresh and dry weights of shoot and root growth. Moreover, treating plants with SA at 150 ppm achieved the highest values (174.3 and 184.6 g for vegetative fresh weight, 46.4 and 52.7 g for vegetative dry weight, 1.095 and 1.146 kg for root fresh weight and 0.315 and 0.344 kg for root dry weight in the 1st and 2nd seasons, respectively).

Regarding the effect of the interaction, the recorded data show that SA at 150 ppm combined with non-saline water was the best treatment for enhancing plant fresh and dry weight for shoot and root growth in both seasons. The values were (218.3 and 231.7 for vegetative fresh weight/tiller, 68.3 and

Table 2. Effect of saline water, salicylic acid and their interaction on vegetative fresh and dry weights, root fresh and dry weights of *Cortaderia selloana* plants during 2017/2018 and 2018/2019 seasons.

Water salinity levels (ppm)	Control (0)	Salicylic acid (ppm)								Mean (A)
		50	100	150	Mean (A)	Control (0)	50	100	150	
		2017/2018				2018/2019				
Vegetative fresh weight (g)										
Control (0)	183.0 c	181.0 c	209.0 b	218.3 a	197.8 a	198.3 c	193.0 c	215.0 b	231.7 a	209.5 a
6000	163.3 d	163.3 d	167.7 d	184.0 c	169.6 b	173.0 e	180.0 d	185.0 d	197.0 c	183.8 b
8000	145.3 fg	145.0 fg	148.3 f	156.0 e	148.7 c	153.7 h	154.7 gh	160.0 fg	163.7 f	158.0 c
10000	122.0 i	122.3 I	131.0 h	138.7 g	128.5 d	118.7 l	127.3 k	139.0 j	146.0 i	132.8 d
Mean (B)	152.9 c	153.4 c	164.0 b	174.3 a		160.9 d	163.8 c	174.8 b	184.6 a	
Vegetative dry weight (g)										
Control (0)	51.6 c	51.4 c	63.5 b	68.3 a	58.7 a	57.5 d	60.0 c	69.2 b	76.9 a	60.9 a
6000	35.7 ef	35.4 ef	40.1 d	52.4 c	40.9 b	35.7 g	40.4 f	48.5 e	59.7 c	46.1 b
8000	28.0 g	27.5 g	34.4 f	36.8 e	31.7 c	32.5 h	32.3 h	34.9 g	41.2 f	35.2 c
10000	20.0 i	21.2 hi	22.0 h	26.8 g	22.5 d	21.7 j	21.8 j	25.9 i	32.9 h	25.6 d
Mean (B)	33.9 c	33.9 c	40.0 b	46.1 a		36.9 c	38.6 c	44.6 b	52.7 a	
Roots fresh weight (kg)										
Control (0)	1.259 c	1.199 d	1.391b	1.563 a	1.353 a	1.331c	1.307 d	1.433b	1.602 a	1.418 a
6000	0.941 f	0.920 f	1.117 e	1.127 e	1.026 b	0.900 g	0.907 fg	1.190 e	1.205 e	1.050 b
8000	0.751j	0.783 ij	0.823 h	0.873 g	0.808 c	0.810 i	0.807 i	0.823 i	0.923 f	0.841 c
10000	0.531 m	0.577 l	0.710 k	0.817 hi	0.659 d	0.607 k	0.600 k	0.767 j	0.853 h	0.707 d
Mean (B)	0.870 c	0.871 c	1.010 b	1.095 a		0.905 c	0.912 c	1.053 b	1.146 a	
Roots dry weight (kg)										
Control (0)	0.420 d	0.445 c	0.477 b	0.563 a	0.476 a	0.466 c	0.462 c	0.497 b	0.577 a	0.500 a
6000	0.233 h	0.257 g	0.298 f	0.314 e	0.276 b	0.216 h	0.227 g	0.311 e	0.362 d	0.279 b
8000	0.158 l	0.165 l	0.184 j	0.207 i	0.178 c	0.162 k	0.179 j	0.202 i	0.234 f	0.194 c
10000	0.106 o	0.119 n	0.147 m	0.174 k	0.137 d	0.107 m	0.122 l	0.174 j	0.202i	0.151 d
Mean (B)	0.229 d	0.247 c	0.277 b	0.315 a		0.238 d	0.247 c	0.296 b	0.344 a	

Means having the same letter are not significantly differed at 0.05 level of probability according to Duncan's Multiple Range Test (Duncan, 1955).

76.9 g for vegetative dry weight/tiller, 1.563 and 1.602 kg for root fresh weight/plant and 0.563 and 0.577 kg for dry root weight/plant in the first and second seasons, respectively. It can also be observed that treating plants with SA could improve the fresh and dry weights of vegetative and roots in plants received saline water.

Visual score:

Referring to Fig. (1), salinity levels decreased the quality of *Cortaderia* plants to the minimum score (3.8) when irrigated with saline water at 10000 ppm.

On the other hand, the visual score of plants increased by increasing the

concentration of salicylic acid which, reached to maximum score (4.6) for plants treated with SA at 150 ppm.

Regarding to the interaction between salinity and SA foliar application, it was found that spraying plants with SA increased plant quality grown under all saline concentrations, reaching to excellent visual score (5.0) in plants received saline irrigated water at 6000 ppm and SA at 150 ppm.

Although salinity stress concentrations correlated negatively with visual score, *Cortaderia* still exhibited a good visual quality. These results indicate that leaf Na⁺ and Cl⁻ concentrations are still not high

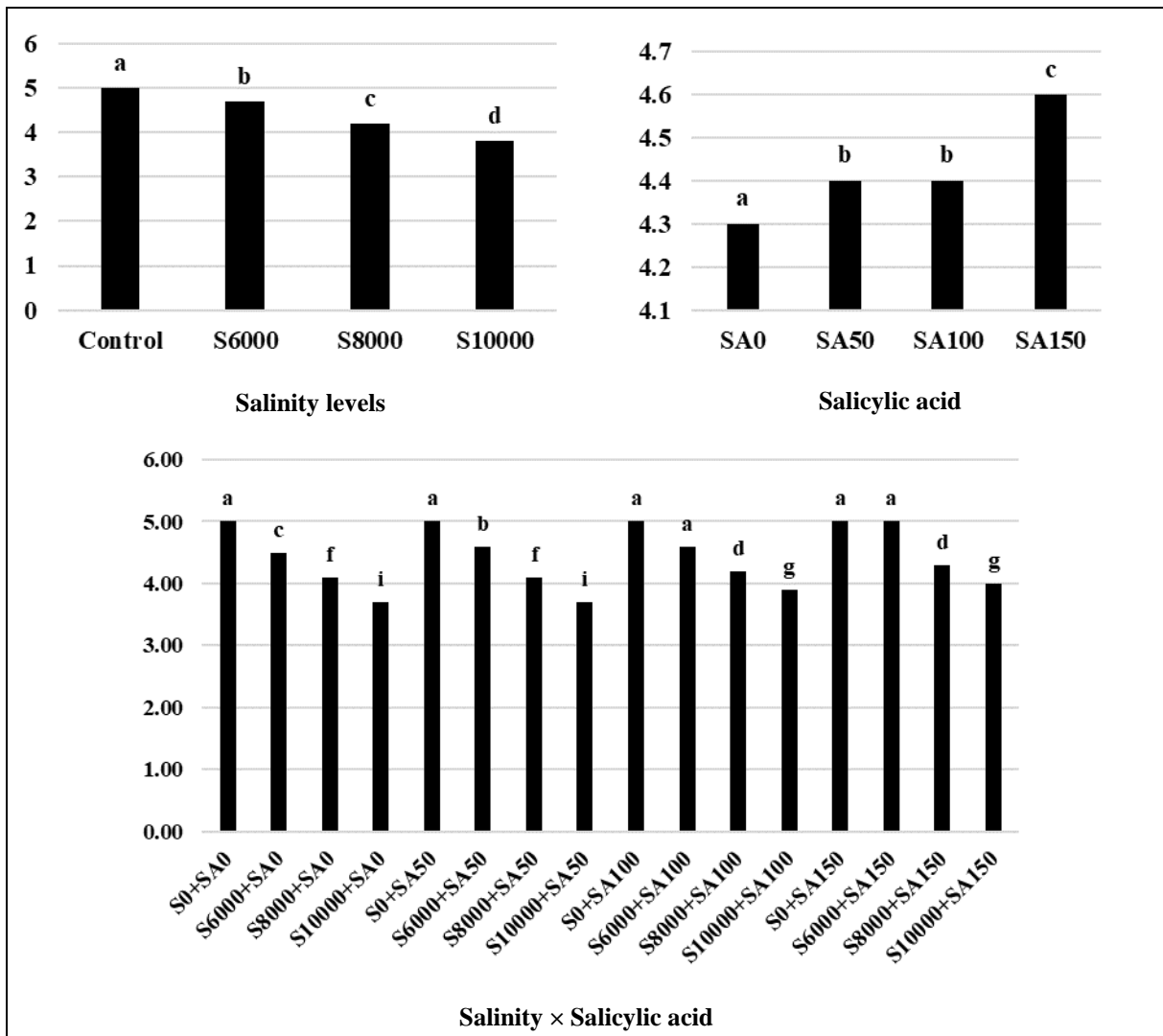


Fig. 1. Effect of saline water, salicylic acid and their interaction on visual score of *Cortaderia selloana* plants during 2018/2019 season.

S = Salinity levels / SA = Salicylic acid levels

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enough to cause salt damage to cortaderia grass.

2. Flowers parameters:

Referring to the effect of salinity, data in Table (3) demonstrated that increasing salinity level indicated early flowering. Plants treated with salinity at 10,000 ppm were the earliest in flowering, but they had the lowest number of inflorescences/plant and the smallest inflorescence diameter. The highest values of flower parameters were obtained in plants irrigated with tap water

(399.67 and 414.83 days for number of days till flowering, 9.90 and 10.79 for number of inflorescences/plant and 15.74 and 17.22 cm for inflorescence diameter in both seasons, respectively.

Concerning the effect of SA application, data in Table (3) indicated that the different rates of SA influenced significantly the abovementioned flowering traits, compared to untreated plants in both seasons. The longest period of vegetative growth (378.25 and 392.17 days) until flowering, the highest number of inflorescences (9.54 and 9.73) and

Table 3. Effect of saline water, salicylic acid and their interaction on number of days till flowering, number of inflorescences/plant and inflorescence diameter of *Cortaderia selloana* plants during 2017/2018 and 2018/2019 seasons.

Water salinity levels (ppm)	Salicylic acid (ppm)									
	Control (0)	50	100	150	Mean (A)	Control (0)	50	100	150	Mean (A)
Number of days till flowering										
Control (0)	395.00 c	390.77 c	402.67 b	410.33 a	399.67 a	415.00 b	403.33 c	416.00 b	425.00 a	414.83 a
6000	350.33gh	355.33 fg	362.00 e	373.77 d	360.33 b	353.67 i	372.00 f	381.00 e	394.33 d	375.25 b
8000	337.67 i	355.67 fg	359.00 ef	371.00 d	355.83 c	343.00 j	361.00 h	379.33 e	378.00 e	365.33 c
10000	323.00 j	322.33 j	348.33 h	358.00 ef	337.92 d	338.00 k	330.67 i	366.67 g	371.33 f	351.67 d
Mean (B)	351.50 d	356.00 c	368.00 b	378.25 a		362.25 d	366.75 c	385.75 b	392.17 a	
Number of inflorescences/plant										
Control (0)	9.10 c	9.20 c	10.30 b	11.00 a	9.90 a	10.10 cd	9.77 d	11.10 b	12.20 a	10.79 a
6000	8.47 d	8.40 d	8.40 d	9.97 b	8.81 b	8.00 f	8.30 f	9.10 e	10.43 c	8.96 b
8000	5.63 e	5.87 e	8.40 d	9.10 c	7.25 c	5.10 h	6.10 g	6.30 g	8.30 f	6.45 c
10000	4.73 f	4.67 f	6.00 e	8.10 d	5.88 d	4.00 i	4.00 i	6.17 g	8.00 f	5.54 d
Mean (B)	6.98 c	7.00 c	8.28 b	9.54 a		6.80 d	7.04 c	8.17 b	9.73 a	
Inflorescence diameter (cm)										
Control (0)	15.60 bc	15.40 c	15.60 bc	16.36 a	15.74 a	15.23 cd	17.33 b	18.00 a	18.30 a	17.22 a
6000	12.20 gh	13.10 ef	14.10 d	16.10 ab	13.87 b	14.13 f	14.60 e	14.83 de	15.33 c	14.73 b
8000	12.00 h	12.60 fg	13.10 ef	14.10 d	12.94 c	12.57 h	12.20 h	13.00 g	13.83 f	12.90 c
10000	11.23 i	11.30 i	13.30 e	14.06 d	12.48 d	10.17 j	11.47 i	12.37 h	13.13 g	11.78 d
Mean (B)	12.76 d	13.10 c	14.00 b	15.16 a		13.00 d	13.90 c	14.55 b	15.15 a	

Means having the same letter are not significantly differed at 0.05 level of probability according to Duncan's Multiple Range Test (Duncan, 1955).

the longest inflorescences diameter (15.16 and 15.15 cm), in both seasons respectively, were obtained with the application of SA at 150 ppm.

Regarding the interaction effect (Table, 3) the data show that increasing SA concentration could alleviate the adverse effect of water salinity, as the plants treated with 0 salinity and SA at 150 ppm recorded the highest values (410.33 and 425.00 days for number of days till flowering, 11.00 and 12.2 for number of inflorescences/plant and 16.36 and 18.30 cm for the inflorescence diameter in both seasons, respectively).

As for irrigation with saline water data in Table (4) show that, there was a reduction in spike length and spike weight with increasing salt concentration. The shortest spikes (1.45 and 1.64 m) and the lowest spike weight (116.2 and 117.1 g) in both seasons, respectively, were recorded in

plants that received 10000 ppm, whereas the greatest values (2.33 and 2.41 m) for spike length and (181.4 and 178.8 g) for spike weight in the 1st and 2nd seasons, respectively) were found in plants irrigated with tap water.

The same data in Table (4) showed the same trend of SA foliar application. Plants treated with increasing doses of SA showed a steady increase in both spike length and weight, the greatest values were 1.99 and 2.15 m and 160.8 and 168.1 g in both seasons, respectively.

Regarding the effect of the interaction between salinity and SA application, the highest values were 2.47 and 2.53 m for spike length and 200.8 and 206.4 g for spike weight in both seasons, respectively, for plants received non-saline water and SA at 150 ppm.

Table 4. Effect of saline water, salicylic acid and their interaction on spike length and spike weight of *Cortaderia seloana* plants during 2017/2018 and 2018/2019 seasons.

Water salinity levels (ppm)	Salicylic acid (ppm)									
	Control (0)	50	100	150	Mean (A)	Control (0)	50	100	150	Mean (A)
					2017/2018					2018/2019
Spike length (m)										
Control (0)	2.23 c	2.22 c	2.39 b	2.47 a	2.33 a	2.31 d	2.36 c	2.44 b	2.53 a	2.41 a
6000	1.61 hi	1.66 g	2.01 e	2.06 d	1.83 b	1.64 j	1.83 h	2.07 f	2.27 e	1.95 b
8000	1.40 k	1.48 j	1.61 hi	1.82 f	1.58 c	1.56 k	1.55 k	1.79 h	1.99 g	1.72 c
10000	1.24 m	1.35 l	1.59 i	1.64 gh	1.45 d	1.47 m	1.52 l	1.73 i	1.83 h	1.64 d
Mean (B)	1.62 d	1.68 c	1.9 b	1.99a		1.75 d	1.81 c	2.01 b	2.15 a	
Spike weight (g)										
Control (0)	167.9 d	173.0 c	184.0 b	200.8 a	181.4 a	162.0 e	165.7 d	181.1 b	206.4 a	178.8 a
6000	135.8 gh	138.3 g	151.3 e	165.5 d	147.8 b	141.1 hi	145.0 gh	147.7 g	171.7 c	151.3 b
8000	111.2 ki	116.7 g	132.4 hi	144.0 f	126.1 c	116.0 i	119.3 k	138.3 j	151.0 f	131.2 c
10000	107.9 m	109.9	114.1 jk	132.8 i	116.2 d	110.7 m	104.6 n	110.0 m	143.1h	117.1 d
Mean (B)	130.7 d	134.5 c	145.4 b	160.8 a		132.4 c	133.8 c	144.3 b	168.1 a	

Means having the same letter are not significantly differed at 0.05 level of probability according to Duncan's Multiple Range Test (Duncan, 1955).

3. Chemical compositions:

For salinity effect Data in Table (5) refers to decreases in the contents of total carbohydrates and chlorophylls with increasing salinity concentrations, the highest values were recorded in plants watered with non-saline water giving 31.8% D.W. for total carbohydrates and 1.44 mg/g F.W. for total chlorophylls.

Regarding SA application, the increase in SA doses caused an increment in total carbohydrates and chlorophylls, reaching the highest values (28.3 % D.W and 1.23 mg/g F.W.) in plants sprayed with SA at 150 ppm. SA applications significantly mitigated the negative effect of salinity. The highest values for total carbohydrates and chlorophylls were 35.0% D.W. and 1.64 mg/g F.W. respectively were recorded for plants irrigated with non-saline water and treated with SA at 150 ppm.

Data in Table (6) clear that increasing salt doses in irrigation water caused an increase in accumulation in the contents of proline, Na and Cl. Salinity at 10,000 ppm resulted in the highest contents (1.08 mg/g

d.w. for proline, 4.85 mg/g d.w. for Na and 2.26 mg/g d.w. for Cl).

Data in Table (6) also show that foliar application with SA increased leaves proline content but decreased Na and Cl accumulation. The highest value was (0.834 mg/g d.w. for proline) for plants received SA at 150 ppm, whenever the highest Na and Cl contents were 4.14 and 2.87 mg/g d.w., respectively for plants non-treated with SA.

Referring to the interaction between salinity and SA application data in Table (6) clear that SA increased proline content according to the increase in saline levels, reaching the maximum values (1.300 mg/g d.w.) for plants received saline water at 10000 ppm and SA at 150 ppm. On the other hand, SA application decreased Na and Cl accumulation under salt stress. The highest values were 5.15 mg/g d.w. for Na content and 3.49 mg/g d.w. Cl content, for plants treated with saline water at 10000 ppm and without SA application.

DISCUSSION

The previous results dealt with treating seedlings of *Cortaderia seloana* with

Table 5. Effect of saline water, salicylic acid and their interaction on total carbohydrate and total chlorophyll on *Cortaderia selloana* plants during 2018/2019 season.

Water salinity levels (ppm)	Salicylic acid (ppm)									
	Control (0)	50	100	150	Mean (A)	Control (0)	50	100	150	Mean (A)
	Total carbohydrate (% d.w.)					Total chlorophyll (mg/g f.w.)				
Control (0)	28.6 d	29.9 c	33.8 b	35.0 a	31.8 a	1.31 de	1.32 d	1.48 b	1.64 a	1.44 a
6000	22.3 g	22.0 h	24.0 f	26.2 e	23.6 b	1.03 f	1.03 f	1.29 e	1.36 c	1.18 b
8000	19.1 k	20.5 i	22.3 g	26.0 e	22.0 c	0.91 h	0.92 h	0.93 h	1.00 g	1.94 c
10000	19.2 jk	19.5 j	22.3 gh	26.0 e	21.7 d	0.88 ij	0.87 j	0.90 hi	0.93 h	0.90 d
Mean (B)	22.3 d	23.0 c	25.6 b	28.3 a		1.03 c	1.04 c	1.15 b	1.23 a	

Means having the same letter are not significantly differed at 0.05 level of probability according to Duncan's Multiple Range Test (Duncan, 1955).

Table 6. Effect of saline water, salicylic acid and their interaction on proline, Na and Cl contents in leaves of *Cortaderia selloana* plants during 2018/2019 season.

Water salinity levels (ppm)	Salicylic acid (ppm)				
	Control (0)	50	100	150	Mean (A)
	Proline content (mg/g d.w.)				
Control (0)	0.433 k	0.440 k	0.481 j	0.506 j	0.465 d
6000	0.581 i	0.580 i	0.614 h	0.644 g	0.605 c
8000	0.784 f	0.787 f	0.822 e	0.885 d	0.820 b
10000	0.974 c	0.982 c	1.077 b	1.300 a	1.080 a
Mean (B)	0.693 c	0.697 c	0.749 b	0.834 a	
	Na (mg /g d.w.)				
Control (0)	2.84 k	2.86 k	2.60 l	2.40 m	2.68 d
6000	3.93 h	3.88 h	3.41 i	3.30 j	3.63 c
8000	4.62 d	4.33 f	4.25 g	3.94 h	4.28 b
10000	5.15 a	4.98 b	4.73 c	4.54 e	4.85 a
Mean (B)	4.14 a	4.01 b	3.75 c	3.55 c	
	Cl (mg /g d.w.)				
Control (0)	2.09 h	1.92 i	1.80 j	1.70 j	1.88 d
6000	2.85 d	2.67 ef	2.31 g	2.25 g	2.52 c
8000	3.04 bc	2.95 c	2.75 e	2.62 f	2.84 b
10000	3.49 a	3.44 a	3.13 b	2.98 c	2.26 a
Mean (B)	2.87 a	2.74 b	2.50 c	2.39 d	

Means having the same letter are not significantly differed at 0.05 level of probability according to Duncan's Multiple Range Test (Duncan, 1955).

salicylic acid grown under salinity stress of irrigation water. Salinity had significant negative effects on growth and physiological traits. Growth parameters and chemical composition improved upon using salicylic acid, as foliar application of SA decreased the negative effects of salinity stress. These results were in accordance with the findings of a lot of other researchers demonstrated in the following discussion: Handreck and Black. (2002) declared that salinity may have

a negative effect on water absorption and biochemical processes, such as N and CO₂ assimilation and protein biosynthesis or may accumulate high concentration of some highly hydrophilic ions (e.g. Na or borate) and toxic ones such as Cl in plant tissues. Our results may be attributed to a decrease in cell size at constant cell number caused by salinity. Netondo *et al.* (2004) and Zhao *et al.* (2007) stated that salinity may inhibit chlorophyll synthesis and/or accelerate its

degradation. In this regard, Baraga *et al.* (2009) reported that salinity inhibited cell division and enlargement, consequently suppression of plant growth. Szepesi *et al.* (2005) and Karlidage *et al.* (2009) stated that the positive effect of SA could be related to an increased CO₂ assimilation and photosynthetic rate and increased mineral uptake by the stressed plant under SA treatment.

Hussain *et al.* (2010) reported that spraying *Pennisetum glaucum* with salicylic acid had increased the fresh and dry weights of shoot and root growth that decreased due to salinity. Bayat *et al.* (2012) showed that foliar applications of SA resulted in greater shoot, root and total dry weights, plant height, flower number/plant and flower diameter of calendula under salt stress. Pacheco *et al.* (2013) showed that SA application increase number of leaves/plant, leaf dry mass, leaf chlorophyll content and number of inflorescences of *Calendula officinalis*. Azimi *et al.* (2014) demonstrated that SA foliar applications at (50, 100 and 200 mg/l) on bluegrass sport mixture increased the vegetative growth and chlorophyll (a, b and total) content.

Ali and Attia (2015) on *Rosmarinus officinalis* reported that SA application increased the shoot growth under salt stress. Manzoor *et al.* (2015) found that salicylic acid significantly affected shoot and root dry matter of some cvs. of maize under salt stress. Foliar application of SA significantly increased proline and chlorophyll contents. Liu *et al.* (2016) on ten ornamental plants, stated that some plants showed difference in the degree of salinity tolerance, as *Chaenomeles speciosa* and *Diervilla rivularis* grown in EC 5 (3200 ppm) conditions had severe salt foliar damage, whereas those in EC 10 (6400) were dead. *Hibiscus syriacus* performed well in EC 5 (3200 ppm) treatment with a shoot dry weight reduction of 26%, but those grown under EC 10 (6400) had severe foliar salt damage. *Hydrangea macrophylla* was the most salt tolerant with minor foliar salt

damage. It had the highest shoot sodium Na and Cl concentrations, indicating that *H. macrophylla* plants adapted to elevated salinity by tolerating high Na and Cl levels in leaf tissue. Salachna and Piechocki (2016) remarked that shoot, root and flower parameters in plants treated with salinity decreased in a concentration dependent manner. They also showed the negative effects of salinity stress on morphological traits and flowering of plants.

Ahmed (2017) on *Hibiscus rosa-sinensis* found that all shoot and root growth traits, flower diameter and flower fresh and dry weights decreased gradually with increasing rate of salinity in irrigation water. Moreover, increasing salinity levels caused an increase in Na, Cl and proline content. Arghavani *et al.* (2017) on Kentucky bluegrass found that SA application ameliorated adverse effects of salinity on shoot and root dry weights, leaf chlorophyll content, sodium and leaf proline contents. Ma *et al.* (2017) on *Dianthus superbus* found that SA application increased fresh weight and biomass compared with non SA treatments under salt stress.

Sun and Palmer (2018) demonstrated that seven ornamental grass or grass-like species had a very strong tolerance to the salinity levels (saline solutions at an EC of 5.0 or 10.0 dS/m = 3200 or 6400 ppm) used in the 4-month experiment, although shoot and root dry weights, number of tillers and number of inflorescences were inhibited as a result of saline irrigation.

On some similar ornamental grasses, Wang *et al.* (2019) stated that *Eragrostis spectabilis*, *Miscanthus sinensis*, *Panicum virgatum* and *Schizachyrium scoparium* showed a very strong salt tolerance with an acceptable visual quality, they also reported that plant height, leaf area, number of inflorescences and tillers of four tested ornamental grasses decreased to some extent, and high Na⁺ and Cl⁻ accumulated in the leaf tissue as a result of the salt-induced water deficit. However, all ornamental grass species still had a good visual quality.

Sabzmeydani *et al.* (2020) on *Poa pratensis* stated that the increase in salinity resulted in impaired shoot and root weight, plant height, number of tillers in addition to an accumulation of Cl and Na in leaves. In contrast, SA mitigated these harmful effects of salinity. SA application increased shoot and root fresh weight and number of tillers in salinity-affected plants.

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تحسين قدره نبات الكورتادريا سيلوانا علي تحمل ملوحة ماء الري من خلال

إستخدام حمض الساليسيليك

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من أجل تحسين قدرة شتلات *Cortaderia selloana* على تحمل ملوحة مياه الري، أجريت الدراسة الحالية تحت ظروف الحقل المكشوف بمشغل قسم بحوث الزينة، معهد بحوث البساتين، مركز البحوث الزراعية، الجيزة، مصر خلال موسمي ٢٠١٧/٢٠١٨ و ٢٠١٨/٢٠١٩. زرعت الشتلات في أصص بلاستيكية قطرها ٣٠ سم مملوءة بحوالي ٥,٥ كجم/وعاء من التربة الطميية، وتم ري الشتلات بمياه مالحة تحتوي على كلوريد الصوديوم بتركيزات صفر و ٦٠٠٠ و ٨٠٠٠ و ١٠٠٠ جزء في المليون ورشها بحمض الساليسيليك مره كل ٣ اسابيع بتركيز ٠ و ٥٠ و ١٠٠ و ١٥٠ جزء في المليون و كذلك التفاعلات بينهما. أظهرت النتائج أن الري بالمياه المالحة أدى إلى إنخفاض تدريجي ملحوظ في جميع الصفات الخضرية والزهرية والجذرية ومحتوى الأوراق من الكربوهيدرات الكلية والكلوروفيل الكلي مع زيادة تركيز الملوحة. بينما أدت زيادة تركيز الأملاح في ماء الري إلى زيادة تراكم البرولين والصوديوم والكلور في الأوراق. كما أظهرت النتائج أن الرش بحمض الساليسيليك أدى إلى زيادة قيم الصفات الخضرية والزهرية والجذرية مع زيادة تركيز حمض الساليسيليك والحصول على أعلى معدل نمو عند الرش بتركيز ١٥٠ جزء في المليون، مع زيادة محتوى الأوراق من الكربوهيدرات الكلية والكلوروفيل الكلي والبرولين. من ناحية أخرى، أدى الرش بحمض الساليسيليك إلى تقليل تراكم الصوديوم والكلور في أوراق النبات. وأوضح التفاعل بين الرش بحمض الساليسيليك والمياه المالحة أن الرش بحمض الساليسيليك قد خفف من الآثار الضارة للملوحة على النمو الخضري والزهرى ونمو الجذور. كان أفضل تركيز لحمض الساليسيليك هو ١٥٠ جزء في المليون مع الري بالماء المالح بتركيز ٦٠٠٠ جزء في المليون. يمكن القول أن الرش بحمض الساليسيليك بتركيز ١٥٠ جزء في المليون قد ازال تأثير الملوحة عند ٦٠٠٠ جزء في المليون، حيث أعطى أفضل نمو خضري وزهري يساوي أو أفضل من الكنترول في معظم الصفات. طبقا لما سبق، يمكن التوصية برش شتلات *Cortaderia selloana* التي تروى بالماء المالح حتى تركيز ٦٠٠٠ جزء في المليون بمحلول حمض الساليسيليك بتركيز ١٥٠ جزء في المليون مرة كل ثلاثة أسابيع للحصول على نمو جيد تحت ظروف الإجهاد الملحي.