

IMPROVING TOLERANCE OF *CORTADERIA SELLOANA* PLANTS TO IRRIGATION WATER DEFICIENCY BY USING ASCORBIC ACID

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ABSTRACT: In order to improve the ability of the *Cortaderia selloana* seedlings to withstand the shortage 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 three irrigation levels at 100% (control), 75% and 50% of pot capacity (PC) and sprayed with ascorbic acid (AsA) at concentrations of 0, 100, 150 and 200 ppm. The results showed that the shortage of irrigation water led to a gradual decrease in all vegetative, flowering and root characteristics as well as the contents of total carbohydrates and chlorophylls, this was accompanied with more accumulation of proline in leaves. Regarding foliar spraying with ascorbic acid, there was an increment in vegetative, floral and root characteristics due to increasing AsA concentrations until reaching the maximum growth rate at a concentration of 200 ppm. There were no significant differences between the effect of AsA at 150 or 200 ppm in most cases, as it led to increase leaf carbohydrates, total chlorophyll, and proline, and it also increased the leaf content of total carbohydrates, total chlorophylls and proline. The interaction between ascorbic acid and levels of irrigation water treatments cleared that AsA application at 150 or 200 ppm ameliorated the adverse effects of lack of irrigation water on shoots, flowers and root growth. The best results of growth and flowering were obtained with AsA at 150 and 200 ppm for plants irrigated with 100% then 75% PC with no significant differences in most cases, while the interaction between irrigation level 50% and ascorbic acid at 200 ppm led to the highest accumulation of proline in leaves. In addition, the interaction between PC at 100% (control) and AsA at 200 ppm achieved the best values of total carbohydrates and total chlorophylls in leaves. Accordingly, it could be recommended to irrigate *Cortaderia selloana* seedlings grown in pots with 75% of the pot capacity once every three days, with spray plants with ascorbic acid solution at 150 ppm every three weeks intervals, as this treatment was economical to save 25% of the applied irrigation water with maintaining high quality plants.

Key words: *Cortaderia selloana*, ascorbic acid, water deficiency, vegetative growth, flowering.

INTRODUCTION

Cortaderia selloana (Schult. & Schult.f.)
Asch. & Graebn. (Fam. Poaceae) is an

evergreen grass native to South America and New Zealand, it is a large, densely tufted, perennial grasses, with common name “pampas grass”, forming large clumps, 1.8-

3.7 m high, the lower internodes are short, the upper ones are very long. Foliage is glaucous green, medium in texture, mostly crowded at the base of the culm; upper leaves 0.3-2.5 m long, Staminate inflorescence a branched, oblong, panicle 60-70 cm long, about 20-30 cm wide, the branches 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 be used in lawns, in rock and water gardens, and around swimming pools and patios; it acts as a screen along driveways and property lines, it is an excellent source of cut flowers when the inflorescence has attained its maximum size and brilliance in color; the mature panicles are useful in dried arrangements, (Oakes, 1990).

Water shortage is a major limitation for the production of agricultural crops (Razaji *et al.*, 2012). Drought is considered as a major physical parameter of environmental constraints, which determines the success or failure of plant establishment. It has various deleterious effects on plant growth and development that limits the yield potential of different crops. Water shortage may cause changes in chlorophyll content, damage to the photosynthetic apparatus and cell death (Hameed *et al.*, 2012). Drought stress can negatively affect the yield of various foods and crops, by influencing their physio-biochemical features (Chai *et al.*, 2015 and Vurukonda *et al.*, 2016). Drought stress can directly affect photosynthesis, development, nutrient uptake/accumulation and osmotic adjustment, ultimately causing a marked suppression in crop yield (Masih *et al.*, 2014 and Chai *et al.*, 2015).

Many enzymatic and non-enzymatic antioxidants accumulate to a considerable level in stressed plants to counteract ROS (Ashraf, 2009).

Adverse environmental factors such as drought and salinity stresses result in a considerable yield loss of crop plants all over

the world. These abiotic stresses elicit complex cellular responses in the plant system, resulting in the production of excessive reactive oxygen species (ROS) such as hydrogen peroxide (H_2O_2), hydroxyperoxyl (HO), superoxide (O_2^-) and singlet oxygen (1O_2) radicals. Excessive ROS generated in plant cells tends to interact with different macromolecules resulting in oxidation of proteins, membrane lipids and nucleic acids and causes cellular damage, ultimately affecting the growth and productivity of plants (Wang *et al.*, 2003). To protect themselves from adverse conditions, plants have evolved a number of cellular defense mechanisms including antioxidants such as ascorbate, as well as ROS-detoxifying enzymes such as superoxide dismutases, peroxidases and catalases (Inzé and Van Montagu, 1995 and Noctor and Foyer, 1998).

Ascorbic acid is commonly known as vitamin C and it is well known to regulate stress tolerance in plants as reported in a number of studies, e.g., canola (Shafiq *et al.*, 2017) and maize (Dolatabadian *et al.*, 2010). Among the plant antioxidants, L-ascorbate is a major antioxidant playing a vital role in the mitigation of excessive ROS activity through enzymatic as well as nonenzymatic detoxification (Mittler, 2002). It also acts as a cell signaling modulator in numerous cellular processes including cell division, cell expansion and cell wall growth (Conklin and Barth, 2004; Wolucka *et al.*, 2005 and Zhang *et al.*, 2007). Recently, it has been reported that ascorbate plays a crucial role in protection against various environmental stresses such as, drought (Hemavathi *et al.*, 2011), salinity (Zhang *et al.*, 2011; Venkatesh *et al.*, 2012), low/high temperatures (Larkindale *et al.*, 2005) and high light intensity (Talla *et al.*, 2011).

MATERIALS AND METHODS

A pot 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 ascorbic acid on *Cortaderia selloana* grown under different levels of irrigation water.

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, Egypt.

The transplants were immediately planted 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 soil are shown in Table (a).

Treatments:

The seedlings were received the following treatments from mid of August:

1. Three irrigation levels, water holding capacity of pot soil was estimated for pot as 100% = 840.0 cm³, 75% = 630.0 cm³ and 50% = 420.0 cm³. The pot capacity was calculated according to Brown (2002). The plants were irrigated once every 3 days (plants irrigated 140 times from the beginning to the end of the experiment). The amount of applied water per pot and per season are shown in Table (b).
2. Ascorbic acid (AsA) was applied as foliar sprays at 0, 100, 150 and 200 ppm every 3 weeks.
3. All ascorbic acid treatments were combined with the different irrigation levels to create 12 interaction treatments.

The seedlings were received the above treatments till the experiment was terminated 14 months later (on October, 15th).

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 drought damage on vegetative growth (visual score), a reference scale (visual score) from 0 to 5 was used 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 [15 cm from the base of the inflorescence (cm)].

Table a. 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

Table b. Amount of applied irrigation water during the experiment period.

Pot capacity (%)	Water amount/pot (cm ³)	Number of irrigations/season	Water amount/pot/season (L)
100	840	140	117.6
75	630	140	88.2
50	420	140	58.8

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.): was determined according to the method described by Wellburn and Lichtenthaler, (1984).
3. Free proline content was colorimetrically estimated 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 all treatments were compared using Duncan’s multiple range tests at 5% level of probability as described by Duncan (1955).

RESULTS

Effect of irrigation levels, ascorbic acid (AsA) rates and their interactions on:

1. Vegetative growth parameters:

Data in Table (1) show that treated plants were affected significantly. The decrease in the amount of irrigation water led to a significant decrease in all characteristics of plant growth, as plant height, number of tillers/plant and number of leaves/tiller decreased progressively with decreasing

Table 1. Effect of irrigation level, ascorbic 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 level (% pot capacity)	Control (0)	Ascorbic acid (ppm)				Mean	Ascorbic acid (ppm)				Mean (A)
		100	150	200	200		Control (0)	100	150	200	
2017/2018					2018/2019						
Plant height (m)											
Control (100)	2.36 c	2.40 b	2.57 a	2.58 a	2.48 a	2.56 c	2.66 b	2.78 a	2.79 a	2.70 a	
75	2.13 e	2.18 d	2.37 bc	2.38 bc	2.27 b	2.33 e	2.40 d	2.56 c	2.61 bc	2.48 b	
50	1.93 g	2.03 f	2.12 e	2.21 e	2.07 c	2.05 g	1.12 f	2.30 e	2.35 e	2.20 c	
Mean (B)	2.14 c	2.21 b	2.36 a	2.39 a		2.31 c	2.39 b	2.55 a	2.58 a		
Number of tillers/plant											
Control (100)	17.17 c	18.33 b	20.00 a	20.33 a	19.96 a	18.07 c	19.33 b	21.83 a	21.86 a	20.28 a	
75	14.20 e	15.83 d	19.67 a	19.67 a	17.34 b	15.33 g	17.00 d	21.33 a	21.50 a	18.79 b	
50	11.50 h	12.67 g	14.67 f	15.50 de	13.58 c	12.40 i	14.27 h	16.10 ef	16.37 e	14.78 c	
Mean (B)	14.29 c	15.61 b	18.11 a	18.50 a		15.27 c	16.87 b	19.75 a	19.91 a		
Number of leaves/tiller											
Control (100)	28.30 c	30.27 b	33.37 a	33.73 a	31.42 a	31.33 c	32.66 b	35.66 a	36.20 a	33.96 a	
75	25.27 e	26.23 d	33.30 a	33.57 a	29.59 b	25.67 e	27.67 d	35.70 a	36.16 a	31.30 b	
50	20.57 h	21.90 g	22.80 f	23.17 f	22.11 c	21.00 g	21.40 g	22.33 f	22.67 f	21.85 c	
Mean (B)	24.71 c	26.13 b	29.82 a	30.16 a		26.00 c	27.24 b	31.23 a	31.68 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).

irrigation level. The least values occurred at the lowest level (50%) of pot capacity (PC), compared to plants irrigated with control (100% PC which recorded the highest values (2.48 and 2.70 m for plant height, 19.96 and 20.28 for number of tillers/plant and 31.42 and 33.93 for number of leaves/tiller, in both seasons, respectively).

Concerning the effect of ascorbic acid (AsA), the same data in Table (1) indicated that there were increases in all data by increasing AsA doses. It is noticed that there were no significant differences between AsA at 150 and 200 ppm, the maximum values were a result of increasing AsA dose to by the highest dose (200 ppm), where the values were 2.39 and 2.58 m for plant height, 18.50 and 19.91 for number of tiller and 30.16 and 31.68 for number of leaves/tiller in the 1st and 2nd seasons, respectively.

The interactions between PC and AsA treatments also exerted a marked effect on studied treats as shown in Table (1), where the plants received AS at either 150 or 200 ppm and irrigated with 100% (control) or 75% PC gave the highest significant values as compared with the other treatments, in the two seasons, with the superiority of the combined treatment of 100% PC + AsA at 200 ppm, as it gave the highest records (2.58 and 2.79 m for plant height, 20.33 and 21.86 for number of tillers/plant and 33.73 and 36.20 for number of leaves/plant in the 1st and 2nd seasons, respectively). In all measurements, generally, the gradual decrement in irrigation water PC was accompanied by a progressive suppress in growth rate, which was improved by the gradual increase in AsA dose.

Data averaged in Table (2) show that increasing irrigation water amount to 100% PC, improved vegetative and root fresh and dry weights compared to 75% and 50% PC, reaching to the highest values (180.75 and 195.25 g for vegetative fresh weight, 61.71 and 60.62 g for vegetative dry weight, 1.442 and 1.388 kg for root fresh weight and 0.478 and 0.446 kg for root dry weight, in both seasons, respectively).

Concerning the effect of AsA application, (Table, 2) it was found that treating plants with higher levels of AsA showed an increase in the fresh and dry weights of shoot and root growth, as treating plants with AsA at 200 ppm achieved the highest values (181.67 and 185.11 g for vegetative fresh weight, 62.36 and 61.70 g for vegetative dry weight, 1.463 and 1.390 kg for root fresh weight and 0.423 and 0.393 kg for root dry weight in the 1st and 2nd seasons, respectively.

Regarding effect of the interaction, data in Table (2) show that AsA at 150 and 200 ppm combined with water regime at 100% or 75% PC were the best treatments with no significant differences effects between them on vegetative and roots fresh weights, meanwhile the interaction 100% PC and AsA at 200 ppm was the best significant affection on vegetative and roots dry weights compared with the other interactions. It gave (200.33 and 206.33 g for vegetative fresh weight/tiller, 71.60 and 68.53 g for vegetative dry weight/tiller, 1.527 and 1.462 kg for root fresh weight/plant and 0.512 and 0.475 kg for root dry weight/plant in the first and second seasons, respectively). It can also observed that treating plants with AsA improved fresh and dry weights of vegetative growth and roots for plants grown under limited water amounts.

2. Visual score:

Fig. 1 show that low irrigation level (50% PC) recorded the lowest value of visual score of *Cortaderia* plants (4.4 points), the outward appearance is still very well, despite the lack of vegetative and flowering characteristics due to the reduction of irrigation water.

On the other hand, the visual score of plants increased by increasing the concentration of ascorbic acid reached to maximum score (4.9 points) for plants treated with AsA at 200 ppm.

Referring to the interaction, foliar spraying with AsA increased plant quality under all irrigation levels reaching to

Table 2. Effect of irrigation level, ascorbic acid and their interaction on vegetative fresh weight, vegetative dry weight, root fresh weight and root dry weight of *Cortaderia selloana* plants during 2017/2018 and 2018/2019 seasons.

Water level (% pot capacity)	Ascorbic acid (ppm)									
	Control (0)	100	150	200	Mean	Control (0)	100	150	200	Mean (A)
Vegetative fresh weight (g)/tiller										
Control (100)	155.33 c	168.67 b	198.67 a	200.33 a	180.75 a	183.00 c	188.33 b	203.33 a	206.33 a	195.25 a
75	145.00 d	156.33 c	197.00 a	198.00 a	174.08 b	163.00 e	170.00 d	202.33 a	204.67 a	185.00 b
50	132.00 e	133.67 e	145.33 d	146.67 d	139.41 c	143.67 f	141.67 f	144.67 f	144.33 f	143.58 c
Mean (B)	144.11 b	152.89 b	180.33 a	181.67 a		164.89 b	165.00 b	183.44 a	185.11 a	
Vegetative dry weight (g)/tiller										
Control (100)	49.68 e	55.22 c	70.34 a	71.60 a	61.71 a	51.06 e	56.38 c	66.51 b	68.53 a	60.62 a
75	45.81 f	53.73 d	68.29 b	70.52 a	59.59 b	46.37 h	54.85 d	66.92 b	67.27 b	58.85 b
50	38.51 i	40.94 h	44.00 g	44.95 fg	42.10 c	41.22 j	43.81 i	47.76 g	49.27 f	45.52 c
Mean (B)	44.67 d	49.97 c	60.88 b	62.36 a		46.22 d	51.68 c	60.40 b	61.70 a	
Roots fresh weight (kg)/plant										
Control (100)	1.336 c	1.396 b	1.511 a	1.527 a	1.442 a	1.268 c	1.361 b	1.460 a	1.462 a	1.388 a
75	1.221 f	1.232 e	1.510 a	1.519 a	1.370 b	1.184 f	1.203 e	1.457 a	1.460 a	1.326 b
50	1.107 g	1.131 e	1.261 d	1.345 c	1.211 c	1.050 h	1.105 g	1.242 d	1.246 d	1.162 c
Mean (B)	1.222 d	2.253 c	1.428 b	1.463 a		1.169 c	1.223 b	1.386 a	1.390 a	
Roots dry weight (kg)/plant										
Control (100)	0.444 d	0.451 c	0.504 b	0.512 a	0.478 a	0.417 d	0.427 c	0.465 b	0.475 a	0.446 a
75	0.357 h	0.382 g	0.415 f	0.423 e	0.395 b	0.325 h	0.343 g	0.393 f	0.400 e	0.363 b
50	0.236 l	0.283 k	0.328 j	0.335 i	0.295 c	0.198 l	0.243 k	0.297 j	0.305 I	0.261 c
Mean (B)	0.346 d	0.372 c	0.416 b	0.423 a		0.313 d	0.338 c	0.385 b	0.393 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).

excellent visual score (5.0 points) for plants received 100% + AsA at all concentrations and plants that received 75% PC + AsA at 100, 150 and 200 ppm (Fig., 1).

3. Flowers parameters:

Regarding the effect of irrigation levels, data in Table (3) showed that the decrease of irrigation levels led to early flowering, as plants irrigated at 50% PC were the earliest in flowering, but this had the lowest number of inflorescences/plant and the smallest inflorescence diameter. The highest values were obtained in plants irrigated with control (100% PC), recording (428.17 and 422.33

days till flowering, 11.95 and 12.74 for number of inflorescences/plant and 15.49 and 15.92 cm for inflorescence diameter in both seasons, respectively.

In addition, data in Table (3) show that the AsA application to *Cortaderia* plants influenced significantly the abovementioned traits, compared to untreated plants, in both seasons. There was a strong convergence between AsA at 150 and 200 ppm in most cases. The longest period of vegetative growth (428.44 and 423.89 days) until flowering, the highest number of inflorescences/plant (11.44 and 12.22) and the largest inflorescences diameter (15.66

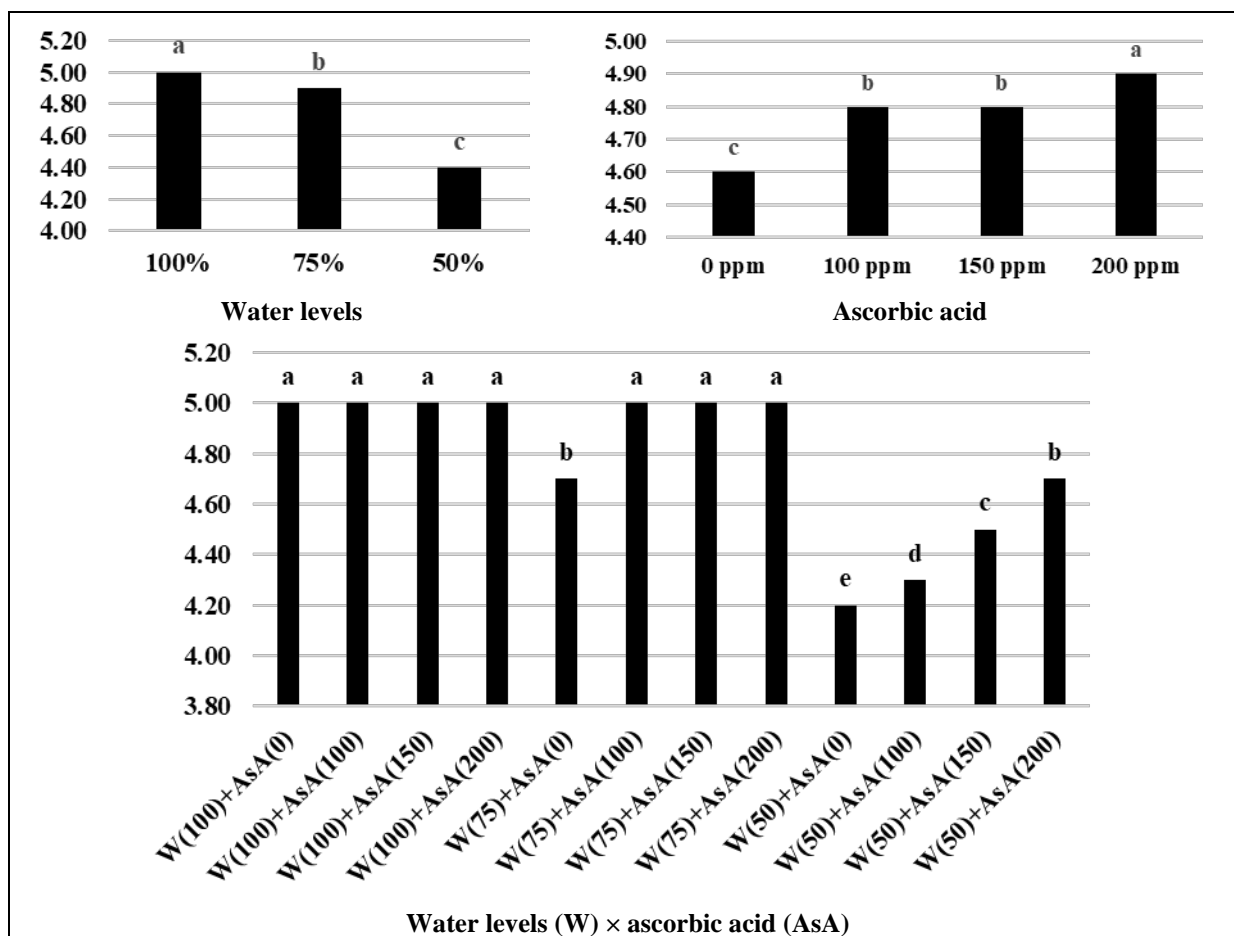


Fig. 1. Effect of water levels, ascorbic acid and their interaction on visual score of *Cortaderia selloana* plants during 2018/2019 season.

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 15.92 cm), in both seasons respectively, were obtained with the application of AsA at 200 ppm.

Regarding the interaction effect, data in Table (3) show that increasing AsA concentration could alleviate the adverse effect of water shortage. The plants watered with 100% PC (control) and AsA at 200 ppm recorded the highest values (436.00 and 430.00 days for number of days till flowering, 13.33 and 14.23 for number of inflorescences/plant and 16.67 and 16.57 cm for the inflorescence diameter in both seasons, respectively).

The data also indicated that there were no significant differences between spraying AsA at concentrations 150 or 200 ppm in plants watered at the level 100% PC or 75% PC, in most cases, and there was superiority

for interaction irrigation with 75% PC and AsA at 150 ppm compared with plants treated with irrigation level control (100% PC) without the application of AsA.

Concerning the effect of irrigation levels on spike length and weight (Table, 4) the data show that, there was a reduction in spike length and spike weight with a decrease of the amount of irrigation water. The greatest values were 2.38 and 2.29 m for spike length and 167.8 and 166.0 g for spike weight in the 1st and 2nd seasons, respectively) for plants irrigated with 100% PC (control).

In addition, data in Table (4) showed a steady increase in spike length and weight with increasing doses of AsA with no significant difference between AsA at 150 and 200 ppm doses on spike length.

Table 3. Effect of irrigation level, ascorbic 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 level (% pot capacity)	Ascorbic acid (ppm)									
	Control (0)	100	150	200	Mean	Control (0)	100	150	200	Mean (A)
Number of days till flowering										
Control (100)	421.33 c	422.67 c	432.67 a	436.00 a	428.17 a	416.00 c	417.00 c	426.33 b	430.00 a	422.33 a
75	400.00 d	401.33 d	427.00 b	427.00 b	413.83 b	393.67 f	396.33 e	425.00 b	430.00 a	411.25 b
50	373.77 e	377.00 e	421.33 c	422.33 c	398.61 c	363.67 h	366.00 g	411.00 d	411.67 d	388.08 c
Mean (B)	398.37 b	400.33 b	427.00 a	428.44 a		391.11 d	393.11 c	420.77 b	423.89 a	
Number of inflorescences/plant										
Control (100)	10.10 cd	11.13 b	13.23 a	13.33 a	11.95 a	10.63 c	11.73 b	14.17 a	14.23 a	12.74 a
75	8.50 e	9.22 d	13.00 a	13.00 a	10.93 b	9.00 e	9.60 d	14.00 a	14.00 a	11.68 b
50	7.17 f	7.30 f	8.00 e	8.00 e	7.62 c	7.00 g	7.00 g	8.23 f	8.30 f	7.63 c
Mean (B)	8.59 c	9.22 b	11.41 a	11.44 a		8.94 c	9.44 b	12.13 a	12.22 a	
Inflorescence diameter (cm)										
Control (100)	14.27 d	14.68 c	16.33 b	16.67 a	15.49 a	15.23 bc	15.33 b	16.53 a	16.57 a	15.92 a
75	13.23 e	14.07 d	16.20 b	16.30 b	15.95 b	14.13 d	14.60 d	15.70 b	16.50 a	15.23 b
50	12.50 f	13.20 e	14.00 d	14.00 d	13.43 c	12.80 f	13.53 e	14.47 d	14.70 cd	13.88 c
Mean (B)	13.33 c	13.98 b	15.51 a	15.66 a		14.06 d	14.49 c	15.57 b	15.92 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 4. Effect of irrigation level, ascorbic acid and their interaction on spike length and spike weight of *Cortaderia selloana* plants during 2017/2018 and 2018/2019 seasons.

Water level (% pot capacity)	Ascorbic acid (ppm)									
	Control (0)	100	150	200	Mean	Control (0)	100	150	200	Mean (A)
Spike length (m)										
Control (100)	2.22 c	2.29 b	2.50 a	2.52 a	2.38 a	2.14 c	2.20 b	2.40 a	2.43 a	2.29 a
75	2.07 f	2.18 d	2.47 a	2.51 a	2.31 b	2.01 e	2.11 d	2.42 a	2.42 a	2.24 b
50	1.67 i	1.78 h	2.00 g	2.02 g	1.87 c	1.61 h	1.72 g	1.93 f	1.94 f	1.80 c
Mean (B)	1.98 c	2.08 b	2.32 a	2.35 a		1.92 c	2.01 b	2.25 a	2.26 a	
Spike weight (g)										
Control (100)	160.0 d	166.0 c	187.0 b	194.3 a	167.8 a	150.0 d	155.0 c	176.3 b	182.7 a	166.0 a
75	137.0 g	141.7 f	151.7 e	162.0 d	148.1 b	131.0 g	132.3 g	141.7 ef	156.0 c	140.0 b
50	123.0 i	128.7 h	131.0 h	142.0 f	131.1 c	122.0 h	129.0 g	140.0 f	144.3 e	133.9 c
Mean (B)	140.0 d	145.4 c	156.6 b	166.1 a		134.0 a	139.0 c	152.7 b	161.0 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 greatest values were 2.35 and 2.26 m for spike length and 166.1 and 161.0 g for spike weight in both seasons, respectively.

Regarding the effect of the interaction between irrigation levels and AsA application (Table, 4), data showed that applying AsA at 150 or 200 ppm recorded similar significant results in plants watered with either control (100% PC) or 75% PC. The highest values were 2.52 and 2.43 m for spike length and 194.3 and 182.7 g for spike weight in both seasons, respectively, for plants watered with 100% PC (control) and treated with AsA at 200 ppm.

3. Chemical compositions:

For irrigation levels effect, data in Table (5) refers to a decrease in total carbohydrates and chlorophyll contents by decreasing water amount, the highest values of these component were recorded when plants were irrigated at 100% PC giving 29.75% D.W. for total carbohydrates and 1.51 mg/g F.W. for total chlorophylls).

Regarding the effect of ascorbic acid application, the increase in AsA doses caused an increment in total carbohydrates and chlorophylls contents, reaching the highest values (28.06 % D.W. for total carbohydrates and 1.57 mg/g F.W. for total chlorophylls) in plants sprayed with AsA at 200 ppm.

Data in Table (5) also show that AsA applications significantly reduce the negative effect of water deficit. The highest values for total carbohydrates and chlorophylls were 34.25% and 1.73 mg/g, respectively for plants irrigated with 100% PC and sprayed with AsA at 200 ppm.

Data in Fig. (2) clear that growing plants under water shortage markedly increased the accumulation in proline; and irrigation level at 50% PC resulted in the highest content (0.83 mg/g D.W.).

Data in Fig. (2) also show that foliar application with AsA increased leaves proline content. The highest value was 0.78 mg/g D.W. for plants received AsA at 200 ppm.

Referring to the interaction between irrigation levels and AsA application data in Fig. (2) clear that AsA increased proline content according to the decrease in irrigation levels, reaching the maximum value (0.92 mg/g D.W.) for plants watered with 50% PC and treated with AsA at 200 ppm.

DISCUSSION

The previous results dealt with treating seedlings of *Cortaderia selloana* with ascorbic acid under drought stress. Drought stress had significant negative effects on growth and physiological traits.

Table 5. Effect of irrigation level, ascorbic acid and their interaction on total carbohydrate and total chlorophylls of *Cortaderia selloana* plants during 2018/2019 seasons.

Water level (% pot capacity)	Ascorbic acid (ppm)					Ascorbic acid (ppm)				
	Control (0)	100	150	200	Mean	Control (0)	100	150	200	Mean (A)
	Total carbohydrate (% D.W.)					Total chlorophylls (mg/g F.W.)				
Control (100)	25.40 d	27.60 c	31.74 b	34.25 a	29.75 a	1.33 e	1.43 d	1.54 c	1.73 a	1.51 a
75	21.57 g	23.57 e	25.37 d	27.78 c	24.57 b	1.31 e	1.33 e	1.51 c	1.65 b	1.45 b
50	18.06 i	20.30 h	21.80 fg	22.13 f	20.71 c	1.08 h	1.14 g	1.24 f	1.34 e	1.19 c
Mean (B)	21.86 d	23.82 c	26.30 b	28.06 a		1.24 d	1.30 c	1.43 b	1.57 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).

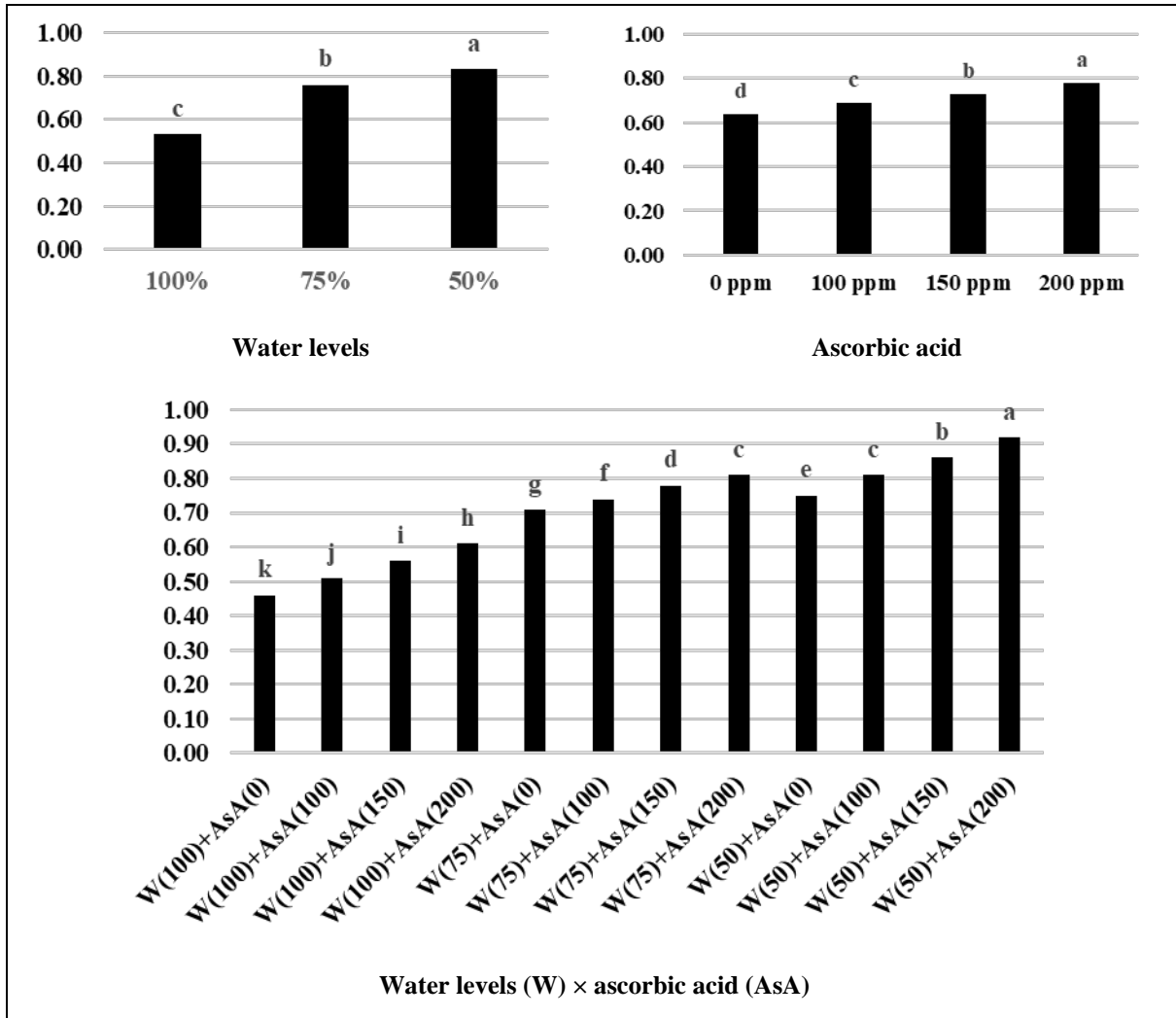


Fig. 2. Effect of water levels, ascorbic acid and their interaction on leaves proline content (mg/g D.W.) of *Cortaderia selloana* plants during 2018/2019 season.

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

Growth parameters and chemical composition improved upon using ascorbic acid, as foliar application of AsA decreased the negative effects of drought.

These results were in accordance with findings of many other researchers demonstrated in the following discussion:

Observed decreases in biomass with decreased irrigation quantities are well documented. Guenni *et al.* (2002) recorded a reduction in dry weight for *Brachiaria brizantha* when subjected to moderate drought stress. Alvarez *et al.* (2007) stated that plant mass, canopy size, root biomass and shoot-to-root ratios increased with increasing irrigation volumes for purple love

grass (*Eragrostis spectabilis*) and *Miscanthus sinensis*. Zhi *et al.* (2007) reported that the proline content increased in zebra grass (*Miscanthus sinensis*), fountain grass (*Pennisetum alopecuroides*) and pampas grass (*Cortaderia selloana*) under drought stress.

These results were corresponded with those findings by Amin *et al.* (2009) and Abdalla (2011), which reported that plant growth reduced by water deficit stress through affecting various physiological and biochemical processes, such as photosynthesis, translocation, nutrient metabolism and growth promoters. Riaz *et al.* (2010) indicated that water deficit

conditions had a significant inhibitory effect on shoot length, fresh and dry weights of three Bermuda grass cultivars. Water deficiency also reduced the total chlorophylls, significantly in all cultivars and it was most pronounced at 55% F.C.

Furthermore, AsA affects nutritional cycle's activity in higher plants and plays an important role in the electron transport system (Liu *et al.*, 1997). It is also important as a cofactor for a large number of key enzymes in plants (Arrigoni and De Tullio, 2000). Exogenous application of ascorbic acid increased reproduction of other plant species as reported by Balbaa (2002) on *Tagetes minuta* L., Youssef and Talaat (2003) on rosemary and Abd El-Aziz *et al.*, (2007) on syngonium. Abd El-Aziz and Taha (2009) on gladiolus reported that the highest increase in plant height, number of leaves, fresh and dry weights of leaves were found in plants treated with 100 ppm ascorbic acid compared with control. Mazher *et al.* (2011) demonstrated that foliar application of ascorbic acid on *Codiaeum variegatum* at (100 and 200 ppm) gradually increased all growth parameters (plant height, number of branches, number of leaves, stem diameter, root length as well as fresh and dry weights of all plant organs) and as well as the content of the total carbohydrates. Sardoei *et al.* (2014) found that spraying *Gazania rigens* with ascorbic acid had a significant effect on increasing total of flowers/plant and prolonging duration of flowering period.

The role of ascorbate in proline synthesis was explained from some reports. For example, Rana *et al.* (2017) reported that AsA might be essential for hydroxyproline synthesis, a non-essential amino acid derivative. Likewise, ascorbate is also essential for collagen synthesis, especially the hydroxylation of prolyl residues. The beneficial effects on plant survival rate, biomass, shoot, and root growth by exogenous AsA have been reported under water stress (Shalata and Neumann, 2001; Athar *et al.*, 2008). Khan *et al.* (2006) on wheat showed that ascorbic acid at the rate

of 100 ppm reduced the adverse effects of drought stress. Xu *et al.* (2015) stated that treating *Festuca arundinacea* roots with ascorbic acid could mitigate root growth decline due to water stress attributed these effects to its role in activating non-enzymatic or enzymatic antioxidant systems.

The results of the studies by Malik *et al.* (2015) showed that application of ascorbic acid under drought could overcome adverse effects of oxidative stress by maintaining growth, relative water content, osmotic adjustment through proline accumulation and by enhanced activity of antioxidant enzymes. Abd-Elmoneim *et al.* (2018) stated that *Euphorbia milii* var. Longifolia plants treated with AsA gained the highest records of plant height, stem length, leaf length, fresh weight of leaves, stem fresh and dry weights and total chlorophyll content under water stress. Farooq *et al.* (2020) also found that water stress significantly decreased the shoot and root fresh and dry weights, shoot and root lengths and chlorophyll content in four safflower cultivars, while it increased the leaf free proline. While foliar-applied (100 mg/l and 150 mg/l) ascorbic acid caused a marked improvement in shoot and root fresh and dry weights, plant height, and chlorophyll content and also increased the accumulation of leaf proline.

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تحسين قدرة نباتات الكورتادريا سيلوانا على تحمل نقص ماء الري باستخدام حمض الاسكوريك

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من أجل تحسين قدرة شتلات *Cortaderia selloana* على تحمل نقص مياه الري، أجريت الدراسة الحالية في أصص تحت ظروف الحقل المكشوف بمشتل قسم بحوث الزينة وتنسيق الحدائق، معهد بحوث البساتين، مركز البحوث الزراعية، الجيزة، مصر خلال موسمي ٢٠١٧/٢٠١٨ و ٢٠١٨/٢٠١٩. حيث زرعت الشتلات في أصص بلاستيكية قطر ٣٠ سم مملوءة بحوالي ٥,٥ كجم تربة طميية، وتم ري الشتلات بثلاثة مستويات مياه الري لهذه التربة وهي (٥٠، ٧٥ و ١٠٠٪ من السعة الحقلية) كما تم رشها بحمض الاسكوريك بتركيز ٠، ١٠٠، ١٥٠ و ٢٠٠ جزء في المليون وكذلك التفاعلات بينهما. أظهرت النتائج أن انخفاض مستويات الري أدى إلى انخفاض تدريجي ملحوظ في جميع الصفات الخضرية والزهرية والجزرية ومحتوى الأوراق من الكربوهيدرات الكلية والكلوروفيل الكلي. بينما أدى نقص مستويات الري إلى زيادة تراكم البرولين في الأوراق. كما أظهرت النتائج أن الرش بحمض الاسكوريك مرة كل ثلاثة أسابيع أحدث زيادة في جميع الصفات الخضرية والزهرية والجزرية وكانت الزيادة تتناسب مع زيادة تركيز حمض الاسكوريك حتى الوصول إلى أقصى معدل نمو عند الرش بتركيز ٢٠٠ جزء في المليون، ولم تكن هناك زيادة معنوية بين تركيز حمض الاسكوريك عند ١٥٠ و ٢٠٠ جزء في المليون في معظم الصفات، كما أدى إلى زيادة محتوى الأوراق من الكربوهيدرات الكلية والكلوروفيل الكلي والبرولين. وأوضح التفاعل بين حمض الاسكوريك ومستويات الري أن الرش بحمض الاسكوريك قد خفف من الآثار الضارة لنقص المياه على النمو الخضري والزهري ونمو الجذور. وكان أفضل تركيز لحمض الاسكوريك عند ١٥٠ و ٢٠٠ جزء في المليون للنباتات النامية تحت ١٠٠ و ٧٥٪ من السعة الحقلية مع عدم وجود فروق معنوية في معظم الحالات بينما أدى التفاعل بين مستوى الري ٥٠٪ وحمض الاسكوريك عند ٢٠٠ جزء في المليون إلى الحصول على أعلى تراكم للبرولين في الأوراق. بالإضافة إلى ذلك، أدى التفاعل بين مستوى الري بمعدل ١٠٠٪ (الكونترول) وحمض الاسكوريك عند تركيز ٢٠٠ جزء في المليون إلى زيادة معدل تراكم الكربوهيدرات الكلية والكلوروفيل الكلي في الأوراق لأعلي مستوى. وبذلك، يمكن التوصية بري نباتات *Cortaderia selloana* النامية في اصص مملوءة بالطمي بـ ٧٥٪ من السعة الحقلية مره كل ثلاثة أيام مع الرش بمحلول حمض الاسكوريك بتركيز ١٥٠ جزء في المليون مرة كل ثلاثة اسابيع، حيث كانت هذه المعاملة اقتصادية لتوفير ٢٥٪ من مياه الري وللحصول على نمو جيد تحت ظروف الإجهاد المائي.

