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The interactive effects of saline irrigation water and fertilization on growth and quality of seashore paspalum turf grown in some soils of Egypt

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ABSTRACT

A n experiment was conducted under the full sun at Orman Botanic Garden, Giza, Egypt during 2015 and 2016 seasons to find out the response of seashore paspalum (*Paspalum vaginatum* Swartz.) cultivated in plastic trays (35 x 20 x 12 cm) filled with either sandy or calcareous soil to NaCl salinity of irrigation water at the levels of 0, 4000, 8000, 12000, 16000 and 20000 ppm, fertilization with kristalon (19:19:19 + micronutrients) at the rates of 0, 2 and 4g/tray (viz. 0, 28.6 and 57.2 g/m^2) and their interactions. The obtained results showed that means of plant height (cm), covering rate (%), herb fresh and dry weights (g) after cut and root length (cm) were descendingly decreased with increasing salinity level of irrigation water comparing with the control means in both seasons, but they were progressively increased as the rate of kristalon was increased. The planting in calcareous soil gave, to some extent taller plants, higher coverage rate, heavier fresh and dry weights of herb after cut and longer roots than cultivating in sandy soil in the two seasons. However, the prevalence was for combining between irrigation with fresh water (non salinized water) and fertilizing with 4 g kristalon/tray, as this combination gave the highest means of various vegetative and root growth parameters mentioned before for plants grown either in sandy or calcareous soil. A similar trend was also obtained regarding the salt resistance index (SRI %) and the leaf content of chlorophyll a, chlorophyll b, nitrogen, phosphorus and potassium %. The opposite was the right concerning the leaf content of sodium, chloride and proline, as the means of these constituents were progressively increased with rising salinity concentration, but were gradually decreased with elevating kristalon rate, except for proline content which was also cumulatively increased with raising kristalon level. So, the highest content of Na and Cl was noticed in plants irrigated with the highest salinity level and abandoned of fertilizing with kristalon, while the highest proline content was observed in treated plants with the highest levels of both salinity and kristalon. From these results, it can be recommended to irrigate seashore paspalum plants grown in sandy soil with saline water up to 12000 ppm NaCl and those grown in calcareous one with saline water up to 16000 ppm NaCl and fertilizing each with kristalon at the rate of 57.2 g/m^2 to obtain the best growth, colour and higher covering density under salinity stress of NaCl.

Key words: Seashore paspalum turf, Kristalon, sandy, calcareous, soil, fertilization, salt resistance index, herb fresh and dry weights.

Introduction

Increased need for salt tolerant grasses is still continues due to salt accumulation in soil, increased restrictions on groundwater utilization and salt water intrusion into groundwater (Hoss, 1981 and Lee *et al*., 2004). The use of the halophytic seashore paspalum as an important warm-season turfgrass indigenous to tropical and coastal areas worldwide for saline situations has been suggested before by Guiot and Flynn (1983), Dudeck and Peacock (1985), Morton (1993) and Lee *et al*., (2004). In this regard, Malcolm and Smith (1991) reported that seashore paspalum can tolerate salt concentrations from 5.5 to 20.3 dS/m. Peacock and Dudeck (1995) mentioned that seashore paspalum cv. FSP-1 can tolerate salinity of synthetic sea water up to 35-40 dS/m more than cv. Adalayd. Aside from, some studies showed that higher salinity may cause some injuries for such halophytic turfgrass. In this concern, Pessarakli and Touchane (2006) found that shoot and root lengths of seashore paspalum were stimulated at the low levels of NaCl salinity (5000 and 10000 ppm), but substantially

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decreased at the higher levels (especially at 30000 ppm). As the exposure time to salt stress was progressed, shoot and root fresh and dry weights were more affected than shoot and root length. Likewise, Guo *et al*., (2016) noticed that the salinity stressed accessions of seashore paspalum (340 and 510 mmol/l NaCl) showed significantly increased leaf firing, decreased shoot growth and caused an increase or decrease in root growth. The P40 accession had the best salinity tolerance with little leaf firing, followed by Sea Isle 2000, P29 and P14. On the other side, Pompeiano *et al*., (2016) observed that biomass fresh and dry weights of Sea Spray seashore paspalum, a recently released seeded cultivar was not affected by NaCl salinity up to 600 mM after exposure to this severe salinity for 14 days.

On the other turfgrass species, similar observations were also, obtained by Abdel-Fattah *et al*., (2008) on Tifway Bermudagrass, Shahin *et al*., (2014) on tall fescue and Shahin *et al*., (2015 b) on Bermudagrass, ryegrass and tall fescue.

On the contrary to the effect of salinity, turf fertilization will maintain good colour, density and vigour, and the turf will not easily succumb to insects, weeds or diseases. In this respect, Shahin (2005) stated that fertilizing seashore paspalum turf grown in either sandy or loamy soil with 41.67 g urea + 66.67 g calcium superphosphate + 41.67 g potassium sulphate/m^2 significantly increased plant height, density, herb fresh and dry weights and leaf content of pigments, total carbohydrates, N, P and K. The growth, colour and chemical composition of paspalum plants grown in a loamy soil were better than those plants grown in a sandy one. Similarly, were those results explored by Newman *et al*., (2006) on Bahiagrass (*Paspalum notatum*) as well as Kopec *et al*., (2007), El-Sayed (2012 a and b), Rimi *et al*., (2013 a and b), Pompeiano *et al*., (2014), Tawila *et al*., (2015) and Shahin *et al*., (2015 a) on seashore paspalum (*Paspalum vaginatum*).

The soil portion of a turf system represents the main fraction of the biological and physical activities necessary for turfgrass growth. It serves as a growing medium and a source of nutrients and water. Basically, the soil particles size and their distribution, beside the soil structure determine the soil water relationships which greatly affect vegetative growth and root distribution (Kopec, 1995). Furthermore, Groffman *et al*., (1996) suggested that soil type is a more important controller of microbial biomass and activity than grass species itself. So, it greatly affects turnover and preservation of organic matter. The present work, however aims to study the effects of soil type, saline water concentrations, kristalon rates and their interactions on growth performance and chemical composition of seashore paspalum turf under the local environments of Egypt.

Materials and Methods

The current investigation was performed under the full sun at Orman Botanic Garden, Giza, Egypt, throughout the two consecutive seasons of 2015 and 2016 to reveal the response of seashore paspalum plants cultivated in either sandy or calcareous soil to salinity of irrigation water, kristalon fertilizer rates and their interactions on growth performance, colour and density of such turfgrass.
Therefore, cuttings of Seashore paspalum (*Paspalum vaginatum* Swartz.) at about 2-2.5 cm long were planted on April, 1st for each season in plastic trays (35 x 20 x 12 cm; long x width x depth) filled with about 7 kg of either sandy or calcareous soil/tray. The physical and chemical properties of the soil textures used in the two seasons are shown in Table (a).

Table a: The physical and chemical properties of the two soils used in 2015 and 2016 seasons.

Soil type	Particle size distribution (%)				E.C. (dS/m)	pH	S.P.	Organic matter (%)	Cations (meq/l)				Anions (Meq/l)		
	Coarse sand	Fine sand	Silt	Clay					Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3^{-}	Cl^{-}	SO_4^{--}
Sandy	81.33	9.75	0.52	8.40	3.69	7.88	21.51	0.13	6.28	1.72	0.92	7.07	2.50	3.76	9.73
Calcareous	9.48	26.50	35.31	28.71	2.11	8.08	30.10	0.40	13.36	3.68	0.39	5.63	4.72	9.18	9.16

The cuttings (about 100 cuttings/tray) were regularly scattered (just as large seeds) on the soil surface of each tray, then gently pressed to be more contact with the soil, and thereafter were covered with a thin layer (1cm) of the same tray soil. Immediately after planting, the trays were daily sprayed with little fresh water (about 200 ml) to wet only the zone in which the cuttings are imbedded. This was done for only 2 weeks (till mid of April) as the cuttings were completely sprouted. The plants then received the following treatments:

a. Saline irrigation water at concentrations of 0 (as control), 4000, 8000, 12000, 16000 and 20000 ppm of NaCl, where the trays were irrigated day after day with 500 ml of the different saline water treatments till the end of the experiment (October, 15th).
b. Fertilization with kristalon (19:19:19 + micronutrients, manufactured by DSM Agro specialists, Holland) as a soil drench at the rates of 0, 2 and 4 g/tray every month, viz. 0, 28.6 and 57.2 g/m^2, respectively.
c. The soil type, salinity and fertilization treatments were combined factorially to from 36 interaction treatments.

The split-split plot design was used for each season with 3 replicates as each replicate contained 3 trays (Mead *et al*., 1993). The main plot was kristolan rate, while the sub-and sub-sub-plots were devoted to soil type and salinity concentration, respectively. All the other agricultural practices needed for such plantation were done as usually growers did.

After one month from commencing of the treatments (on mid of May), the first cut was handily done using a very sharp stainless steel shear to leave only one inch long stubbles, while the other five cuts were carried out monthly afterwards. Before each cut, plant height (cm) was measured, while covering rate % (Mahdi, 1953), herb fresh and dry weights (g) and root length (cm) were determined after each cut. However, the means of each parameter mentioned above in the six taken cuts were collected and expressed in the tables as an average for all cuts. Besides, the salt resistance index (SRI %), as a real indicator for salinity tolerance was calculated from the equation mentioned before by Wu and Huff (1983):

SRI (%) = Mean root length of the salt treated plants/mean root length of control one x 100

In fresh leaf samples taken from the last cut, chlorophyll a and chlorophyll b content (mg/g f.w.) was evaluated by the method of Moran (1982), while in dry ones, the percentages of nitrogen (Pregl, 1945), phosphorus (Luatanab and Olsen, 1965) and potassium (Jackson, 1973), sodium and chloride content as mg/g d.w. (Jackson, 1973), as well as the free amino acid proline (mg/100 g d.w.) by the method explained by Bates *et al.,* (1973) were determined.

Data were then tabulated and subjected to analysis of variance using program of SAS Institute (2009) followed by Duncan's New Multiple Range Test (Steel and Torrie, 1980) to explore the significancy among means of the different treatments.

Results and Discussion

Effect of soil type, saline water, kristolan rate and their interactions on:

1. Vegetative and root growth traits:

Data presented in Tables (1, 2, 3, 4 and 5) show that means of plant height (cm), covering rate (%), herb fresh and dry weights (g) and root length (cm) were descendingly decreased with increasing salinity concentration of irrigation water compared to control means regardless of soil type and kristalon rate in both seasons. Thus, the highest means were recorded in the two seasons by plants irrigated with fresh water, while the least records were attained by the highest level of salinity (20000 ppm). This may be due to a decrease in all volume at a constant cell number caused by salinity (Lee *et al*., 2004 a). Likewise, Pessarakli and Touchane (2006) stated that mechanism of salt may result in cell division inhibitory and hence, reduces the rate of plant development. Besides, Harivandi *et al*., (1992) suggested that plants known to exhibit salt tolerance often mediate salt stress by osmotic adjustment, therefore minimizing changes in turgor potential and reducing the overall effect on plant growth responses linked to carbon dioxide assimilation and cell elongation. Further, Jou *et al*., (2006) revealed that ATpase participates in the endoplasmic reticulum Golgi mediated protein sorting machinery for both housekeeping function and compartmentalization of excess Na^+ under high salinity. In this connection, Pompeiano *et al*., (2016) reported that the use of straight seawater or brackish water for "Sea Spray" seashore paspalum as a salt tolerant species, creating the opportunity to develop turfgrass landscapes in arid and seashore regions.

Table 1: Effect of soil type, saline water, kristalon rate and their interactions on plant height (cm) of *Paspalum vaginatum* Swartz. during 2015 and 2016 seasons.

Soil type	Salinity level (ppm) \ Kristalon rate (g/tray)	First season: 2015			Mean (salinity level)	Second season: 2016			Mean (salinity level)
		0	2	4		0	2	4	
Sandy	0	21.54e-i	26.47a-c	28.35ab	25.29a	21.76d-j	27.15ab	28.80a	25.53a
	4000	18.67g-m	23.16c-g	22.20d-h		18.87i-m	23.86b-g	24.76b-e	
	8000	14.35m-p	21.79e-i	22.80c-h	21.97b	14.50op	22.45d-i	23.25c-h	22.67b
	12000	12.18n-p	18.82g-l	21.33e-i		12.33pq	19.40h-l	21.73d-j	
	16000	10.88op	18.62g-m	20.45e-j	19.78c	11.01q	19.00i-l	20.91f-j	20.10c
	20000	10.46p	16.48j-m	17.51i-m		10.50q	16.91k-o	18.00j-o	
Calcareous	0	20.14f-k	26.18a-d	29.07a	18.57cd	20.45f-k	26.23a-c	28.78a	18.57d
	4000	18.93g-l	23.95c-f	24.90b-e		19.22i-l	24.18b-f	25.15b-d	
	8000	15.99k-n	21.53e-i	22.20d-h	17.69de	16.25l-o	21.75d-j	22.43d-i	17.68d
	12000	15.73l-n	21.18e-i	22.17d-h		15.98l-o	21.00e-j	21.00e-j	
	16000	14.98l-o	20.33f-k	20.89e-j	16.43e	15.21m-p	19.78h-l	20.16g-k	16.21e
	20000	14.83l-o	18.46h-m	20.83e-j		15.07n-p	17.99j-o	18.79i-n	
Mean (soil type)		19.23b		20.68a		19.73b		20.52a	
Mean (Kristalon rate)		15.72c	21.41b	22.73a		15.93c	21.64b	22.81a	

Means followed by the same letter in column or row do not differ significantly according to Duncan's New Multiple Range t-Test at P = 0.05

Table 2: Effect of soil type, saline water, kristalon rate and their interactions on covering rate (%) of *Paspalum vaginatum* Swartz. turf during 2015 and 2016 seasons.

Soil type	Salinity level (ppm) \ Kristalon rate (g/tray)	First season: 2015			Mean (salinity level)	Second season: 2016			Mean (salinity level)
		0	2	4		0	2	4	
Sandy	0	78.47h-j	96.34ab	100.00a	89.34a	77.50g-k	98.81a	100.00a	91.32a
	4000	70.68m-o	84.65e-g	88.26d-f		65.61no	87.20b-d	88.90bc	
	8000	61.20qr	79.67g-i	83.31f-h	82.49b	55.10rs	82.00d-g	84.15c-f	83.45b
	12000	55.99rs	68.89n-p	77.93h-k		50.46s	71.33lm	78.71g-j	
	16000	45.79t	67.92op	72.69k-o	74.34c	41.29t	70.00mn	71.48lm	74.68c
	20000	43.95t	60.16qr	64.03pq		39.67t	62.81op	64.67op	
Calcareous	0	73.23j-o	95.00a-c	92.98b-d	70.81d	75.29i-m	96.33a	100.00a	69.78d
	4000	71.45-o	88.90de	91.02cd		73.51j-m	90.15b	95.31a	
	8000	60.76qr	78.54h-j	82.54gh	66.17e	61.73o-q	79.63f-i	85.50b-e	64.44e
	12000	64.77pq	76.33i-l	80.96g-i		60.00p-r	76.41h-l	71.76e-h	
	16000	60.05qr	73.86j-n	76.68i-l	61.06f	56.97qr	71.98k-m	74.90i-m	59.41f
	20000	53.82s	68.74n-p	75.68i-m		51.48s	65.58no	72.27k-m	
Mean (soil type)		72.22b		75.85a		71.65b		76.04a	
Mean (Kristalon rate)		61.68c	78.25b	82.17a		59.05c	79.35b	83.14a	

Means followed by the same letter in column or row do not differ significantly according to Duncan's New Multiple Range t-Test at P = 0.05

On the other side, the means of previously mentioned characters were progressively increased as the rate of kristalon was increased to reach the maximal values by the rate of 4 g kristalon /tray relative to control in the two seasons. However, the rate of increment in the means of these traits was greater between 2 g/tray application rate and control, but was close to some extent between 2 g/tray rate and 4 g/tray one in both seasons. This may indicate the role of kristalon as a quick soluble complete fertilizer in providing the turf plants with various nutrients necessary for good and healthy growth, even under salinity stress. In this regard, Abdel-Fattah *et al*., (2008) pointed out that Tifway

Bermudagrass grown in sand and loam soil mixture (1:1, v/v) can proportionally tolerate salinity of irrigation water up to 16000 ppm when the soil mixture was drenched with humic acid at 20 ml/l.

It was also noticed from data listed in Tables (1, 2, 3, 4 and 5) that soil type had a marked effect on the different vegetative and root growth parameters measured in this study, as planting in calcareous soil gave, to some extent taller plants, higher covering rate, heaviest fresh and dry weights of herb and longer roots comparing with cultivating in sandy soil in the first and second seasons. This may be attributed to that calcareous soil has better texture than sandy one. It may be also retain more water than sandy soil due to it's smaller sized particles (Kopec, 1995). In this respect, Shahin (2005) found that paspalum plants grown in loamy soil gave better height, density, clippings fresh and dry weights and longer roots than those grown in sandy one.

As for the interaction treatments, it is observed that plants irrigated with fresh water (zero salinity) and fertilized with the higher level of kristalon (4 g/ tray) scored the utmost high means of plant height, covering rate, herb fresh and dry weights and root length over all the individual and combined treatments in the two seasons irrespective of the soil type wherein they are grown. The second rank was occupied in both seasons by combining either between irrigating with fresh water and dressing with 2 g kristalon/tray or between irrigating with saline water at 4000 ppm level and dressing with either rate of kristalon applied, as these three combinations registered means greatly close together in most cases of the two seasons.

In general, fertilizing seashore paspalum plants with kristalon at the rate of 4 g/tray relatively attained better results than 2g/tray rate and culturing in calcareous soil slightly improved vegetative and root growth traits more than cultivating in sandy one regardless of salinity concentration in both seasons. This may indicate the role of both kristalon at higher rate and calcareous soil that has a better texture in enhancing growth of paspalum plants under salinity stress. However, these results go in line with those obtained by Malcolm and Smith (1991), Peacock and Dudeck (1995), Shahin (2005), Kopec *et al*., (2007), Rimi *et al*., (2013 a, b), Tawila *et al*., (2015) and Guo *et al*., (2016) on seashore paspalum turfgrass. In this respect, Shahin *et al*., (2015) advised to fertigate seachore paspalum turf grown in sand + clay mixture with humic acid at 20 ml/l + Moringa leaf powder at 1 g/l to obtain the best growth, density rate, colour and chemical composition.

Table 3: Effect of soil type, saline water, kristalon rate and their interactions on herb fresh weight (g) of *Paspalum vaginatum* Swartz. plants during 2015 and 2016 seasons.

Soil type	Kristalon rate (g/tray) / Salinity level (ppm)	First season: 2015			Mean (salinity level)	Second season: 2016			Mean (salinity level)
		0	2	4		0	2	4	
Sandy	0	10.10g-m	14.31b-e	16.58ab	14.30a	11.08h-k	15.58c-e	18.10ab	15.57a
	4000	9.26i-n	12.87c-h	12.85c-h		9.98i-m	13.79d-g	13.98d-g	
	8000	7.73l-p	11.63e-k	12.40d-i	12.34b	8.50k-o	12.51f-i	12.56f-i	13.20b
	12000	6.71m-p	10.01g-m	11.43e-k		7.32m-p	10.91h-k	10.97h-k	
	16000	5.70op	9.57h-n	10.18g-m	11.11c	6.23op	10.47h-l	9.79j-m	11.66c
	20000	5.03p	8.35j-p	9.23i-n		5.50p	9.15j-n	9.10j-n	
Calcareous	0	11.89e-i	15.33a-d	17.57a	9.97c	12.86f-h	16.68bc	19.10a	10.29d
	4000	10.12g-m	13.11c-g	15.80a-c		10.80h-k	14.27c-f	16.35b-d	
	8000	9.46h-n	11.80e-j	13.65b-f	8.79d	9.59j-n	12.61f-i	14.20c-f	9.23d
	12000	8.90i-o	10.41f-l	12.35d-i		8.34k-o	11.00h-k	13.18e-h	
	16000	7.73l-p	9.00i-o	10.53f-l	7.61e	7.93l-p	9.50j-n	11.45g-j	8.06e
	20000	6.51n-p	8.19k-p	8.36j-p		7.00n-p	8.43k-o	9.17j-n	
Mean (soil type)		10.22b		11.15a		10.86b		11.80a	
Mean (Kristalon rate)		8.26c	11.22b	12.58a		8.76c	12.08b	13.16a	

Means followed by the same letter in column or row do not differ significantly according to Duncan's New Multiple Range t-Test at P = 0.05

Table 4: Effect of soil type, saline water, kristalon rate and their interactions on herb dry weight (g) of *Paspalum vaginatum* Swartz. plants during 2015 and 2016 seasons.

Soil type	Kristalon rate (g/tray) / Salinity level (ppm)	First season: 2015			Mean (salinity level)	Second season: 2016			Mean (salinity level)
		0	2	4		0	2	4	
Sandy	0	2.73e-l	3.50c-h	4.68a-c	3.95a	2.98e-m	3.82c-g	5.10ab	4.31a
	4000	2.48f-m	3.21d-j	3.63b-g		2.70h-n	3.40d-k	3.96c-f	
	8000	2.10i-m	2.91e-k	3.46d-h	3.48ab	2.21l-o	3.11e-l	3.80c-h	3.77b
	12000	1.81k-m	2.50f-m	3.00e-k		1.95m-o	2.73g-n	3.13e-l	
	16000	1.54lm	2.36g-m	2.81e-k	3.11bc	1.68no	2.46j-o	2.90f-m	3.33c
	20000	1.33m	2.10i-m	2.47f-m		1.42o	2.15l-o	2.49j-n	
Calcareous	0	3.28d-i	4.25a-d	5.27a	2.72cd	3.48d-j	4.67bc	5.78a	2.90d
	4000	3.14d-j	3.67b-f	4.76ab		3.33d-k	4.03c-e	5.20ab	
	8000	2.94e-k	3.26d-i	3.96b-e	2.44de	3.10e-l	3.50d-j	4.25b-d	2.59de
	12000	2.76e-l	2.73e-l	3.51c-h		2.91f-m	2.98e-m	3.72c-i	
	16000	2.31h-m	2.50f-m	3.10d-j	2.10e	2.47j-o	2.67i-n	3.35d-k	2.19e
	20000	1.94j-m	2.23h-m	2.50f-m		2.11l-o	2.36k-o	2.58j-n	
Mean (soil type)		2.70b		3.23a		2.89b		3.47a	
Mean (Kristalon rate)		2.36c	2.94b	3.60a		2.53c	3.16b	3.86a	

Means followed by the same letter in column or row do not differ significantly according to Duncan's New Multiple Range t-Test at P = 0.05

Table 5: Effect of soil type, saline water, kristalon rate and their interactions on root length (cm) of *Paspalum vaginatum* Swartz. plants during 2015 and 2016 seasons.

Soil type	Kristalon rate (g/tray) / Salinity level (ppm)	First season: 2015			Mean (salinity)	Second season: 2016			Mean
		0	2	4		0	2	4	
Sandy	0	12.40e-k	15.29ab	16.46a	14.54a	12.50e-j	15.58a-d	16.71a	14.81a
	4000	11.23i-m	13.45c-g	13.40c-g		11.34i-l	13.71d-g	13.79c-f	
	8000	9.31m-q	12.64e-j	13.28d-h	13.15b	9.41l-o	12.79e-j	13.55e-h	13.40b
	12000	8.62p-r	10.82j-o	12.37f-k		8.71n-p	11.02j-m	12.33f-j	
	16000	7.13rs	9.98l-p	10.89j-n	11.98c	7.20pq	10.10k-n	11.12j-m	12.18c
	20000	6.20s	8.94n-r	9.78l-p		6.26q	9.10m-p	9.98k-n	
Calcareous	0	12.11f-k	15.59ab	15.36a-c	10.89d	12.33f-j	15.76a-c	15.98ab	11.03d
	4000	11.34h-m	14.40b-e	15.08a-d		11.53h-k	14.50b-e	15.54a-d	
	8000	9.64l-p	13.11e-i	13.92b-f	9.87e	9.80k-n	13.21e-i	14.32b-f	9.99e
	12000	8.95n-r	11.55g-l	13.00e-i		9.07m-p	11.68g-k	13.36e-i	
	16000	8.78o-r	10.11l-p	12.31f-k	8.74f	8.69n-p	10.20k-n	12.65e-j	8.89f
	20000	7.61q-s	9.54l-q	10.38k-p		7.20o-q	9.60k-o	10.71j-n	
Mean (soil type)		11.23b		11.82a		11.40b		12.04a	
Mean (Kristalon rate)		9.44c	12.22b	13.02a		9.55c	12.27b	13.34a	

Means followed by the same letter in column or row do not differ significantly according to Duncan's New Multiple Range t-Test at P = 0.05

2. Salt resistance index (SRI %):

The salt resistance index (%), as a real indicator for salt tolerance was 100 % for control plants grown in either sandy or calcareous soil as in the first and second seasons shown in Table (6). However, the percent of this index was increased to more than 100 % for plants fertilized with either 2 or 4 g kristalon/tray and irrigated with either fresh water or saline water at low level (4000 and 8000 ppm) in both seasons regardless of the soil type. This means that kristalon as a complete chemical fertilizer plays a vital role in improving salinity tolerance of paspalum plants grown in either sandy or calcareous soil and irrigated with saline water up to 8000 ppm to be more than that of control through elongating their root. In general, kristalon rate of 4 g/tray gave higher salt resistance indices than 2g/tray rate, especially in the calcareous soil, in which the percent of such index was more than 100 % even for plants irrigated with saline water up to 16000 ppm in the two seasons. The plants irrigated with 12000 ppm saline water and fertilized with 4 g kristalon/tray in sandy soil exhibited good tolerance for salinity giving SRI % closely near to that of control plants in both seasons (99.76 % in the first season and 98.64 % in the second one).

Hence, paspalum plants grown in the sandy soil can tolerate salinity of irrigation water up to 12000 ppm if they were fertilized with the higher rate of kristalon (4 g/tray), while in the calcareous soil, that was true for plants irrigated with saline water up to 16000 ppm and dressed with the same rate of kristalon (4 g/tray). This gain is coincided with that of Peacock and Dudeck (1995) who declared that root growth of seashore paspalum cv. "Adalayd" was decreased linearly, but rooting in cv. "FSP-1" was increased to a maximum at 10000 ppm synthetic salinity before decreasing with higher salinity levels, viz. FSP-1 cultivar exhibited increased salinity tolerance due to increased rooting as salinity increased up to 10000 ppm. Likewise, Guo *et al*., (2016) clarified that 27 seashore paspalum accessions showed an increase or decrease in root growth when subjected to NaCl salinity at 340 and 510 mmol/l concentrations.

Table 6: Effect of soil type, saline water, kristalon rate and their interactions on salt resistance index (%) of *Paspalum vaginatum* Swartz. plants during 2015 and 2016 seasons.

Soil type	Kristalon rate (g/tray) / Salinity level (ppm)	First season: 2015			Mean	Second season: 2016			Mean
		0	2	4		0	2	4	
Sandy	0	100.00gh	123.31bc	132.74a	118.61a	100.00gh	124.64b	133.68a	119.29a
	4000	90.57i-k	108.47ef	108.07ef		90.72ij	109.68de	110.32de	
	8000	75.08n-q	101.94fg	107.10f	107.37b	75.28n-p	102.32fg	108.40ef	107.98b
	12000	69.52q	87.26j-l	99.76gh		69.68p	88.16i-k	98.64gh	
	16000	57.50r	80.48l-n	87.82jk	97.82c	57.60q	80.80l-n	88.96i-k	98.13c
	20000	50.00s	72.10pq	78.87m-p		50.08r	72.80op	79.84m-o	
Calcareous	0	100.00gh	128.74ab	126.84ab	88.86d	100.00gh	127.82ab	129.60ab	88.86d
	4000	93.64h-j	118.91cd	124.53bc		93.51h-j	117.60c	126.04b	
	8000	79.60m-o	108.26ef	114.95de	80.57e	79.48m-o	107.14ef	116.14cd	80.53e
	12000	73.91n-q	95.38g-i	107.35f		73.56op	94.73hi	108.36ef	
	16000	72.50o-q	83.49k-m	101.65fg	71.38f	70.48p	82.73k-m	102.60fg	71.65f
	20000	62.84r	78.78m-p	85.71k-m		62.45q	77.86m-o	86.86j-l	
Mean (soil type)		90.59b		97.62a		91.20b		97.61a	
Mean (Kristalon rate)		77.10c	98.93b	106.28a		76.90c	98.86b	107.45a	

Means followed by the same letter in column or row do not differ significantly according to Duncan's New Multiple Range t-Test at P = 0.05

3. Chemical composition of the leaves:

A similar trend to that of vegetative and root growth traits was also obtained in relation to leaf content of chlorophyll a and chlorophyll b (mg/g f.w.), as well as the percentages of nitrogen, phosphorus and potassium, (Tables 7, 8 and 9), as the content of these constituents was descendingly decreased with increasing salinity level, but ascendingly increased as the rate of kristalon was increased. Besides, plants grown in the calcareous soil possessed higher content of the aforenamed constituents than those grown in the sandy one, except for phosphorus concentration which was higher in plants cultivated in sandy soil and less in those cultivated in calcareous one. This may be due to that calcareous soil contains higher content of organic matter than sandy one (Table, a). In this regard, Dudeck and Peacock (1985) stated that K content decreased sharply in paspalum leaves with increasing salt level.

Table 7: Effect of soil type, saline water, kristalon rate and their interactions on chlorophyll a and chlorophyll b content in the leaves of *Paspalum vaginatum* Swartz. plants during 2016 season.

Soil type	Salinity level (ppm) / Kristalon rate (g/tray)	Chlorophyll a (mg/g f.w.)				Chlorophyll b (mg/g f.w.)			
		0	2	4	Mean	0	2	4	Mean
Sandy	0	1.379	2.176	2.349	2.030	0.860	0.921	1.133	0.990
	4000	1.288	2.019	2.163		0.801	0.839	1.045	
	8000	1.167	1.942	1.990	1.870	0.728	0.768	0.883	0.930
	12000	1.073	1.698	1.831		0.636	0.661	0.767	
	16000	0.981	1.435	1.589	1.740	0.523	0.560	0.631	0.810
	20000	0.836	1.214	1.425		0.441	0.511	0.582	
Calcareous	0	1.584	2.269	2.418	1.550	0.793	0.979	1.230	0.710
	4000	1.456	2.088	2.225		0.731	0.981	1.210	
	8000	1.341	1.92	2.101	1.340	0.629	0.833	1.029	0.610
	12000	1.157	1.645	1.883		0.561	0.711	0.941	
	16000	1.048	1.376	1.594	1.150	0.489	0.624	0.807	0.530
	20000	0.921	1.163	1.358		0.407	0.550	0.679	
Mean (soil type)		1.586		1.642		0.740		0.790	
Mean (Kristalon rate g/tray)		1.190	1.750	1.910		0.630	0.740	0.910	

Table 8: Effect of soil type, saline water, kristalon rate and their interactions on nitrogen and phosphorus % in the leaves of *Paspalum vaginatum* Swartz. plants during 2016 season.

Soil type	Salinity level (ppm) / Kristalon rate (g/tray)	N (%)				P (%)			
		0	2	4	Mean	0	2	4	Mean
Sandy	0	1.270	1.610	2.800	1.960	0.217	0.263	0.389	0.270
	4000	1.107	1.518	1.934		0.214	0.232	0.247	
	8000	1.029	1.367	1.840	1.720	0.193	0.207	0.283	0.230
	12000	0.918	1.310	1.657		0.170	0.189	0.230	
	16000	0.833	1.108	1.348	1.580	0.141	0.158	0.187	0.220
	20000	0.769	0.996	1.201		0.118	0.129	0.154	
Calcareous	0	1.593	1.991	2.471	1.410	0.176	0.228	0.327	0.190
	4000	1.271	2.000	2.465		0.196	0.211	0.291	
	8000	1.178	1.831	2.215	1.180	0.171	0.186	0.265	0.160
	12000	1.053	1.529	1.969		0.153	0.163	0.216	
	16000	0.874	1.312	1.624	1.050	0.143	0.150	0.191	0.140
	20000	0.781	1.173	1.401		0.129	0.140	0.157	
Mean (soil type)		1.368		1.596		0.207		0.194	
Mean (Kristalon rate)		1.060	1.480	1.910		0.170	0.190	0.240	

The results cleared also that the interaction treatments caused a pronounced effect on the content of chlorophylls, N, P and K % as the highest values of such components were attained by plants irrigated with fresh water and dressed with kristalon at 4 g/tray. Moreover, combining between irrigation with saline water up to 8000 ppm in the sandy soil and up to 12000 ppm in the calcareous one and fertilizing with kristalon at any rate often recorded higher content of these constituents than the control. Furthermore, kristalon at the high level (4 g/tray) raised the content of previous constituents more than the low level (2 g/tray) irrespective of salinity concentration.

On the other hand, sodium and chloride content (mg/g d.w.) was progressively increased with increasing salinity concentration, whereas gradually declined as a result of increasing kristalon rate (Tables, 9 and 10). This may indicate the main role of fertilizing with kristalon in enhancing tolerance

of paspalum plants to salinity. Another main reason is increasing content of the free amino acid proline (mg/100 g d.w.) with increasing either salinity level or kristalon rate (Table, 10). Contrary to the content of chlorophylls, N, P and K %, the highest content of Na and Cl was obtained by plants irrigated with the highest level of salinity and abandoned of fertilizing with kristalon, while the highest content of proline was gained by plants watered with the highest salinity level and dressed with the highest rate of kristalon. In this connection, Peacock and Dudeck (1995) claimed that the suitability of irrigation water containing salts depends on the salinity, sodium and boron levels. Jou *et al*., (2006) reported that higher salt level in the soil solution usually leads to an increase in the uptake of some highly hydrophilic ions, e.g. Na or borate. Moreover, Barnett and Naylor (1966) found that free proline in the leaves of stressed bermudagrass plants was 10-125 fold the value in control plants.
The aforementioned results are in harmony with those of Kopec *et al*., (2007) who revealed that leaf tissue N in seashore pasplum was increased in response to increasing levels of N application. Pompeiano *et al*., (2014) noted that pigment content in the leaves of *Paspalum vaginatum* "Salam" was not affected by salinity level, though chlorophyll a was slightly decreased at the highest salinity level (20000 ppm). Guo *et al*., (2016) postulated that K^+ concentration in the shoots and roots of seashore paspalum accessions was decreased in response to NaCl salinity of 340 and 510 mmol/l, the reduction in the shoots was lower (26.2 %) than in the roots (69.7 %), whereas Na^+ content was greatly increased in the shoots and roots, the percent of increase in the shoot was 15-fold, but in the roots was 25-fold compared to nonsalinized control. Pompeiano *et al*., (2016) stated that changes were observed in pigment and carbohydrates content "Sea Spray" seashore paspalum leaves among the different NaCl salinity treatments (0-600 mM).

Table 9: Effect of soil type, saline water, kristalon rate and their interactions on potassium and sodium % in the leaves of *Paspalum vaginatum* Swartz. plants during 2016 season.

Soil type	Kristalon rate (g/tray) / Salinity level (ppm)	K (%)				Na (mg/g d.w.)			
		0	2	4	Mean	0	2	4	Mean
Sandy	0	0.815	1.078	1.149	1.000	1.19	1.18	1.16	1.13
	4000	0.809	0.898	0.964		1.41	1.33	1.35	
	8000	0.748	0.837	0.931	0.900	1.95	2.10	1.74	1.28
	12000	0.659	0.739	0.876		2.31	2.16	2.01	
	16000	0.601	0.723	0.832	0.860	3.24	2.79	2.33	1.80
	20000	0.584	0.678	0.754		4.50	3.18	2.41	
Calcareous	0	0.806	1.029	1.152	0.790	1.12	1.05	1.05	2.07
	4000	0.804	0.920	0.996		1.34	1.16	1.10	
	8000	0.735	0.927	0.958	0.740	1.93	1.64	1.41	2.66
	12000	0.689	0.849	0.932		2.32	1.98	1.63	
	16000	0.613	0.823	0.848	0.690	3.03	2.39	2.17	3.10
	20000	0.590	0.751	0.801		3.37	2.81	2.34	
Mean (soil type)		0.815		0.846		2.13		1.88	
Mean (Kristalon rate)		0.700	0.850	0.930		2.31	1.98	1.73	

Table 10: Effect of soil type, saline water, kristalon rate and their interactions on chloride and proline content in the leaves of *Paspalum vaginatum* Swartz. plants during 2016 season.

Soil type	Kristalon rate (g/tray) / Salinity level (ppm)	Cl (mg/g d.w.)				Proline (mg/g d.w.)			
		0	2	4	Mean	0	2	4	Mean
Sandy	0	1.34	1.19	1.07	1.12	0.535	0.554	0.883	0.54
	4000	1.68	1.50	1.33		0.762	1.083	1.151	
	8000	1.93	1.72	1.46	1.38	0.998	1.749	1.503	0.96
	12000	2.78	2.25	1.83		1.456	2.340	2.541	
	16000	3.97	2.71	2.41	1.60	2.196	4.213	3.390	1.46
	20000	4.86	3.80	2.90		3.128	6.582	5.300	
Calcareous	0	1.15	1.03	0.94	2.11	0.320	0.377	0.582	2.29
	4000	1.40	1.21	1.13		0.528	1.079	1.161	
	8000	1.76	1.48	1.26	2.85	0.871	1.750	1.879	3.62
	12000	2.37	1.85	1.55		1.536	2.834	3.045	
	16000	3.48	2.41	2.11	3.52	2.373	4.592	4.932	5.61
	20000	4.23	2.92	2.39		3.914	7.138	7.589	
Mean (soil type)		2.26		1.93		2.24		2.58	
Mean (Kristalon rate)		2.58	2.01	1.70		1.55	2.86	2.83	

According to the previous findings, it can be concluded that seashore paspalum plants grown in a sandy soil can tolerate salinity (NaCl) of irrigation water up to 12000 ppm if they were fertilized monthly with kristalon at 57.2 g/m2, while those grown in a calcareous soil can tolerate irrigation water salinity up to 16000 ppm if they were fertilized as well with the same rate of kristalon.

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