Nutrient uptake responses of tropical turfgrass species to salinity stress

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Abstract

The need for salinity tolerance of turfgrasses is increasing because of the augmented use of effluent or other low quality water (seawater) for turfgrass irrigation. Irrigation seawater of different salinity levels (0, 24, 48, and 72 dS/m) were applied to turfgrass species grown in a plastic pots filled with a mixture of sand and peat (9:1). Increasing salinity reduced uptake of K, Ca, and Mg but increased Na content in the shoot tissue. The lowest K, Ca, Mg content reduction was found in the species of *Paspalum vaginatum* and *Zoysia japonica* while the maximum was recorded in the species of *Digitaria didactyla* and *Cynodon dactylon* 'tifdwarf'. Other species *Zoysia matrella* and *Cynodon dactylon* 'satiri' were intermediate. The overall, shoot K:Na ratio was the highest in *Paspalum vaginatum* followed by *Zoysia japonica*. The results revealed that K, Ca and Mg ions uptake and their distribution to shoot tissues under salinity stress may be relevant issues for plant nutrition along with salt (Na^+) exclusion for salinity tolerance.

Key Words

Salinity stress, nutrient uptake, turfgrass, seawater

Introduction

Salinity is one of the most important abiotic stresses widely distributed in both irrigated and non-irrigated areas of the world and include imposition of ion toxicities (e.g., Na and Cl), ionic imbalances, osmotic stress and soil permeability problems (Ashraf *et al.,* 2008).Salt tolerance in plants is generally associated with low uptake and accumulation of Na^+, which is mediated through the control of influx and/ or by active efflux from the cytoplasm to the vacuoles and also back to the growth medium (Jacoby, 1999). In addition to inorganic ion contributions to osmotic adjustment, genotypic differences in nutrient elements uptake under salinity have implications for maintaining adequate nutrition and for optimizing nutrient/element related salinity tolerance mechanisms. Uptake of essential ions (both cations and anions) including K^+, Ca^{2+}, Mg^{2+}, NH_4^+, and NO_3^- have been reported to be suppressed in various species by high concentrations of NaCl, especially in saline soils and irrigation waters (Rubinigg *et al.,* 2003). So the study on nutrient uptake in tropical turfgrass under salinity stress may be helpful in breeding salt tolerant cultivars by identifying chemical potential of salinity tolerance and the current study is designed to address the aforesaid issues critically.

Methods

The experiment was conducted with six turfgrass species in the glasshouse of Faculty of Agriculture at Universiti Putra Malaysia under sand culture system. The soil was sandy with pH 5.23, EC 0.3 dS/m, OC 0.69%, sand 97.93 %, silt 1.89% and clay 0%. The diameter of plastic pots was 14 cm with 15 cm depth. The average day temperature and light intensity of glasshouse were 28.5-39.5 ^oC and 1500-20400 lux respectively. Four saline water concentrations: 0, 24, 48, 72 dS/m were applied in this study. Untreated checks were irrigated with distilled water. Seawater was diluted 50% and NaCl was added to seawater to obtain the salty water level of 48, 72 dS/m respectively. To avoid osmotic shock, salinity levels were gradually increased by daily increments of 8 dS/m until the final salinity levels were achieved. After the targeted salinity levels were achieved, the irrigation water was applied once daily basis for a period of four weeks. At the end of the experiment shoots and roots were harvested and were washed with deioniozed water and dried at 70 ^oC for 72 hrs. All elemental analyses were conducted on acid digested material through micro-Kjeldahl digestion system. The content of Na, K, Ca and Mg ions were measured by Atomic Absorption Spectrophotometer (AAS).The experimental design was a randomized complete block design (RCBD) with five replications. The results were analyzed using (SAS, 2006) and treatment means were compared using LSD Test.

Results

Sodium content of turf grasses increased and potassium, calcium, magnesium content, K/Na ratio decreased with increasing salinity levels (Table 1,2,3,4,& 5). At 0 dS/m salinity, Na contents in different turf species ranged between 0.52 to 0.59 mg /g dry weights. However, at 24, 48 and 72 dS/m salinity levels, Na uptake ranged between 6-10, 22-30 and 23-35folds over the control, respectively (Table 1). At 24 dS/m salinity, least Na accumulations were recorded in species *Paspalum vaginatum* (6-fold), *Zoysia japonica* (6-fold), and *Cynodon dactylon* 'satiri' (6-fold); while maximum accumulations were recorded in species *Digitaria didactyla* (10-fold) and *C. dactylon* 'tifdwarf' (8-fold). At 72 dS/m salinity, least Na accumulations were recorded in species *P. vaginatum* (23-fold) and *Z. japonica* (25-fold); while maximum accumulations were recorded in species *C. dactylon* 'tifdwarf' (34-fold) and *D. didactyla* (30-fold).

Table 1. The effect of different salinity levels on shoot Na content of different turfgrass species (Values in the parentheses indicate percent decrease compared to control).

Species	Sodium content in mg /g, dry weight				LSD (0.05)
	Salinity levels (dS/m)				
	0	24	48	72	
C. dactylon 'satiri'	0.52 d (1)	3.23 c (6)	11.50 b (22)	16.48 a (32)	1.70
C. dactylon 'tifdwarf'	0.57 d (1)	4.42 c (8)	17.30 b (30)	19.43 a (34)	1.92
Digitaria didactyla	0.56 d (1)	5.86 c (10)	13.54 b (24)	16.83 a (30)	1.39
Paspalum vaginatum	0.54 d (1)	3.09 c (6)	8.11 b (15)	12.68 a (23)	0.79
Zoysia japonica	0.59 d (1)	3.77 c (6)	11.21 b (19)	14.82 a (25)	0.94
Zoysia matrella	0.55 c (1)	3.87 b (7)	12.53 a (23)	13.65 a (25)	1.17

Means accompanied by common letters in rows are not significantly different at $P \leq 0.05$ by LSD test.
Potassium content of different turfgrass species ranged from 15.38 to 28.97 mg /g dry weight in control treatment (Table 2). At 24 dS/m least reduction was observed in species *P. vaginatum* (4%), *Z. japonica* (6%) and *Z. matrella* (6%) while maximum reduction were found in species *D. didactyla* (33%) and *C. dactylon* 'tifdwarf' (21%) . At 72 dS/m salinity, the lowest K reduction were recorded in species *P. vaginatum* (26%) *and Z. japonica* (30%) while highest reduction was found in species *D. didactyla* (46%).

Table 2. The effect of different salinity levels on shoot K content of different turfgrass species (Values in the parentheses indicate percent decrease compared to control).

Species	potassium content in mg /g, dry weight				LSD (0.05)
	Salinity levels (dS/m)				
	0	24	48	72	
C. dactylon 'satiri'	16.39 a (100)	14.46 b (88)	10.55 c (64)	9.88 c (60)	1.40
C. dactylon 'tifdwarf'	15.65 a (100)	12.38 b (79)	10.06 c (64)	9.70 c (62)	1.83
Digitaria didactyla	15.87 a (100)	10.64 b (67)	10.33 b (65)	8.56 c (54)	1.22
Paspalum vaginatum	28.97 a (100)	27.78 a (96)	24.38 b (84)	21.56 c (74)	1.33
Zoysia japonica	25.40 a (100)	23.92 a (94)	20.40 b (80)	17.95 c (71)	1.48
Zoysia matrella	18.63 a (100)	17.52 a (94)	13.45 b (72)	13.04 b (70)	2.22

Means accompanied by common letters in rows are not significantly different at $P \leq 0.05$ by LSD test

The highest K/Na ratio was found at control treatment and it ranged from 22.36-54.13 (Table 3). The overall, at all salinity levels the highest K/Na value was recorded in *P. vaginatum* followed by *Z. japonica*, on the other hand the lowest value was found in *C. dactylon* 'tifdwarf' followed by *D. didactyla*. The overall, shoot K:Na ratio was highest in *P. vaginatum* and lowest in *C. dactylon* 'tifdwarf'. The relative salt tolerance between species may be related to the maintenance of higher root growth, or high K: Na ratio in the shoot (Qian *et al.*, 2001).

Table 3.The effect of different salinity levels on K/Na ratio of different turfgrass species.

Species	Potassium/Sodium ratio				LSD (0.05)
	Salinity levels (dS/m)				
	0	24	48	72	
C. dactylon 'satiri'	31.39 a	4.52 b	0.92 c	0.61 c	1.28
C. dactylon 'tifdwarf'	27.40 a	2.89 b	0.58 c	0.50 c	0.86
Digitaria didactyla	28.17 a	1.83 b	0.77 bc	0.51 c	1.29
Paspalum vaginatum	54.13 a	9.26 b	3.02 c	1.70 c	3.72
Zoysia japonica	42.86 a	6.37 b	1.82 c	1.21 c	3.14
Zoysia matrella	33.72 a	4.69 b	1.08 bc	0.86 c	3.68

Means accompanied by common letters in rows are not significantly different at $P \leq 0.05$ by LSD test.

On average all the species, Ca (mg /g) content decreased due to increasing salinity levels at 24, 48 and 72 dS/m salinity (Table 4). The highest reduction of Ca content at 24 dS/m was observed in species *D. didactyla* (24%), while least reduction was recorded in species *P. vaginatum* (6%). At highest salinity level (72 dS/m), Ca content of all species decreased but *C. dactylon* 'tifdwarf' and *C. dactylon* 'satiri' increased in compared to 48 dS/m. Shoot Ca contents varied inconsistently under different salt stress in species *C. dactylon* 'satiri' and *C. dactylon* 'tifdwarf'. There are several reports on considerable inhibition of Ca uptake under salinity (Netondo *et al*., 2004).

Table 4. The effect of different salinity levels on shoot Ca content of different turfgrass species (Values in the parentheses indicate times decrease compared to control).

Species	calcium content in mg /g, dry weight				LSD (0.05)
	Salinity levels (dS/m)				
	0	24	48	72	
C. dactylon 'satiri'	1.93 a (100)	1.58 b (82)	1.17 c (61)	1.43 d (74)	0.15
C. dactylon 'tifdwarf'	2.05 a (100)	1.76 a (86)	1.61 ab (79)	1.74 b (85)	0.28
Digitaria didactyla	1.48 a (100)	1.13 b (76)	0.79 c (53)	0.61 d (41)	0.06
Paspalum vaginatum	2.79 a (100)	2.62 b (94)	2.39 c (86)	2.07 d (74)	0.20
Zoysia japonica	2.17 a (100)	2.02 b (93)	1.75 c (81)	1.54 d (71)	0.17
Zoysia matrella	2.02 a (100)	1.85 b (92)	1.69 c (84)	1.40 c (69)	0.24

Means accompanied by common letters in rows are not significantly different at $P \leq 0.05$ by LSD test.

Shoot tissue Mg content decreased as salinity increased (Table 5). The highest Mg content in the shoot tissue was recorded at 24 dS/m salinity level and the lowest was at 72 dS/m. At 24 dS/m salinity, the highest Mg reduction was recorded in species *D. didactyla* (21%) and *C. dactylon* 'tifdwarf'; while least reduction were recorded in species *P. vaginatum* (3%) and *Z. japonica* (9%). Magnesium content at highest salinity level (72 dS/m), maximum reductions was found in species *D. didactyla* (56%) and *C. dactylon* 'tifdwarf' (53%) while least reduction were recorded in *P. vaginatum* (33%) *and Z. japonica* (41%). Dudeck and Peacock (1993) also reported that increasing Na affected Mg and K more than Ca tissue content in several turfgrasses they studied.

Table 5. The effect of different salinity levels on shoot Mg content of different turfgrass species (Values in the parentheses indicate times decrease compared to control).

Species	magnesium content in mg /g, dry weight				LSD (0.05)
	Salinity levels (dS/m)				
	0	24	48	72	
C. dactylon 'satiri'	3.60 a (100)	2.95 b (82)	2.10 c (58)	1.74 c (48)	0.37
C. dactylon 'tifdwarf'	3.18 a (100)	2.53 b (80)	1.91 c (60)	1.50 d (47)	0.21
Digitaria didactyla	3.01 a (100)	2.37 b (79)	1.70 c (57)	1.31 d (44)	0.17
Paspalum vaginatum	4.36 a (100)	4.21 b (97)	3.51 c (81)	2.91 d (67)	0.54
Zoysia japonica	3.07 a (100)	2.79 b (91)	2.42 c (79)	1.82 d (59)	0.21
Zoysia matrella	2.95 a (100)	2.59 b (88)	2.02 c (68)	1.46 d (50)	0.14

Means accompanied by common letters in rows are not significantly different at $P \leq 0.05$ by LSD test.

Conclusion

Increasing salinity resulted in enhanced Na uptake with the concomitant reduction of K, Ca, and Mg uptake in the shoot tissue. The lowest category of salt-tolerant species *D. didactyla* and *C. dactylon* 'tifdwarf' exhibited higher Na uptake and lower K, Ca, Mg uptake at high salinity compared to the salt-tolerant types (*P. vaginatum,* and *Z. japonica*). The shoot tissue content relationships of K, Mg, and Ca to increasing salinity provided insight into nutritional programs on salt-affected sites for these species. At the highest salinity level (72 dS/m), Ca content of all species decreased *.C .dactylon* 'satiri' and *C. dactylon* 'tifdwarf', in contrast, showed increased accumulation of Ca.

References

Ashraf M, Athar HR, Harris PJC, Kwon TR (2008) Some prospective strategies for improving crop salt tolerance. *Adv. Agron*. **97**, 45-110.

Carrow RN, Waddington DV, Rieke PE (2001) Turfgrass soil fertility and chemical problems: Assessment and management. (John Wiley & Sons, Hoboken, NJ).

Dudeck AE, Peacock CH (1993) Salinity effects on growth and nutrient uptake of selected warm season turf. *Int. Turfgrass Soc. Res. J.* 680-686.

Jacoby B (1999) Mechanism involved in salt tolerance of plants. In 'Handbook of plant and crop stress'. (Ed M Pessarakli) pp. 97-124. (Marcel Dekker, Inc., New York).

Netondo GW, Onyangoa JC, Beck E (2004) Sorghum and salinity, I: response of growth, water relations, and ion accumulation to NaCl salinity. *Crop Sci*. **44**, 797-805.

Qian YL, Wilhelm SJ, Marcum KB (2001) Comparative responses of two Kentucky bluegrass cultivars to salinity stress. *Crop Sci*. **41**, 1895-1900.

Rubinigg M, Posthumus F, Ferschke M, Elzenga JTM, Stulen I (2003) Effects of NaCl salinity on ^{15}N-nitreate f fluxes and specific root length in the halophyte *Plantago martima* L. *Plant Soil* **250**, 201-213.

SAS Institute (2006) 9.1.3 Procedures guide, second edition, Volumes 1- 4. Cary, NC: SAS Institute Inc.