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Response of Paspalum Turfgrass Grown in Sandy Soil to Trinexapac-Ethyl and Irrigation Water Salinity

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Abstract: This study was conducted at a private turf nursery in El-Kassassin, Ismailia Governorate, Egypt, during the two successive seasons of 2006/2007 and 2007/2008, with the aim of investigating the response of paspalum (*Paspalum vaginatum*, Swartz), grown in sandy soil, to trinexapac-ethyl (TE) and irrigation water salinity. The turfgrass was irrigated with water containing NaCl and $CaCl_2$ (1:1, w/w) at concentrations of 5000, 7000 and 9000 ppm. Control plants were irrigated using water from Ismailia canal (310 ppm). Plants receiving each of the irrigation water salinity treatments were sprayed monthly with TE at concentration of 200 and 400 ppm. Control plants were sprayed with tap water. Results showed that spraying turfgrass with TE increased most of the vegetative growth characteristics (coverage percentage, lawn density, fresh and dry weights of underground parts) as well as concentrations of total chlorophylls, carotenoids, total carbohydrates and K in clippings, whereas raising the salt concentration in irrigation water resulted in steady reductions in the values of these parameters, compared to the control. On the other hand, spraying the turfgrass with TE decreased the concentrations of proline, Na, Cl and Ca in clippings, whereas raising the irrigation water salinity resulted in steady increases in the values of these parameters, compared to the control. Both TE and irrigation water salinity treatments decreased sward height before mowing as well as fresh and dry weights of clippings, compared to the control. In both seasons, paspalum turfgrass irrigated with saline water up to 7000 ppm and sprayed with TE at 400 ppm gave coverage percentage, turf density, fresh and dry weights of underground parts as well as concentrations of total chlorophylls and carotenoids which were insignificantly different than those recorded with control plants. It can be concluded that for improving the tolerance of *Paspalum vaginatum* grown in sandy soil to irrigation water salinity up to 7000 ppm, with no significant reduction in most of vegetative characteristics and quality, the turf should be sprayed monthly with TE at 400 ppm.

Key words: *Paspalum vaginatum* · Trinexapac-ethyl · TE · salinity

INTRODUCTION

Turfgrasses are among the most important plant groups that are used extensively in the landscape of new cities, coastal resorts and touristic villages. Most of these communities are built in desert areas where irrigation depends primarily on relatively saline water from wells or desalination units [1]. *Paspalum* is a large genus containing 320 species; however, only two [bahiagrass (*Paspalum notatum*, Flugge) and seashore paspalum (*Paspalum vaginatum*, Swartz)] are used as turfgrasses. Seashore paspalum is adapted to tropical and warm subtropical climates. It forms a dense, fine-textured turf of dark green color. It can be used for utility lawns and sport turfs (including golf course greens) on salt-affected sites [2]. *Paspalum vaginatum* is capable of tolerating high salinity levels (3000-5000 ppm) with no adverse effect on plant growth, quality and appearance [1,3].

Plant growth regulators, such as growth inhibitors, are widely used in turfgrass management to suppress shoot growth and inflorescences [2]. The growth inhibitor trinexapac-ethyl (TE) blocks the final step in the biosynthesis of the biologically active forms of gibberellins, resulting in slower shoot growth [4]. Pessarakli [5] stated that TE applications increased leaf tissue levels of the cytokinin zeatin riboside. Cytokinins are known to strongly delay senescence via a number of mechanisms, including acting as antioxidants, inhibiting respiration, decreasing enzymes (lipase and lipoxygenase) involved in membrane breakdown, limiting stomatal closure and preventing chlorophyll loss. Such positive physiological responses

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enhance resistance of turfgrasses to environmental stresses. In this respect Ervin and Koski [6] on *Lolium perenne*, L., Bingaman *et al.* [7], Ervin and Koski [8,9] Heckman *et al.* [10] and Beasley *et al.* [11] on Kentucky bluegrass (*Poa pratensis*), Pannacci *et al.* [12] on five cool-season turfgrass species and McCann and Huang [13] on creeping bentgrass (*Agrostis stolonifera*, L.) reported that TE application increased turf quality, turf density, chlorophyll content and reduced shoot extension rate. Also, the application of TE to two cultivars of bermudagrass plants during their exposure to salinity enhanced root growth [14].

The ultimate goal of this study was to improve the tolerance of *Paspalum vaginatum*, Swartz grown in sandy soil to irrigation water salinity by using trinexapac-ethyl (TE).

MATERIALS AND METHODS

This study was carried out at a private turf nursery in El-Kassassin, Ismailia Governorate, Egypt, during the two successive seasons of 2006/2007 and 2007/2008. The objective of this study was to investigate the response of seashore paspalum (*Paspalum vaginatum*, Swartz) grown in sandy soil to foliar application of trinexapac- ethyl (TE) and irrigation water salinity. Forty eight beds (1 m x 1 m) were well prepared by incorporating Milogranite (activated sewage sludge, containing 6% N) into the soil to depth of 12-15 cm, at the rate of 2 m^3/100 m^2. Round-Up, a non-selective weed killer, was applied prior to planting at the rate of 1 liter/Fed. to eliminate all vegetation. The physical and chemical characteristics of the sandy soil are shown in Table 1.

On March 1st (in both seasons), plugs of *Paspalum vaginatum*, Swartz were planted in the beds at a spacing of 15 x 15 cm (one square meter of sod gave enough plugs to plant about 7 m^2). The experimental area was irrigated daily at the rate of 6 liters/m^2 from the planting date till 15th October, then the irrigation rate was reduced to 5 liters /m^2 three times a week till 1st March of the following year (the termination of the experiment). The plants were irrigated using water from the Ismailia canal (310 ppm) from 1st March till 15th April (during the establishment of the turfgrass), then irrigation was carried out using saline water at concentrations of 5000, 7000 or 9000 ppm until the termination of each season. The different saline water concentrations were prepared using a mixture of NaCl and $CaCl_2$ (1:1 w/w) in Ismailia canal water (310 ppm). In addition, the control plants continued to be irrigated with the Ismailia canal water. In both seasons, plants receiving each of the irrigation water salinity treatments were sprayed monthly (from 15th April, 2006 and 2007 till 15th February, 2007 and 2008 in the first and second seasons, respectively), after mowing, with trinexapac-ethyl [TE, 97% a.i., 4-cyclopropyl-á-hydroxyl-methylene-3, 5-dioxocyclohexanecarboxylic acid ethyl ester ($C_{13}H_{16}O_5$), purchased from Hebei Kaidi Agrochemical Enterprises Group, China] at concentrations of 200 and 400 ppm. Every 1 m^2 of the turfgrass required 150 cm^3 of solution. Control plants were sprayed with tap water.

All the turfgrass beds received chemical NPK fertilization in the form of ammonium nitrate (33.5 % N), calcium superphosphate (15.5 % P_2O_5) and potassium sulphate (48% K_2O), mixed at the ratio of 2:1:1 (N : P_2O_5 : K_2O) and applied monthly at the rate of 28.96 g/m^2 as recommended by Hussein and Mansour [15] on *Paspalum vaginatum.*

The layout of the experiment was a randomized complete blocks design with 4 blocks (replicates) and 12 treatments (4 irrigation water salinity levels X 3 TE concentrations).

In both seasons, the turfgrass was mowed biweekly to a height of 3 cm starting on 15th April till the termination of the experiment. The average sward height (cm) before mowing, as well as the average fresh and dry weights of the clippings (g/m^2) after mowing were recorded throughout each growing season. At the end of each growing season (on 1st March), the coverage percentage [16], turf density (number of tillers/100 cm^2, recorded using a 10 cm x 10 cm wooden frame) as well as fresh and dry weights of underground parts (g/m^2) were recorded.

Table 1: Physical and chemical characteristics of the sandy soil used for growing *Paspalum vaginatum* during 2006/2007 and 2007/2008 seasons

Physical characteristics							
Clay (%)	Coarse sand (%)	Fine sand (%)	Silt (%)	Soil texture	Field capacity (% V)		
2.8	38.5	52.4	6.3	Sandy	14.6		
Chemical characteristics					Available macro-nutrients (ppm)		
pH	Organic matter (%)	$CaCO_3$ (%)	EC (dS/m) (1:2.5)	CEC (meq/100 g)	N	P	K
7.4	1.03	0.63	0.76	4.1	18.2	1.1	56.0

At the end of each season, fresh clipping samples were chemically analyzed to determine their total chlorophylls (a+b) and carotenoids contents (mg/g fresh matter) [17]. Also, the total carbohydrates content (% of dry matter) was determined in dried clipping samples [18]. Other dried clipping samples were digested to extract nutrients [19] and the extract was analyzed to determine its contents of potassium (% of dry matter) [20]. The contents of Na and Ca in the extract (% of dry matter) were also determined by using a Pye Unicam Atomic Absorption Spectrophotometer (Model SP 1900). Also, the Cl content was determined [21]. The proline content in fresh leaves (μ moles /g fresh matter of clippings) was also determined [22].

Data collected for vegetative growth characteristics and chemical constituents were subjected to an analysis of variance and the means were compared using the "Least Significant Difference (LSD)" test at the 0.05 level [23]. The coverage percentage data was subjected to arcsine transformation and the transformed data were statistically analyzed.

RESULTS AND DISCUSSION

A-Vegetative Growth Characteristics of *Paspalum Vaginatum*

Coverage Percentage: The data presented in Table 2 indicate that, in both seasons, *Paspalum vaginatum* plants treated with trinexapac-ethyl (TE) gave insignificantly higher coverage percentages as compared to the untreated plants (control). This result is in agreement with the findings of Goss *et al.* [24] on creeping bentgrass (*Agrostis stolonifera*).

In both seasons, the coverage percentage of *Paspalum vaginatum* was decreased steadily with raising the salt concentration in irrigation water, as compared to the control plants. Raising the irrigation water salinity up to 5000 ppm resulted in insignificant reductions in coverage percentage in the two seasons. In the first season, higher salt concentrations (7000-9000 ppm) in the irrigation water resulted in significant reductions in coverage percentage, compared to the control. In the second season, raising the irrigation water salinity up to

Table 2: Effect of TE and saline irrigation water on coverage percentage, sward height before mowing (cm) and lawn density (number of tillers/100 cm^2) of *Paspalum vaginatum* during the 2006/2007 and 2007/2008 seasons

	First season (2006/2007)				Second season (2007/2008)			
	TE concentration (TE), ppm				TE concentration (TE), ppm			
Salt concentration (S), ppm	Control	200	400	Mean (S)	Control	200	400	Mean (S)
Coverage percentage								
Control	100.0a	100.0a	100.0a	100.0a	100.0a	100.0a	100.0a	100.0a
5000	90.0a-c	95.0ab	90.0a-c	91.7ab	95.0ab	95.0ab	95.0ab	95.0a
7000	85.0b-d	90.0a-c	90.0a-c	88.3b	85.0bc	95.0ab	95.0ab	91.7ab
9000	75.0d	75.0d	80.0cd	73.3c	80.0c	85.0bc	80.0c	81.7b
Mean (TE)	87.5a	90.0a	90.0a	---	90.0a	93.8a	92.5a	---
In each season, within the column for salinity treatment means, the row for TE treatment means, or the means for combinations of the two factors, means sharing one or more letters are insignificantly different at the 5% level, according to the "Least Significant Difference" test								
Sward height before mowing (cm)								
Control	6.50	5.80	5.50	5.93	7.08	5.10	4.45	5.54
5000	6.00	5.50	5.10	5.53	6.80	4.60	4.20	5.20
7000	5.10	4.90	4.20	4.73	5.50	4.20	4.08	4.59
9000	4.90	4.30	3.80	4.33	4.40	4.08	3.90	4.13
Mean (TE)	5.63	5.13	4.65	---	5.95	4.50	4.16	---
LSD (0.05)								
TE		0.67				0.72		
S		0.86				0.94		
TE X S		1.10				1.18		
Lawn density (number of tillers/ 100 cm^2)								
Control	184.5	198.0	222.3	201.6	196.0	211.0	232.0	213.0
5000	175.8	181.3	186.0	181.0	180.5	191.0	198.8	190.1
7000	142.3	169.5	180.0	163.9	156.0	160.3	178.0	164.8
9000	120.0	140.8	145.5	135.4	125.3	134.0	141.0	133.4
Mean (TE)	155.7	172.4	183.5	---	164.5	174.1	187.5	---
LSD (0.05)								
TE		13.4				14.8		
S		18.5				21.6		
TE X S		26.6				32.5		

7000 ppm insignificantly reduced coverage percentage, whereas the highest salt concentrations (9000 ppm) reduced the coverage percentage significantly, compared to the control. Such results were reported on *Paspalum vaginatum* [1, 3], *Cynodon dactylon*, *C. transvaalensis* and Tifway (*C. dactylon* X *C. transvaalensis*) [25] and *Pennisetum clandestinum* turfgrass [26].

Regarding the interaction between the effects of spraying *Paspalum vaginatum* plants with TE and irrigation with different levels of saline water, the data recorded on the coverage percentage show that, within each TE concentration, raising saline water concentration decreased coverage percentage, in most cases. Within each irrigation water salinity level, increasing TE concentration to 200 or 400 ppm increased the coverage percentage as compared to that recorded with plants sprayed with water (in most cases). Generally, in both seasons, plants sprayed with TE at 200 or 400 ppm could be irrigated with saline water at 7000 ppm with no significant reduction in coverage percentage than that of control plants.

Sward Height Before Mowing: Data presented in Table 2 show that spraying *Paspalum vaginatum* with trinexapac-ethyl (TE) resulted in shorter sward heights as compared to the untreated plants (control). In the first season, raising TE concentration to 200 ppm insignificantly reduced sward height, whereas the high TE concentration (400 ppm) significantly reduced it, as compared to the control. In the second season, using both TE concentrations (200 and 400 ppm) significantly reduced sward height as compared to the control plants. Such results were reported on *Lolium perenne* [6], Kentucky bluegrass (*Poa pratensis*) [7-11], five cool-season turfgrass species namely *Poa pratensis*, *Lolium perenne*, *Festuca arundinacea*, *F. rubra* subsp. *rubra* and *F. rubra* subsp. *commutata* [12] and creeping bentgrass (*Agrostis stolonifera*, L.) [13]. The decrease in sward height as a result of spraying TE may be attributed to its structural resemblance to 2-oxoglutaric acid, thus acting competitively with 2-oxoglutaric acid to inhibit the 3β-hydroxylase conversion of gibberellic acid-20 (GA_{20}) to GA_1, resulting in reduced shoot elongation [27].

Concerning the effect of irrigation water salinity on sward height (regardless of the effect of TE), the data in Table 2 show that sward height was decreased steadily with raising the salt concentration in both seasons, compared with the untreated control plants. However, the reduction in plant height was insignificant at the lowest salt concentration (5000 ppm), compared to the control. This result is in agreement with the findings of Hussein and Darwish [1] on seashore paspalum. Higher salt concentrations (7000 and 9000 ppm) decreased sward height significantly compared to the control. The decrease in plant height under saline conditions was probably due to the insufficient uptake of water and nutrients, as well as sodic toxicity [28, 29]. Such results were reported on *Paspalum vaginatum* [1,3], *Cynodon dactylon*, *C. transvaalensis* and Tifway (*C. dactylon x C. transvaalensis*) [25], as well as *Pennisetum clandestinum* turfgrass [26].

Regarding the interaction between the effects of spraying TE and irrigation water salinity treatments, the data recorded on the sward height of *Paspalum vaginatum* plants show that, within each TE concentration, raising saline water concentration decreased sward height steadily. Within each irrigation water salinity level, increasing TE concentration to 200 or 400 ppm decreased sward height steadily, compared to that of plants sprayed with water. The tallest swards were those of control plants, whereas the shortest swards were those of plants sprayed with TE at 400 ppm and irrigated with saline water at the concentration of 9000 ppm.

Lawn Density (Number of Tillers / 100 cm^2): Data presented in Table 2 show that spraying *Paspalum vaginatum* with trinexapac-ethyl (TE) increased lawn density, as compared to the untreated plants (control). In the first season, using both TE concentrations (200 and 400 ppm) significantly increased lawn density as compared to the control plants. In the second season, raising TE concentration to 200 ppm insignificantly increased lawn density, whereas the higher concentration (400 ppm) increased it significantly, as compared to the control. In this respect, Ervin and Koski [6] on *Lolium perenne*, Bingaman *et al.* [7], Ervin and Koski [8], Beasley *et al.* [11] on Kentucky bluegrass, Fagerness *et al.* [30] on Tifway bermudagrass, Ervin *et al.* [31] on *Zoysia japonica* and McCann and Huang [13] on creeping bentgrass, reported that TE application at concentration of 0.1-0.27 Kg ha^{-1} at 3-4 week intervals resulted in a 12-67% increase in tiller density. The increase in lawn density as a result of using TE may be attributed to the role of TE in increasing leaf tissue levels of the cytokinin zeatin riboside [5].

Data shown in Table 2 also reveal that, in both seasons, increasing salt concentration in the irrigation water caused steady significant reductions I n the number of tillers/100 cm^2, as compared to the control.

Table 3: Effect of TE and saline irrigation water on fresh and dry weights (g/m^2) of clippings and underground parts of *Paspalum vaginatum* during the 2006/2007 and 2007/2008 seasons

	First season (2006/2007)				Second season (2007/2008)			
	TE concentration (TE), ppm				TE concentration (TE), ppm			
Salt concentration (S), ppm	Control	200	400	Mean (S)	Control	200	400	Mean (S)
Fresh weight of clippings (g/m^2)								
Control	28.5	26.1	22.2	25.6	35.1	32.0	28.1	31.7
5000	26.1	23.0	21.2	23.4	32.0	28.0	25.5	28.5
7000	22.8	21.1	19.0	21.0	27.5	21.5	19.8	22.9
9000	20.1	17.5	14.1	17.2	20.2	18.1	16.8	18.4
Mean (TE)	24.4	21.9	19.1	---	28.7	24.9	22.6	---
LSD (0.05)								
TE	1.9	2.1						
S	2.5	2.8						
TE X S	3.4	3.5						
Dry weight of clippings (g/m^2)								
Control	5.84	4.86	4.01	4.90	6.74	5.60	4.42	5.59
5000	4.89	3.98	3.35	4.07	5.79	4.62	4.34	4.92
7000	4.01	3.87	3.20	3.69	5.36	3.96	3.17	4.16
9000	3.66	3.11	2.86	3.21	4.14	3.46	3.03	3.54
Mean (TE)	4.60	3.96	3.36	---	5.51	4.41	3.74	---
LSD (0.05)								
TE		0.32				0.38		
S		0.45				0.48		
TE X S		0.61				0.68		
Fresh weight of underground parts (g/m^2)								
Control	512.5	564.6	581.7	552.9	560.4	581.9	600.7	581.0
5000	461.1	485.1	504.0	483.4	492.5	526.7	540.8	520.0
7000	396.8	432.5	458.1	429.1	409.7	426.0	445.2	427.0
9000	349.4	366.8	370.1	362.1	378.3	386.7	408.2	391.1
Mean (TE)	430.0	462.3	478.5	---	460.2	480.3	498.7	---
LSD (0.05)								
TE		33.2				36.8		
S		42.9				56.5		
TE X S		55.7				63.7		
	Dry weight of underground parts (g/m^2)							
Control	93.28	115.74	123.32	110.78	98.07	108.23	123.14	109.81
5000	82.08	97.51	99.77	93.12	94.07	98.66	121.05	104.59
7000	77.77	80.01	98.95	85.58	76.79	83.50	96.38	85.56
9000	60.80	71.53	76.24	69.52	75.42	83.14	94.74	84.43
Mean (TE)	78.48	91.20	99.57	---	86.09	93.38	108.83	---
LSD (0.05)								
TE		8.98				9.24		
S		9.97				10.18		
TE X S		14.11				17.21		

The reduction in number of tillers/100 cm^2 (tillering) may be attributed to the reduction in the activity level of cytokinins as a result of the salinity treatments [32]. Such results were reported by many researchers [1, 3, 25, 26, 33, 34, 35].

The data recorded on the lawn density show that, within each TE concentration, raising saline water concentration decreased lawn density steadily. On the other hand, within each irrigation water salinity level, increasing TE concentration to 200 or 400 ppm resulted in steady increases in the lawn density as compared to that of plants sprayed with water. In the first season, plants sprayed with 200 or 400 ppm TE and irrigated with saline water at the concentration of 7000 ppm had insignificantly lower lawn densities as compared to the control plants. In the second season, plants sprayed with 400 ppm TE and irrigated with saline water at concentration of 7000 ppm had an insignificantly lower lawn density as compared to the control plants. In both seasons, the highest lawn density was recorded with plants sprayed with 400 ppm TE and irrigated with unsaline water (control, 310 ppm), whereas the lowest lawn density was recorded with plants sprayed with water and irrigated with saline water at the concentration of 9000 ppm.

Fresh and Dry Weights of Clippings (g/m^2): Data presented in Table 3 reveal that spraying *Paspalum vaginatum* with TE significantly decreased fresh and dry weights of clippings, as compared to the untreated plants (control). Moreover, increasing TE concentration from 200 to 400 ppm caused a significant reduction in fresh and dry weights of clippings. Such results were reported on *Zoysia* sp. [31, 36].

Data recorded in the two seasons (Table 3) also indicate that increasing salt concentrations in irrigation water salinity caused steady significant decreases in the fresh and dry weights of clippings, compared to the control (in most cases). The only exception to this trend was recorded in the first season with plants irrigated with saline water at the concentration of 5000 ppm, which gave a fresh weight of clippings that was insignificantly lighter than that of control plants. Such results were reported by many researchers [1, 3, 25, 26, 37, 38].

Regarding the interaction between the effects of spraying *Paspalum vaginatum* plants with TE and irrigation water salinity treatments, the recorded data show that the fresh and dry weights of clippings were decreased steadily with TE and/or irrigation water salinity treatments, compared to the control plants, which gave the heaviest fresh and dry weights of clippings, whereas the lowest weights were recorded with plants sprayed with TE at 400 ppm and irrigated with saline water at the highest concentration (9000 ppm).

Fresh and Dry Weights of Underground Parts (g/m^2): Data presented in Table 3 show that spraying *Paspalum vaginatum* with TE increased fresh and dry weights of underground parts, as compared to the untreated plants (control). In most cases, spraying turf with TE at the concentration of 200 ppm caused insignificant increases in fresh and dry weights of underground parts. The only exception to this trend was recorded in the first season, with plants sprayed with TE at concentration of 200 ppm giving a significantly higher dry weight of underground parts than that recorded with control plants. Fresh and dry weights of underground parts of plants sprayed with TE at concentration of 400 ppm were significantly heavier than those recorded with the control plants. These results are in agreement with the findings of McCullough ***et al.*** [39] on Miniverde and Floradwarf hybrid bermudagrasses and Baldwin ***et al.*** [41] on Tifeagle ultradwarf bermudagrasses. The increase in fresh and dry weights of underground parts as a result of TE treatments was explained by Qian and Engelke [36] on *Zoysia matrella*, they suggested that TE decreased the sink strength of the shoot and shifted the limited assimilates to the root system.

The data presented in Table 3 also reveal that the fresh and dry weights of underground parts were decreased steadily as a result of increasing salt concentrations in irrigation water (in both seasons). In general, the reduction in fresh and dry weights of underground parts, as a result of irrigation water salinity, was significant compared with the untreated control plants. The only exception to this trend was recorded in the second season, with plants irrigated using saline water at the lowest concentration (5000 ppm) giving an insignificantly lighter dry weight of underground parts than that recorded with control plants. Similar reductions in fresh and dry weights of underground parts were obtained by many researchers [1, 3, 25, 26]. Generally, it has been accepted that the major causes of plant-growth inhibition under salinity stress are osmotic stress (osmotic inhibition of plant water absorption) and specific ion effects, including toxicities and imbalances [5].

The data recorded on the fresh and dry weights of underground parts show that, within each TE concentration, raising saline water concentration decreased fresh and dry weights of underground parts steadily. On the other hand, within each water salinity level, increasing TE concentration to 200 or 400 ppm resulted in steady increases in the fresh and dry weights of underground parts, as compared to those of plants sprayed with water. The underground parts of plants sprayed with TE at the concentration of 400 ppm and irrigated with saline water at the concentration of 7000 ppm had fresh weights that were insignificantly lighter in the first season, as well as dry weights that were insignificantly different in both seasons, as compared to the control plants.

Chemical Constituents of *Paspalum Vaginatum*:

Total Chlorophylls and Carotenoids Concentration: Data presented in Table 4 show that the total chlorophylls and carotenoids concentrations in clippings of *Paspalum vaginatum* sprayed with TE were significantly higher than those recorded with control plants (in most cases). The only exception to this trend

Table 4: Effect of TE and saline irrigation water on total chlorophylls (a + b), carotenoids, total carbohydrates and proline concentrations in clippings of *Paspalum vaginatum* during the 2006/2007 and 2007/2008 seasons

	First season (2006/2007)				Second season (2007/2008)			
	TE concentration (TE), ppm				TE concentration (TE), ppm			
Salt concentration (S), ppm	Control	200	400	Mean (S)	Control	200	400	Mean (S)
Total chlorophylls (a+ b) concentration (mg/g fresh matter)								
Control	2.20	2.31	2.38	2.30	2.16	2.32	2.44	2.31
5000	1.96	2.11	2.19	2.09	2.10	2.13	2.28	2.17
7000	1.89	2.01	2.16	2.02	1.94	2.11	2.14	2.06
9000	1.60	1.71	1.80	1.70	1.70	1.76	1.92	1.79
Mean (TE)	1.91	2.04	2.13	---	1.98	2.08	2.20	---
LSD (0.05)								
TE		0.11				0.12		
S		0.15				0.21		
TE X S		0.21				0.29		
Carotenoids concentration (mg/g fresh matter)								
Control	0.70	0.83	0.84	0.79	0.67	0.84	0.91	0.81
5000	0.60	0.71	0.73	0.68	0.65	0.81	0.84	0.77
7000	0.56	0.58	0.70	0.61	0.54	0.65	0.75	0.65
9000	0.39	0.42	0.50	0.44	0.37	0.49	0.60	0.49
Mean (TE)	0.56	0.64	0.69	---	0.56	0.70	0.78	---
LSD (0.05)								
TE		0.05				0.06		
S		0.07				0.08		
TE X S		0.10				0.12		
Total carbohydrates (% of dry matter)								
Control	26.4	26.9	27.9	27.1	24.8	25.5	25.9	25.4
5000	25.2	25.6	26.3	25.7	23.9	25.0	25.6	24.8
7000	23.1	23.9	24.1	23.7	21.5	22.8	23.1	22.5
9000	20.0	20.6	21.4	20.7	20.1	20.8	21.3	20.7
Mean (TE)	23.7	24.3	24.9	---	22.6	23.5	24.0	---
LSD (0.05)								
TE		1.8				1.6		
S		2.1				2.0		
TE X S		2.9				3.1		
Proline concentration (µ moles/g fresh matter)								
Control	16.22	16.10	14.28	15.53	19.39	17.02	16.11	17.51
5000	20.19	18.08	17.51	18.59	22.18	19.08	18.13	19.80
7000	28.12	22.40	21.90	24.14	34.06	23.40	20.10	25.85
9000	41.10	29.59	25.43	32.04	42.12	33.05	26.14	33.77
Mean (TE)	26.41	21.54	19.78	---	29.44	23.14	20.12	---
LSD (0.05)								
TE		1.90				2.11		
S		2.32				2.73		
TE X S		3.24				3.86		

was recorded in the second season with plants sprayed with TE at concentration of 200 ppm, which gave an insignificantly higher concentration of total chlorophylls than that of control plants. These results are in agreement with the findings of Ervin and Koski [6] on *Lolium perenne*, Bingaman *et al.* [7], Ervin and Koski [8,9], Heckman *et al.* [10] and Beasley *et al.* [11] on Kentucky bluegrass (*Poa pratensis*), Pannacci *et al.* [12] on five cool-season turfgrass species and McCann and Huang [13] on creeping bentgrass (*Agrostis stolonifera*, L.). The increase in total chlorophylls as a result of using TE may be attributed to the inhibition of cell elongation, which has been shown to increase mesophyll cell density and chlorophyll concentration, resulting in dwarfed shoots that are darker green [9, 40, 41]. Also, Pessarakli [5] stated that TE applications increased leaf tissue levels of the cytokinin zeatin riboside. Cytokinins are known to strongly delay senescence via a number of mechanisms, including acting as antioxidants, inhibiting respiration, decreasing enzymes (lipase and lipoxygenase) involved in membrane breakdown, limiting stomatal closure and preventing chlorophyll loss.

In both seasons, the total chlorophylls (a+b) and carotenoids concentrations in clippings were generally decreased steadily with raising the salt concentration, compared with the untreated control. Such results were reported by many researchers [1, 3, 25, 26, 42].

In the first season, the reductions in total chlorophylls (a+b) and carotenoids concentrations were significant even with the lowest salt concentration (5000 ppm), as compared to the control. In the second season, the total chlorophylls (a+b) and carotenoids concentrations were insignificantly decreased as a result of using saline water at the concentration of 5000 ppm, whereas higher salt concentrations (7000-9000 ppm) resulted in significant reductions, compared to the control.

The data recorded on total chlorophylls (a+b) and carotenoids concentrations also show that, within each TE concentration, raising saline water concentration decreased total chlorophylls (a+b) and carotenoids concentrations steadily. On the other hand, within each irrigation water salinity level, increasing TE concentration to 200 or 400 ppm steadily increased the total chlorophylls (a+b) and carotenoids concentrations, compared to those of plants sprayed with water. In both seasons, plants sprayed with TE at the concentration of 400 ppm and irrigated with saline water at the concentration of 7000 ppm had total chlorophylls (a+b) and carotenoids concentrations which were insignificantly different than those of control plants.

Total Carbohydrates (% of Dry Matter): The data in Table 4 show that total carbohydrates concentrations in clippings of *Paspalum vaginatum* sprayed with TE (at concentrations of 200 and 400 ppm) were insignificantly higher than those recorded with control plants. These results are in agreement with the findings of Qian and Engelke [36] on *Zoysia matrella*.

Data presented in Table 4 also show that in both seasons, the total carbohydrates concentration was decreased steadily with raising the salt concentration in irrigation water, compared with the untreated control. In both seasons, the total carbohydrates percentage in plants irrigated using the lowest water salinity level (5000 ppm) was insignificantly lower than that of control plants, whereas higher salt concentrations (7000 - 9000 ppm) significantly decreased the recorded values compared to the control. These results are in agreement with the findings of Hussein and Darwish [1] and El-Bagoury *et al.* [3] on *Paspalum vaginatum*, Mansour and Hussein [25] on *Cynodon dactylon*, *C. transvaalensis* and Tifway (*C. dactylon* x *C. transvaalensis*), as well as Sakr and Darwish [26] on *Pennisetum clandestinum* turfgrass. The reduction in total carbohydrates concentration under saline conditions was explained by Moursi *et al.* [43], who attributed this phenomenon to an increase in the respiration rate, in order to produce enough energy to overcome the relatively low availability of water and nutrients under saline conditions.

The data recorded on total carbohydrates concentrations also show that, within each TE concentration, raising saline water concentration decreased total carbohydrates percentage steadily. Within each irrigation water salinity level, increasing TE concentration to 200 or 400 ppm resulted in steady increases in the total carbohydrates percentages, compared to that recorded in plants sprayed with water. In both seasons, plants sprayed with TE at concentrations of 200 or 400 ppm and irrigated with saline water at the concentration of 7000 ppm had total carbohydrates percentages that were insignificantly lower than those of control plants.

Proline Concentration: Data tabulated in Table 4 show that proline concentrations in clippings of *Paspalum vaginatum* sprayed with TE (at 200 and 400 ppm) were significantly lower than those in clippings of control plants. This result is in agreement with the findings of Ashour [44] on *Plumbago capensis*, who found that spraying plants with Pix (mepiquate chloride) reduced the proline concentration in leaves and stems.

Data presented in Table 4 also show that, in both seasons, the proline concentration was increased steadily with raising the salt concentration in irrigation water to 5000, 7000 or 9000 ppm. In the first season, the increase in proline concentration was significant (compared to the control) even with the lowest salt concentration (5000 ppm). In the second season, the increases in proline concentration was insignificant with the lowest salinity level (5000 ppm), whereas higher salt concentrations (7000-9000 ppm) increased proline concentration significantly, compared to the control. Similar increases in the proline concentration of

Table 5: Effect of TE and saline irrigation water on K, Na, Cl and Ca concentrations (% of dry matter) in clippings of *Paspalum vaginatum* during the 2006/2007 and 2007/2008 seasons

	First season (2006/2007)				Second season (2007/2008)			
	TE concentration (TE), ppm				TE concentration (TE), ppm			
Salt concentration (S), ppm	Control	200	400	Mean (S)	Control	200	400	Mean (S)
K (% dry matter)								
Control	1.62	1.68	1.70	1.67	1.70	1.82	1.86	1.79
5000	1.49	1.58	1.62	1.56	1.65	1.70	1.73	1.69
7000	1.35	1.40	1.50	1.42	1.44	1.46	1.54	1.48
9000	1.31	1.38	1.42	1.37	1.35	1.43	1.45	1.41
Mean (TE)	1.44	1.51	1.56	---	1.54	1.60	1.65	---
LSD (0.05)								
TE		0.10				0.10		
S		0.13				0.15		
TE X S		0.19				0.22		
Na (% dry matter)								
Control	0.136	0.120	0.111	0.122	0.126	0.115	0.111	0.117
5000	0.182	0.154	0.141	0.159	0.148	0.132	0.124	0.135
7000	0.211	0.194	0.173	0.193	0.179	0.152	0.146	0.159
9000	0.289	0.270	0.259	0.273	0.219	0.188	0.165	0.191
Mean (TE)	0.205	0.185	0.171	---	0.168	0.147	0.137	---
LSD (0.05)								
TE		0.018				0.011		
S		0.026				0.014		
TE X S		0.034				0.020		
Cl (% dry matter)								
Control	0.141	0.120	0.111	0.124	0.125	0.120	0.108	0.118
5000	0.173	0.142	0.124	0.146	0.168	0.131	0.120	0.140
7000	0.244	0.193	0.185	0.207	0.227	0.209	0.194	0.210
9000	0.296	0.265	0.229	0.263	0.269	0.242	0.221	0.244
Mean (TE)	0.214	0.180	0.162	---	0.197	0.176	0.161	---
LSD (0.05)								
TE		0.018				0.016		
S		0.021				0.020		
TE X S		0.030				0.028		
Ca (% dry matter)								
Control	0.243	0.221	0.210	0.225	0.295	0.281	0.260	0.279
5000	0.256	0.240	0.222	0.239	0.319	0.298	0.270	0.296
7000	0.324	0.284	0.271	0.293	0.348	0.325	0.301	0.325
9000	0.358	0.346	0.311	0.338	0.469	0.442	0.410	0.440
Mean (TE)	0.295	0.273	0.254	---	0.358	0.337	0.310	---
LSD (0.05)								
TE		0.024				0.028		
S		0.029				0.038		
TE X S		0.043				0.051		

4 *Zoysia* species and 4 hybrids grown under saline conditions have been reported by Lee *et al.* [45], who suggested that a significant increase in proline concentration could be a good parameter for salt tolerance of zoysiagrasses. It was also concluded by several other researchers [46, 47,48] that proline accumulation in turfgrasses grown under saline conditions can make a substantial contribution to cytoplasmic osmotic adjustment. Such results were reported on *Paspalum vaginatum* [1, 3], *Cynodon dactylon*, *C. transvaalensis* and Tifway (*C. dactylon* x *C. transvaalensis*) [25], as well as *Pennisetum clandestinum* turfgrass [26].

The data recorded on proline concentration show that, within each TE concentration, raising the irrigation water salinity level increased proline concentration steadily. Within each irrigation water salinity level, increasing TE concentration to 200 or 400 ppm resulted in a steady decrease in proline concentration, as compared to that recorded in plants sprayed with water. In both seasons, plants sprayed with TE at concentrations of 200 or 400 ppm and irrigated with saline water at the concentration of 5000 ppm as well as the plants sprayed with TE at 400 ppm and irrigated with saline water at 7000 ppm in the second season had insignificantly different proline concentrations, as compared to the control plants.

K (% of Dry Matter): Data presented in Table 5 show that K% in dried clippings of *Paspalum vaginatum* was steadily increased by spraying with TE at concentrations of 200 and 400 ppm, compared to that recorded with control plants. In both seasons, plants sprayed with 200 ppm TE had insignificantly higher values, whereas the highest TE concentration (400 ppm) resulted in significantly higher values, as compared to the control plants. This result is in agreement with the findings of Ashour [44] on *Plumbago capensis*, who found that spraying plants with Pix (mepiquate chloride) increased K% in leaves and stems.

Data presented in Table 5 also reveal that, in both seasons, raising salt concentrations in irrigation water resulted in steady reductions in the K% in dried clippings of *Paspalum vaginatum*, compared with the untreated control plants. Raising the salt concentration up to 5000 ppm resulted in insignificant reductions, whereas higher salt concentrations (7000-9000 ppm) significantly reduced the recorded values, as compared to the control. Such results were reported by many [3, 26, 49, 50, 51, 52]. The data recorded on K% in dried clippings showed that, within each TE concentration, raising saline water concentration decreased K% steadily. The data also show that within each irrigation water salinity level, increasing TE concentration to 200 or 400 ppm steadily increased the K% as compared to the values recorded in plants sprayed with water. In both seasons, plants sprayed with TE at the concentration of 400 ppm and irrigated with saline water at the concentration of 7000 ppm had an insignificantly lower K%, as compared to the control plants.

Na, Cl and Ca (% of Dry Matter): Data presented in Table 5 show that the Na, Cl and Ca percentages in dried clippings of *Paspalum vaginatum* sprayed with TE at concentrations of 200 and 400 ppm were steadily decreased as compared to those recorded with control plants. In both seasons, the decrease in Na and Cl% was significant even with the low TE concentration (200 ppm), as compared to the control. The decrease in Ca% was insignificant in plants sprayed with TE at concentration of 200 ppm, whereas the higher concentration (400 ppm) resulted in a significant reduction, as compared to the control. These results are in agreement with the findings of Ashour [44] on *Plumbago capensis*, who found that spraying plants with Pix (mepiquate chloride) reduced the Na, Cl and Ca% in leaves and stems.

Data presented in Table 5 also reveal that, in both seasons, raising the salt concentration in irrigation water increased the Na, Cl and Ca% in dried clippings, compared with the untreated control. The increase in Na and Cl% was significant even with the lowest concentration (5000 ppm), as compared to the control plants. On the other hand, the increase in Ca% was insignificant with the lowest concentration (5000 ppm), whereas higher salt concentrations (7000-9000 ppm) significantly increased Ca% in clippings, as compared to the control plants. Such results were reported by many researchers [1, 3, 25, 26, 42, 49-54].

The accumulation of these three elements (Na, Cl and Ca) at relatively high concentration in the plant tissues may result in some toxic effects, which may be responsible for the reduction in vegetative growth characteristics. Also, the accumulation of these elements at high concentrations may interfere with mechanisms responsible for the closure of stomata, thus resulting in an increase in the rate of transpiration from the plant. This may eventually lead to plant wilting or death, as found when the coverage percentage was measured [55].

The data recorded on Na, Cl and Ca% show that, within each TE concentration, raising saline water concentration increased Na, Cl and Ca% steadily. On the other hand, within each irrigation water salinity level, increasing TE concentration to 200 or 400 ppm resulted in steady decreases in Na, Cl and Ca% as compared to the values recorded with plants sprayed with water. In both seasons, plants sprayed with TE at concentration of 200 or 400 ppm and irrigated with saline water at concentration of 5000 ppm had Na and Cl percentages which were insignificantly different than those of control plants. Also, plants sprayed with TE at 200 or 400 ppm and irrigated with saline water at the concentration of 7000 ppm had an insignificantly higher Ca% (in both seasons), as compared to the control plants.

From the above results, It can be concluded that for improving the tolerance of *Paspalum vaginatum* turfgrass grown on a sandy soil to irrigation water salinity up to 7000 ppm, with no significant reduction in most of vegetative characteristics and quality, the turf should be sprayed monthly with TE at 400 ppm.

REFERENCES

1. Hussein, M.M.M. and M.A. Darwish, 2001. Tolerance of *Paspalum vaginatum* grown in sandy soil to irrigation water salinity. Egypt. J. Appl. Sci., 16: 244-255.
2. Turgeon, A.J., 1999. Turfgrass Management. Prentice-Hall International Ltd., pp: 82-83 & 165-185.

3. El-Bagoury, H.M., T.A.M. Abou Dahab, M.M.M. Hussein and Y.A. Abd-Elsalam, 2006. Growth of seashore paspalum (*Paspalum vaginatum*, Swartz cv. Saltene) turfgrass as affected by irrigation water salinity and seasonal variations. Egypt. J. Appl. Sci., 21: 736-758.
4. King, R.W., G.F.W. Gocal and O.M. Heide, 1997. Regulation of leaf growth and flowering of cool season turf grasses. Int. Turfgrass Soc. Res. J., 8: 565-573.
5. Pessarakli, M., 2008. Turfgrass Management and Physiology. CRC Press - Taylor & Francis Group, NewYork, pp: 175-408.
6. Ervin, E.H. and A.J. Koski, 1998. Growth responses of *Lolium perenne* L. to trinexapac-ethyl. HortSci., 33: 1200-1202.
7. Bingaman, B.R., N.E. Christians and D.S. Gardner, 2001. Trinexapac-ethyl effects on rooting of Kentucky bluegrass (*Poa pratensis*) sod. Int. Turfgrass Soc. Res. J., 9: 832-834.
8. Ervin, E.H. and A.J. Koski, 2001a. Kentucky bluegrass growth responses to trinexapac-ethyl, traffic and nitrogen. Crop Sci., 41: 1871-1877.
9. Ervin, E.H. and A.J. Koski, 2001b. Trinexapac-ethyl increases Kentucky bluegrass leaf cell density and chlorophyll concentration. HortSci., 36: 787-789.
10. Heckman, N.L., G.L. Horst, R.E. Gaussoin and K.W. Frank, 2001. Storage and handling characteristics of trinexapac-ethyl treated Kentucky bluegrass sod. HortSci., 36: 1127-1130.
11. Beasley, J.S., B.E. Branham and L.M. Ortiz-Ribbing, 2005. Trinexapac-ethyl affects Kentucky bluegrass root architecture. HortSci., 40: 1539-1542.
12. Pannacci, E., G. Covarelli and F. Tei, 2004. Evaluation of trinexapac-ethyl for growth regulation of five cool-season turfgrass species. Acta Hortic. 661: 349-351.
13. McCann, S.E. and B. Huang, 2007. Effect of trinexapac-ethyl foliar application on creeping bentgrass responses to combined drought and heat stress. Crop. Sci., 47: 2121-2128.
14. Baldwin, C. M., H. Liu, L.B. McCarty, W.L. Bauerle and J.E. Toler, 2006. Effects of trinexapac-ethyl on the salinity tolerance of two bermudagrass cultivars. HortSci., 41: 808-814.
15. Hussein, M.M.M. and H.A. Mansour, 2001. Organic and chemical fertilization of seashore paspalum turfgrass in sandy soil. Al-Azhar J. Agric. Res., 34: 211-234.
16. Mahdi, M.Z., 1953. The Influence of Management on Botanical Composition and Quality of Turf. Doctorate Thesis, University of California, U.S.A.
17. Nornai, R., 1982. Formula for determination of chlorophyll pigments extracted with N.N. dimethyl formamide. Plant Physiol., 69: 1371-1381.
18. Dubois, M., F. Smith, K.A. Gilles, J.K. Hamilton and P.A. Rebers, 1956. Colorimetric method for determination of sugar and related substances. Anal. Chem., 28: 350-356.
19. Piper, C.S., 1947. Soil and Plant Analysis. Univ. of Adelaide, Adelaide, pp: 258-275.
20. Chapman, H.D. and P.F. Pratt, 1961. Methods of Soil, Plants and Water Analysis. Univ. of California, Division of Agricultural Sci., pp: 60-69.
21. Higinbothan, N., B. Etherto and R.J. Foster, 1967. Mineral ion contents and cell transmembrane electropotential of pea and oat seedling tissue. Plant Physiol., 42: 37-46.
22. Bates, L.S., R.P. Waldern and L.D. Teare, 1973. Rapid determination of free proline under water stress studies. Plant and Soil, 39: 205-207.
23. Little, T.M. and F.J. Hills, 1978. Agricultural Experimentation – Design and Analysis. John Wiley & Sons, Inc., New York, USA, pp: 53-63.
24. Goss, R.M., J.H. Baird, S.L. Kelm and R.N. Calhoun, 2002. Trinexapac-ethyl and nitrogen effects on creeping bentgrass grown under reduced light conditions. Crop Sci., 42: 472-479.
25. Mansour, H.A. and M.M.M. Hussein, 2002. Tolerance of three turfgrasses grown in three types of soil to irrigation water salinity. Bull. Fac. Agric., Cairo Univ., 53: 235-264.
26. Sakr, W.R. and M.A. Darwish, 2008. Tolerance of kikuyugrass (*Pennisetum clandestinum*, Hochst ex Chiov) turfgrass grown in sandy soil to irrigation water salinity. J. Product. & Dev., 13: 475-487.
27. Rademacher, W., 2000. Growth retardants: Effect on gibberellin biosynthesis and other metabolic pathways. Annu. Rev. Plant Physiol. Plant Mol. Biol. 51: 501-531.
28. Yasseen, B.T., H.A. Mohammed and E.D. Soliman, 1987. Growth of prophyll and proline accumulation due to salt stress in three barley cultivars. Iraqi J. Agric. Sci. "Zanco", 5: 155-166. (C.f. Field Crop Abst., 40: 5633).
29. St. Arnaud, M. and G. Vincent, 1990. Influence of high salt levels on the germination and growth of five potentially utilizable plants for median turfing in northern climates. J. Environ. Hort., 6: 118-121. (C.f. Hort. Abst., 61: 10052).

30. Fagerness, M.J., 2001. Trinexapac-ethyl affects canopy architecture but not thatch development of Tifway bermudagrass. Int. Turfgrass Soc. Res. J., 9: 860-864.
31. Ervin, E.H., C.H. Ok, B.S. Fresenburg and J.H. Dunn, 2002. Trinexapac-ethyl restricts shoot growth and prolongs stand density of "Meyer" zoysiagrass fairway under shade. HortSci., 37: 502-505.
32. Ghazi, S.M., 1976. Physiological Studies of Cycocel and Alar in Relation to Salt Tolerance of *Vicia faba*, L. Plants. Ph. D. Thesis, Fac. Sci., Ain-Shams Univ., Egypt.
33. Brod, H.G. and H.U. Preusse, 1980. The influence of deicing salt on soil and turf cover. Amer. Soc. Agron., 5: 461-468. (C.f. Hort. Abst., 53: 5313).
34. Torello, W.A. and L.A. Spokas, 1983. Evolution of Kentucky bluegrass (*Poa pratensis* L.) cultivars for salt tolerance. Rasen Groflachen Begrunungen, 14: 71-73.
35. Nus, J.L. and C.F. Hodges, 1986. Differential sensitivity of turfgrass to water stress. HortSci., 21: 1014-1015.
36. Qian, Y.L. and M.C. Engelke, 1999. Influence of trinexapac-ethyl on diamond zoysiagrass in a shade environment.Crop Sci., 39: 202-208.
37. Smith, M.A.L., J.E. Meyer, S.L. Knight and G.S. Chen, 1993. Gauging turfgrass salinity responses in whole-plant microculture and solution culture. Crop Sci., 33: 566-572.
38. Nabati, D.A., R.E. Schmidt and D.J. Parrish, 1994. Alleviation of salinity stress in Kentucky bluegrass by plant growth regulators and iron. Crop Sci., 34: 198-202.
39. McCullough, P.E., H. Liu and L.B. McCarty, 2005. Response of six dwarf-type bermudagrasses to trinexapac-ethyl. HortSci., 40: 460-462.
40. Heckman, N.L., R.E. Caussoin, G.L. Horst and C.G. Elowsky, 2005. Growth regulator effects on cellular characteristics of two turfgrass species. Int. Turfgrass Soc. Res. J., 10: 857-861.
41. McCullough, P.E., H. Liu, L.B. McCarty, T. Whitwell and J.E. Toler, 2006. Nutrient allocation of "Tifeagle" bermudagrass as influenced by trinexapac-ethyl. J. Plant Nutr., 29: 273-282.
42. Xia, H.P., S.Z. Liu and H.X. Ao, 2000. Comparative study on salt resistance of *Vetiveria zizanioides, Paspalum notatum* and *Alternanthera philoxeroides.* Chinese J. Applied and Environmental Biol., 6: 7-17.
43. Moursi, M.A., A. El-Tabbakh and E.T. Kirk, 1976. Combined sugar metabolism in *Ricinus communis* and *Hyoscyamus muticus* in relation to adaption to salinity. Egypt. J. Agron., 2: 265-272.
44. Ashour, H.A., 2008. A study of Some Factors Affecting Growth, Flowering and Chemical Composition of *Plumbago capensis*, Thunb. Plants. M.Sc. Thesis, Fac. Agric., Cairo Univ. Egypt.
45. Lee, G.J., Y.K. Yoo and K.S. Kim, 1994. Comparative salt tolerance study in zoysiagrasses. III. Changes in inorganic constituents and proline contents in eight zoysiagrasses (*Zoysia* spp.). J. Korean Soc. Hort. Sci., 35: 241-250. (C.f. Hort. Abst., 65: 3245).
46. Maraim, K.B., 1990. Physiological parameters of salinity tolerance in C_4 turfgrasses. Dissertation Abstracts International. B, Sciences and Engineering, 51(2): 484B. (C.f. Hort. Abst., 61: 10274).
47. Marcum, K.B. and C.L. Murdoch, 1994. Salinity tolerance mechanisms of six C_4 turfgrasses. J. Amer. Soc. Hort. Sci., 119: 779-784.
48. Qian, Y.L., S.J. Wilhelm and K.B. Marcum, 200l. Comparative responses of two Kentucky bluegrass cultivars to salinity stress. Crop Sci., 41: 1895-1900.
49. Dudeck, A.E., S. Singh, C.E. Giordano, T.A. Nell and D.B. McConnell, 1983. Effects of sodium chloride on *Cynodon* turfgrasses. Agron. J., 75: 927-930.
50. Kumar, A., 1988. Performance of forage grasses in saline soils. Ind. J. Agron., 33: 26-30.
51. Peacock, C. H., A.E. Dudeck and J.C. Widmon, 1993. Growth and mineral content of *Stenotaphrum* Augustine grass cultivars in response to salinity. J. Amer. Soc. Hort. Sci., 118: 464-469.
52. Qian, Y.L., M.C. Engelke and M.J. Foster, 2000. Salinity effects on zoysiagrass cultivars and experimental lines. Crop Sci., 40: 488-492.
53. Kim, C.S. and Y.S. Kim, 1984. Study on the salt tolerance of several forage crops. Res. Rep. Agric. Sci. and Techn., 11: 183-189.
54. Stark, C., 1985. Salt resistance and potassium nutrition of *Lolium perenne* L. following treatment with growth regulators. Beitrage zor tropischen Landwirtschaft und Veterinarmedzin, 23: 159-164.
55. Meidner, H. and T.A. Mansfield, 1968. Physiology of Stomata. McGraw-Hill Book Co., Maidenhead, England, pp: 179.