Bangladesh J. Bot. **46**(1): 343-353, 2017 (March) Supplementary

# GROWTH RESPONSES OF SALT TOLERANT TURFGRASS TO SALINITY STRESS

**NOOR AZWA ZULKALIPH[1], ABDUL SHUKOR JURAIMI[1]*, MD KAMAL UDDIN[2], MOHD RAZI ISMAIL[3] AND SM SHAMSUZZAMAN[4]**

*Faculty of Agriculture, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia*

*Keywords:* Growth response, Turfgrass, Salinity stress

## Abstract

To select the most suitable salt tolerant turfgrass species, an experiment with five salt water concentrations *viz.*, 0, 12, 24, 36 and 48 dS/m was carried out. The result of this experiment revealed that relative shoot growth of *Paspalum vaginatum* Sw., *Zoysia matrella* (L.) Merr. and *Cynodon dactylon* (L.) Pers. 'satiri' were 80, 68 and 67%, respectively over the control at the highest salinity level (48 dS/m). *Paspalum vaginatum* produced the highest shoot density in every salinity levels among the tested species. Turf quality ratings followed the same trend as leaf firing and turf colour index, which were the best in *P. vaginatum* and *Z. matrella* across all salinity levels, but quality ratings were slightly better in *P. vaginatum* due to higher shoot densities at all salinity levels compared to *Z. matrella* and *C. dactylon* 'satiri'. Therefore, *P. vaginatum* was found to be the most suitable salt tolerant species compared to *Z. matrella* and *C. dactylon* 'satiri'.

## Introduction

Global issues of water quality and quantity are becoming increasingly important (Miyamoto *et al.* 1996, Glenn *et al.* 1997, Westcott 1988). In turfgrass areas, critical water shortages are occurring in rapidly growing urban areas, resulting in restrictions on the use of portable water for irrigating non-food producer plants such as turfgrass landscape areas (Kjelgren *et al.* 2000). Historically, one of the first water uses to be restricted has been turfgrass irrigation (Harivandi 2011).

It is likely that water resources allocated for turf irrigation in the future will be of poor quality. Water related problems are enhanced in turfgrass sites using recycled water (Carrow and Duncan 1998, Marcum 1999). Managers for perennial turfgrass must deal with reduced growth, tissue dehydration, nutritional imbalances and specific ion toxicities, slow recovery from injury and poor long-term persistence that can be caused by salinity stress (Carrow and Duncan 1998, Katerji *et al.* 2000). One strategy to enhance turfgrass survival and recovery from salt stress is to use cultivars with superior salinity tolerance (Ashraf 1994, Flowers and Yeo 1995, Glenn *et al.* 1999).

In addition, salt-tolerant turfgrass species might allow landscape development in saline environments and might be ideal in such environments where, salt water spray is a problem or where, limited or no fresh water is available for irrigation. Variations in salt tolerance among turf grasses have been demonstrated in many studies under control environment (Qian *et al.* 2000, 2001, Alshammary 2003). To our knowledge, there are no published studies on salt water tolerance among turfgrass species under tropical environment. The proper utilization of highly salt tolerant turf grass species may benefit the growing turf grass industries especially in the coastal areas of Malaysia. The objective of this study was to examine the effect of different salinity levels on growth and turf quality of three potential salt tolerant turfgrass species under field condition.

---

*Author for correspondence: <ashukur@upm.edu.my>. [1]Department of Crop Science, Universiti Putra Malaysia 43400 Serdang, Selangor, Malaysia. [2]Department of Land Management, Universiti Putra Malaysia 43400 Serdang, Selangor, Malaysia. [3]Institute of Tropical Agriculture, Universiti Putra Malaysia 43400 Serdang, Selangor, Malaysia. [4]Soil Resource Development Institute, Krishi Khamar Sarak, Dhaka-1215, Bangladesh.

## Materials and Methods

The experiment was conducted at Turf Unit, Taman Pertanian Universiti (TPU), Universiti Putra Malaysia, Serdang, Selangor. Three most salt tolerant species were selected for this study (Table 1). Soil media was prepared by thoroughly mixing washed river sand and Peat-Grow (KOSASR) at the ratio 9 : 1 (v/v). Basal fertilizer at the rate 0.5 kg P/100 $m^2$ and liming at the rate of 0.8 g /tray were mixed with the soil mixtures before planting. The prepared soil media was pulverized and visible insect pests and plant propagules were removed. The medium was filled into plastic container of size 65 cm length × 50 cm width × 13 cm depth (42250 $cm^3$ volume).

**Table 1. Scientific and common names and locations of turfgrass species.**

| Scientific name | Common name | Locations |
|---|---|---|
| *Paspalum vaginatum* Sw. | Seashore pasplaum | UPM |
| *Zoysia matrella* L. | Manila grass | Pantai Bisikan Bayu |
| *Cynodon dactylon* (L.) Pers. | Bermuda grass (satiri) | UPM |

The adhering native soil was washed off from the turfgrass sods (5 cm × 5 cm) and three sods were transplanted into each of the plastic container containing the soil medium. Plants were grown for 16 weeks with non-saline irrigation water in order to achieve full establishment prior to treatment. Trays were supplied with sufficient water in the morning and evening to maintain optimum moisture levels. All trays were fertilized (10.65 g/tray) every two weeks with NPK Green (15 : 15 : 15) @ 50 kgN/ha. Grass foliage was clipped every week at a cutting height of 15 mm for coarse leaf and 5 mm for fine leaf species using a pair of scissors.

The required quantity of sea water was collected from Port Dickson, Negeri Sembilan, Malaysia. The EC of the sea water was 48 dS/m. Five salt water concentrations, *viz.* 0, 12, 24, 36, and 48 dS/m were evaluated in this study. The salinity level was measured by an EC meter (HANNA® Model HI 8733). Untreated checks were irrigated with distilled water. Seawater was diluted with distilled water to obtain 12, 24, 36, and 48 dS/m salinity levels. To avoid osmotic shock, salinity levels were gradually increased by daily increment of 12 dS/m salinity in all treatments until the final salinity levels were achieved. After two weeks, when the targeted salinity levels were achieved, 1500 ml of the respective treatment solutions were applied to each tray on a daily basis for a period of four weeks at morning (10 a.m.) and evening (6 p.m.) time. The experiment was laid out in a RCBD with a 3 × 5 (three turf grasses × five salinity levels) factorial combination of treatments in three replications.

Leaf firing was estimated as total percentage of chlorotic leaf area, with 0% corresponding to no leaf firing and 100% as totally brown leaves. Turf quality was estimated based on a scale of 1-9, with 9 as green, dense and uniform turf and 1 as thin and completely brown turf. The leaf firings of 0, 1-10, 11-20, 21-30, 31-40, 41-50, 51-60, 61-70, 71-80, 81-90, 91-100% had the turf quality score of 9, 8, 7, 6, 5, 4, 3, 2 and 1, respectively (Alshammary *et al.* 2004).

The Field Scout TCM 500 NDVI Turf Color Meter was used to measure Turf Colour Index on grass. Based on measuring reflected light from turf grass in the red (660 nm) and near infrared (850 nm -NIR) spectral bands, data are presented in Grass Index from 1.00 (no or less green colour) to 9.00 (darker green colour). As the different species have different turf colour index, relative (%) turf colour index was calculated following the formula:

$$\text{Relative turf colour (\%)} = \frac{\text{Turf colour index of salinized treatment of a species}}{\text{Turf colour index of control treatment of that species}} \times 100$$

Two units of 10 cm × 10 cm quadrat were placed randomly in a tray. Shoot density was measured quantitively by counting the number of shoot per unit area quadrat. Average data of two quadrat samples was calculated, and given as shoot density of the tray area.

At the end of the experiment two units of 10 cm × 10 cm quadrat were placed randomly in a tray. Samples of shoots and roots from the quadrat were harvested and washed with tap water and finally with distilled water. The samples were carefully washed to remove all soil particles. Samples were then dried in oven at $70^0$C for 3 days until constant weight was achieved and dry weight (g/tray) was recorded. Average data of two quadrat samples was calculated and given as shoot or root dry weight of the tray area. Shoot and root dry weights were also expressed as percentages, relative to control for each species by the following formula proposed by Ashraf and Waheed (1990):

$$\text{Relative dry weight (\%)} = \frac{\text{Dry weight of salinized treatment value of a species}}{\text{Dry wight of control treatment value of that species}} \times 100$$

Amount of water were put inside the volumetric flask just high enough to fill with root sample. Washed fresh root samples from a quadrat of 10 cm × 10 cm size were transferred to the volumetric flask. The water levels in the volumetric flask before and after filled of root samples were recorded. Root volume was measured by finding difference between two readings. The increasing of volume is the data of root volume. Average data of two quadrat samples were calculated and given as root volume of the tray area.

Data were analyzed statistically using ANOVA and the treatment means were compared by LSD at 5% level from Statistical Analysis System Software (SAS version 9.2). Regression analysis was performed by using the replicated data.

## Results and Discussion

Significant differences of leaf firing were observed among the tested species in response to salinity levels (Fig. 1). All species were not affected at salinity level up to 12 dS/m. At 24 dS/m, 5% leaf firing was observed in *C. dactylon* 'satiri' and 1.67% in *Z. matrella*, but *P. vaginatum* was not affected. As salinity increased, leaf firing was increased on *C. dactylon* 'satiri' (6.67%) and *Z. matrella* (8.33%). Meanwhile, *P. vaginatum* exhibited very low percentage (1.67) of leaf firing at the same salinity level. Increasing the salinity to the highest salinity level (48 dS/m), very less percentage of leaf firing was noticed on *P. vaginatum* (5) which indicates the highest tolerant to salinity followed by *Z. matrella* (8.33). On the other hand, *C. dactylon* 'satiri' showed the highest percentage (13.33) of leaf firing at the same salinity level. The effect of salinity on leaf firing was particularly prominent and this parameter mostly used as a primary criterion for screening the salinity tolerance among turfgrasses (Lee *et al.* 2004a, Adavi *et al.* 2006). In previous studies, most seashore *P. vaginatum* ecotypes exhibited halophytic responses to salinity and some could tolerate up to sea water salinity (Lee *et al.* 2004a, 2004b).

The effect of salinity on turf colour index and relative to control of three turfgrass species have been presented in Table 2 and Fig. 2, respectively. As salinity increased, turf colour index was decreased in all species. However, *P. vaginatum* affected very less turf colour by salinity compared to *Z. matrella* and *C. dactylon* 'satiri'. The colour index of *C. dactylon* 'satiri' significantly decreased at 12 dS/m over the control. *P. vaginatum* and *Z. matrella* showed the ability to maintain turf colour index at the highest salinity level (48 dS/m). In a field study at Saudi Arabia, under salinity stress Bermudagrass demonstrated the best colour throughout the growing seasons, while Zoysiagrass and St. Augustine grass (*Stenotaphrum secundatum*) developed yellowish colors (Nasser 2004).

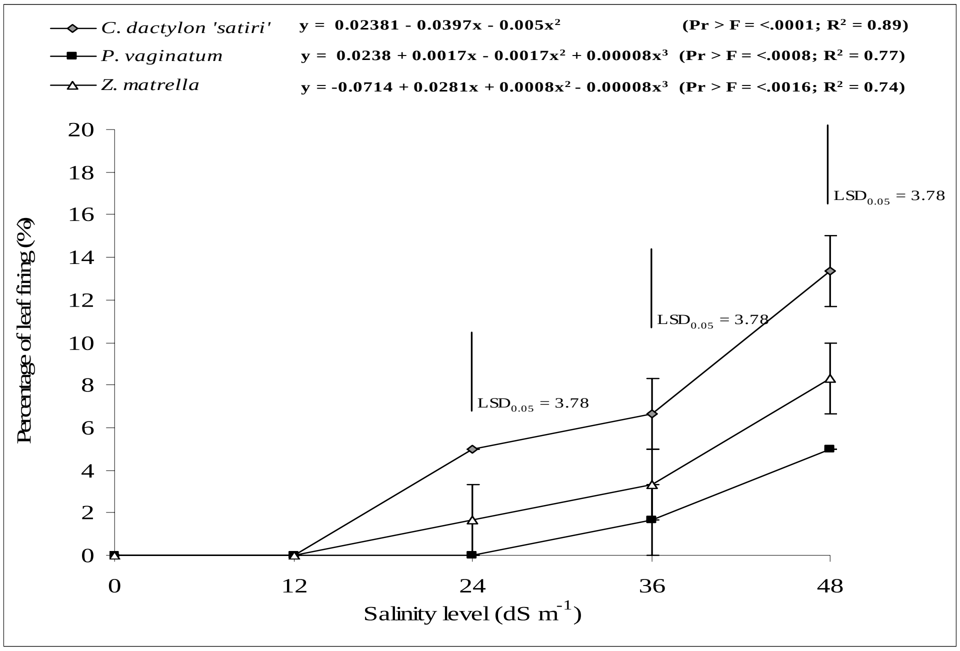

Fig. 1. Leaf firing of three turfgrass species at different salinity levels. Each LSD test was used for mean comparison among species at respective salinity level. Mean ± standard error.

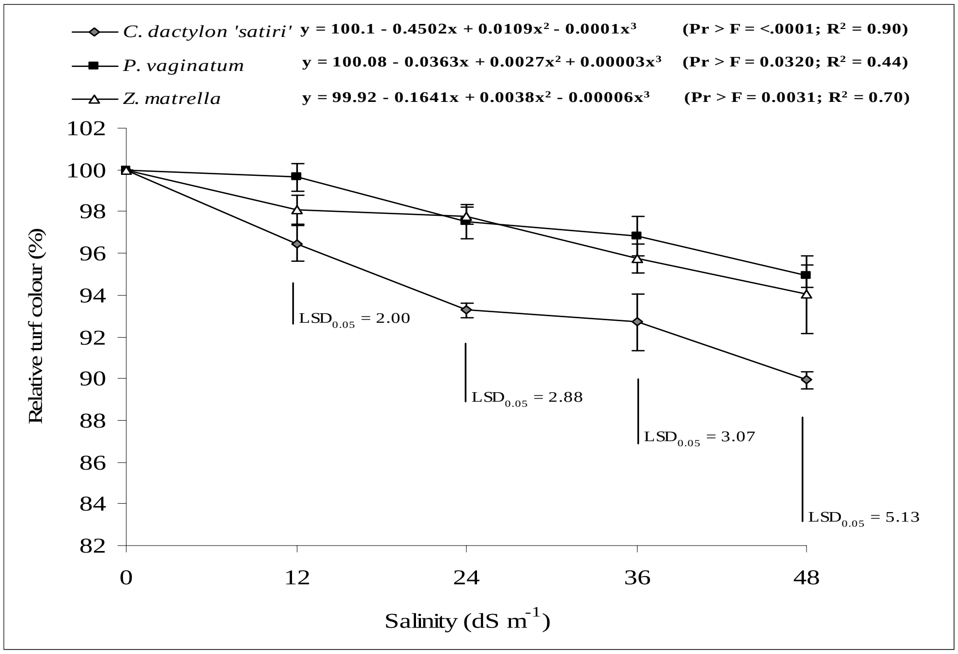

Fig. 2. Relative turf colour of three turfgrass species at different salinity levels. Each LSD test was used for mean comparison among species at respective salinity level. Mean ± standard error.

**Table 2. Effect of salinity on turf colour index of three turfgrass species.**

| Salinity level (dS/m) | Species | | |
|---|---|---|---|
| | *C. dactylon* 'satiri' | *P. vaginatum* | *Z. matrella* |
| 0 | 7.62 a | 7.32 a | 7.27 a |
| 12 | 7.35 a | 7.29 a | 7.13 ab |
| 24 | 7.11 b | 7.13 b | 7.11 ab |
| 36 | 7.07 c | 7.08 bc | 6.96 bc |
| 48 | 6.86 d | 6.94 c | 6.83 c |
| $LSD_{0.05}$ | 0.17 | 0.13 | 0.25 |

Means within columns followed by the same letter are not significantly different at p = 0.05.

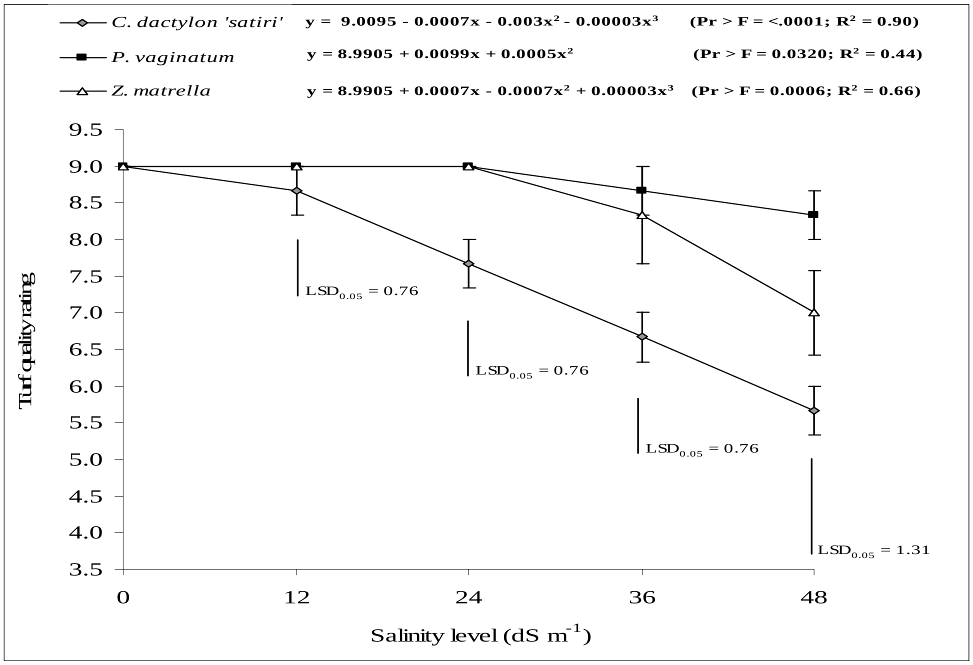

Fig. 3. Turf quality of three turfgrass species at different salinity levels. Each LSD test was used for mean comparison among species at respective salinity level. Mean ± standard error.

Turf quality ratings of all tested species were decreased with increasing the salinity (Fig. 3). Turf quality of *C. dactylon* ‘satiri’ was gradually decreased as salinity increased from 12 dS/m to 48 dS/m. On the contrary, the turf quality ratings of *P. vaginatum* and *Z. matrella* were not affected by salinity stress up to 24 dS/m and decreased slightly with increasing salinity. *P. vaginatum* and *Z. matrella* produced better quality turf compared to *C. dactylon* 'satiri' when these species were treated with 36 dS/m salinity. At the highest salinity level (48 dS/m), the highest turf quality was obtained from *P. vaginatum* (8.33) followed by *Z. matrella* (7.0). Nevertheless, *C. dactylon* 'satiri' produced the lowest turf quality among the tested species (5.67). The effect of salinity on quality parameters may have been related to the development of osmotic stress producing physiological drought, direct ion toxicity from constituent ions such as B or $Na^+$, nutrient imbalances, soil physical/chemical problems related to $Na^+$ or combinations of all these parameters (Beard 1973, Harivandi *et al.* 1992).

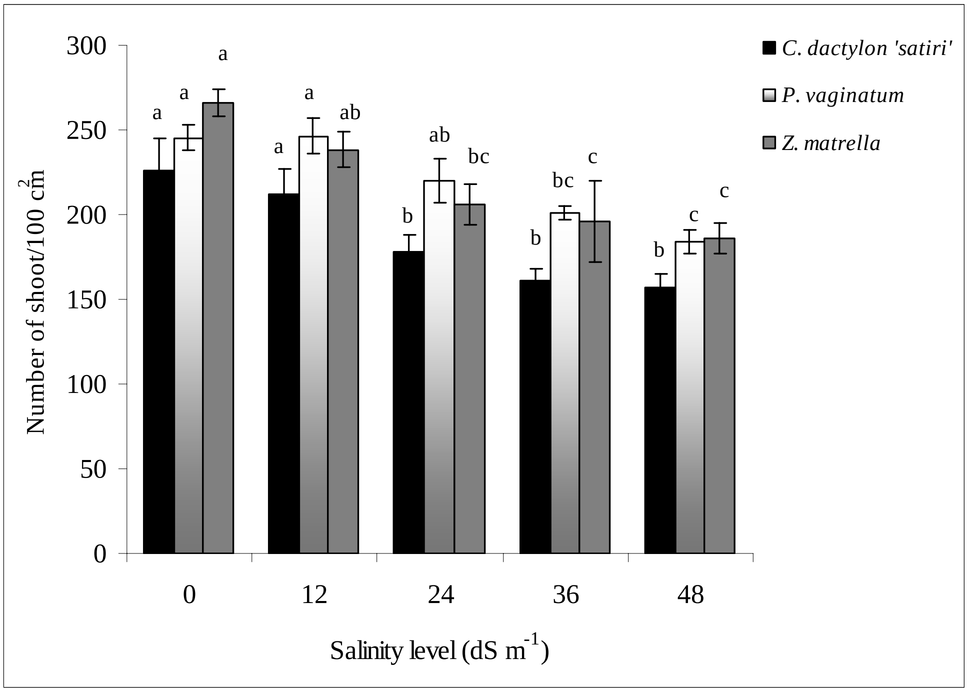

Fig. 4. Shoot density of three turfgrass species at different salinity levels. Mean ± standard error. Means followed by the same letter are not significantly.

Number of shoots ranged from 226 to 266 among the species under control treatment. There was a continuous gradual reduction in shoot density with increasing the salinity levels of all species except *P. vaginatum* (Fig. 4). In response to 12 dS/m salinity, shoot density of *P. vaginatum* was incrementally on number but not significantly different compared to control. At 24 dS/m, the highest shoot density was found on *P. vaginatum* (220) followed by *Z. matrella* (206) while the less was on *C. dactylon* 'satiri' (178). The same trend was observed in 36 dS/m salinity treatment. Even the shoot density of *P. vaginatum* was less than *Z. matrella* in 48 dS/m salinity, but based on relative to control; *P. vaginatum* was the best species that maintained shoot density (75%) compared to *Z. matrella* (70%) and *C. dactylon* 'satiri' (70%).

Among the species, *P. vaginatum* exhibited the good tolerance to salinity in terms of shoot growth. Dry weight of shoot was highest in *Z. matrella* (12.61 g) followed by *P. vaginatum* (12.39g) under non saline irrigation (Table 3). At the same time, *C. dactylon* 'satiri' had very less in shoot weight (4.12 g). No significant difference was observed on shoot growth compared to control of all species as salinity increased to 12 dS/m (Fig. 5). At 24 dS/m salinity stress, shoot growth of *P. vaginatum*, *Z. matrella* and *C. dactylon* 'satiri' were reduced for about 8, 16 and 24%, respectively over the control. A common response of plants to salinity was shoot dehydration and loss of cell turgor resulting in reduced growth rate (Neumann *et al.* 1988). Dissolved salts in the soil solution reduces the uptake of water in turf (Carrow *et al.* 2001, Turgeon 2002, McCarty *et al.* 2003). The result of reduced water uptake in plants is an internal moisture stress that has been linked to deleterious or adaptive changes (Chaves *et al.* 2002) leading to a number of morphological modifications such as decreased tillering, decreased leaf number, thinner leaves and reduced shoot elongation (Turgeon 2002). At 24 dS/m salinity stress, shoot growth of *P. vaginatum*, *Z. matrella* and *C. dactylon* 'satiri' were reduced to about 8, 16 and 24%, respectively over the control. A common response of plants to salinity was shoot dehydration, and loss of cell turgor, resulting in reduced growth rate (Neumann *et al.* 1988). Dissolved salts in the soil solution reduce the uptake of water in turf (Carrow *et al.* 2001, Turgeon 2002, McCarty *et al.* 2003).

**Table 3. Effect of salinity on shoot dry weight (g/100 cm$^2$) and relative shoot growth (%) of three turfgrass species.**

| Salinity level (dS/m) | Species | | |
|---|---|---|---|
| | *C. dactylon* 'satiri' | *P. vaginatum* | *Z. matrella* |
| 0 | 4.12 a | 12.39 a | 12.61 a |
| 12 | 3.94 a | 12.10 a | 11.98 a |
| 24 | 3.11 b | 11.34 b | 10.48 b |
| 36 | 2.87 b | 10.37 c | 9.71 bc |
| 48 | 2.73 b | 9.87 c | 8.50 c |
| $LSD_{0.05}$ | 0.73 | 0.72 | 1.49 |

Means within columns followed by the same letter are not significantly different at p = 0.05.

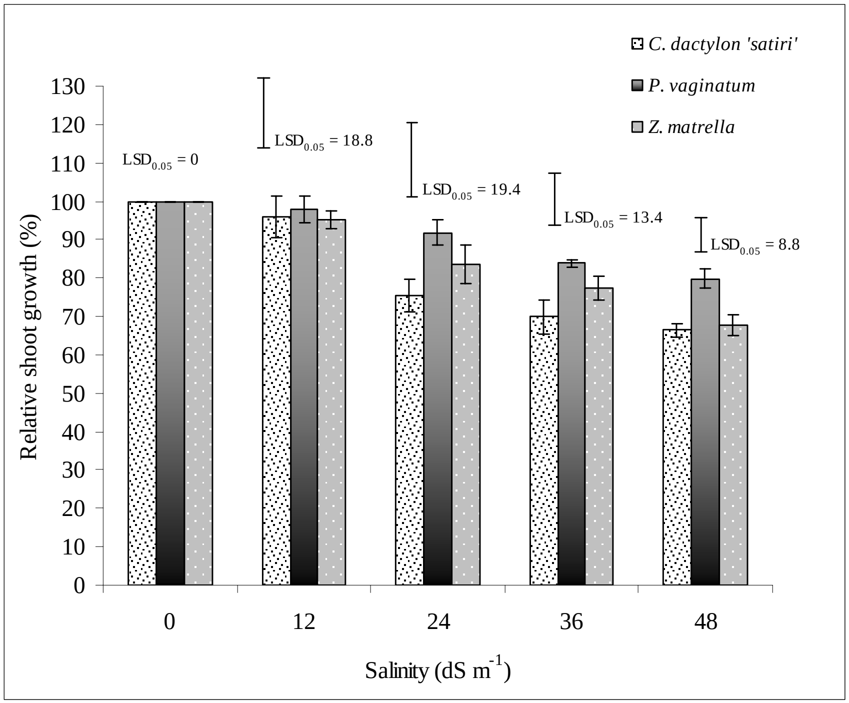

Fig. 5. Relative shoot growth of three turfgrass species at different salinity levels. Mean ± standard error.

The salinity effects on root volume varied according to the species (Table 4). The highest root volume found in *P. vaginatum* (106.67cm$^3$) followed by *Z. matrella* (56.67cm$^3$) and *C. dactylon* 'satiri' (15.83cm$^3$) under non-saline treatment. As salinity increased to 12 dS/m, root volume of *P. vaginatum* and *C. dactylon* 'satiri' increased to 12 and 9% over the control. *P. vaginatum* was able to maintain the same root growth at 24 dS/m, while *C. dactylon* 'satiri' was decreasing in 7% of root volume compared to the control. However, *P. vaginatum* showed slightly reduced in root volume when treated with 36 dS/m salinity. At the highest salinity level (48 dS/m), *P. vaginatum* showed the less reduction on root volume (27%) compared to *Z. matrella* (40%) and *C. dactylon* 'satiri' (47%). According to Marcum (1999), the more salt tolerant grasses had higher rooting depth with greater total root dry weight which indicates that well adapted plants have vigorous root systems to seek water at deeper soil depths under salt stress condition. Regardless of the turfgrass species, extensive root system is related to salinity tolerance with better plant survival, lower leaf firing and higher shoot yield (Marcum and Kopec 1997).

**Table 4. Effect of salinity on root volume per 100 cm$^2$ of three turfgrass species and percentage relative to control.**

| Salinity level dS/m) | Root volume (cm$^3$) | | | Relative to control (%) | | |
|---|---|---|---|---|---|---|
| | *C. dactylon* 'satiri' | *P. vaginatum* | *Z. matrella* | *C. actylon* 'satiri' | *P. vaginatum* | *Z. matrella* |
| 0 | 15.83 a | 106.67 b | 56.67 a | 100 | 100 | 100 |
| 12 | 16.67 a | 119.17 a | 51.67 ab | 95 | 98 | 94 |
| 24 | 14.17 ab | 119.17 a | 41.67 bc | 89 | 96 | 90 |
| 36 | 10.83 bc | 100.00 b | 40.83 bc | 84 | 95 | 89 |
| 48 | 8.33 c | 78.33 c | 34.17 c | 81 | 90 | 88 |
| LSD$_{0.05}$ | 3.58 | 11.11 | 11.72 | - | - | - |

Means within columns followed by the same letter(s) are not significantly different at p = 0.05%.

There was significant effect of salinity on root growth of all species (Table 5 and Fig. 6). Dry weight of root was the highest on *P. vaginatum* (20.55 g) followed by *Z. matrella* (8.77 g) and the lowest was in *C. dactylon* 'satiri' (4.69 g). The greatest root mass was found at 12 and 24 dS/m salinity levels with 27.5 and 25.33 g weight, respectively. Root growth of *P. vaginatum* at 36 and 48 dS/m salinity levels showed no significant difference. Meanwhile, root growth of *C. dactylon* 'satiri' showed slightly increased at 12 dS/m and decreased 7% from control at 24 dS/m treatment. Root growth of both of these salinity levels showed no significant difference compared to control. Overall, *P. vaginatum* obtained the highest root growth with increasing salinity. Root growth stimulation in salt tolerant turfgrasses is typically more common and often more accentuated response to moderate salinity stress than shoot growth stimulation (Bernstein and Hayward 1958, Gorham *et al.* 1985). Stimulation of rooting on turfgrass under low to moderate salinity stress has been observed in *P. vaginatum* as well as in *Cynodon* spp. (Marcum and Murdoch 1990, Dudeck and Peacock 1985).

**Table 5. Effect of salinity on dry weight of root (g/100cm$^2$) of three turfgrass species.**

| Salinity level (dS/m) | Species | | |
|---|---|---|---|
| | *C. dactylon* 'satiri' | *P. vaginatum* | *Z. matrella* |
| 0 | 4.69 a | 20.55 b | 8.77 a |
| 12 | 4.68 a | 27.50 a | 8.52 ab |
| 24 | 4.31 a | 25.33 a | 7.10 bc |
| 36 | 3.06 b | 19.55 b | 6.70 cd |
| 48 | 2.33 b | 17.34 b | 5.57 d |
| $LSD_{0.05}$ | 0.91 | 3.65 | 0.81 |

Means within columns followed by the same letter are not significantly different at p = 0.05.

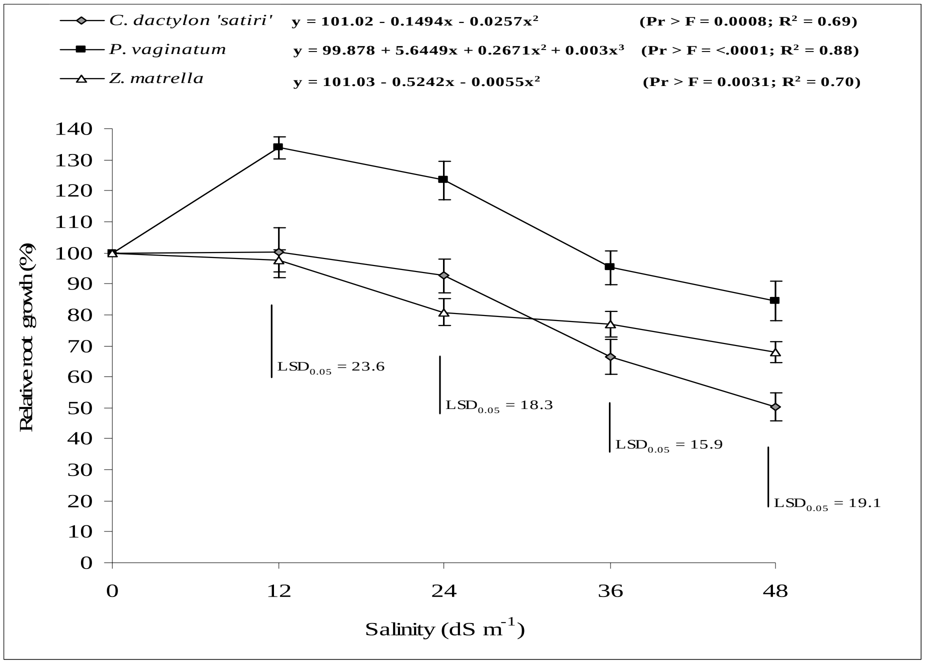

Fig. 6. Relative root growth of three turfgrass species at different salinity levels.

*Paspalum vaginatum* was found to be the best salt tolerant turfgrass species among the warm season turfgrass. This species can tolerate the salinity up to sea water (48 dS/m) and grow near to the coastal area. Meanwhile, *Z. matrella* and *C. dactylon* 'satiri' can tolerate salinity up to 36 dS/m and 24 dS/m, respectively. Salinity tolerance ranking of the tested species was - *Paspalum vaginatum* > *Zoysia matrella* > *Cynodon dactylon* 'satiri'. However, *Paspalum vaginatum* showed the highest performance among the species with different saline irrigation at the open field.

## References

Adavi Z, Razmjoo K and Mobli M 2006. Salinity tolerance of Bermuda grass (*Cynodon* spp. L. C. Rich) cultivars and shoot, Na, K and Cl contents under a high saline environment. J. Hort. Sci. Biotech. **81:** 1074-1078.

Alshammary SF, YL Qian and Wallner SJ 2004. Growth response of four turfgrass species to salinity. Agril. Water Manage. **66**: 97-111.

Alshammary SF, Qian YL and Walner SJ 2003. Growth responses of four turfgrass species to salinity. Agil. Water Manage. **66**: 97-111.

Ashraf M 1994. Breeding for salinity tolerance in plants. Crit. Rev. Plant Sci. **13**: 17-42.

Ashraf M and Waheed A 1990. Screening of local/exotic accessions of lentil (*Lens culinaris* Medic.) for salt tolerance at two growth stages. Plant Soil **128**: 167-176.

Beard JB 1973. Turfgrass: Science and Culture. Prentice Hall Engle wood Cliffs, N.J. pp. 353-356.

Bernstein L and Hayward HE 1958. Physiology of salt tolerance. Annual Rev. Plant Physiol. **9:** 25-46.

Carrow RN and Duncan RR 1998. Salt-affected Turfgrass Sites: Assessment and Management.Wiley, Hoboken, NJ.

Carrow RN, Waddington DV and Rieke PE 2001. Turfgrass soil fertility and chemical problems: Assessment and problems (Ann Arbor Press, Chelsea, MI).

Chaves MM, Pereira JS, Maroco J, Rodrigues ML, Ricardo CPP and Osório ML 2002. How plants cope with water stress in the field: photosynthesis and growth. Annals Bot. **89**: 907-916.

Dudeck AE and CH Peacock 1985. Effects of salinity on seashore paspalum turfgrasses. Agron. J. **77:** 47-50.

Flowers TJ and Yeo AR 1995. Ion relations of plants under drought and salinity. Aust. J. Plant Physiol. **13**: 75-91.

Glenn EP 1997. Relationship between cations accumulation and water content of salt-tolerant grasses and a sedge. Plant Cell Environ. **10**: 205-212.

Glenn EP, Brown J and Blamwald E 1999. Salt tolerance and crop potential of halophytes. Crit. Rev. Plant Sci. **18**: 227-255.

Glenn EP, Miyamoto S, Moore D, Brown JJ, Thompson TL and Brown PW 1997. Water requirements for cultivating *Salicornia bigelovii* Torr. with seawater on sand in a coastal desert environment. J. Arid Environ. **36:** 711-730.

Gorham J, Wyn Jones RG and McDonnell E 1985. Some mechanisms of salt tolerance in crop plants. Plant Soil. **89**(1): 15-40.

Harivandi A, Bulter JD and Wu L 1992. Salinity and turfgrass culture. *In: Turfgrass Agron. Monogor*, ed. Waddington *et al.*, ASA. CSSA and SSSA, Madison WI, pp. 208-230.

Harivandi and Ali M 2011."Purple Gold: A Contemporary View of Recycled Water Irrigation." USGA Green Section Record **49**(45): 1-10.

Katerji N, van Horn JW, Hamdy A and Mastrorilli M 2000. Salt tolerance classification of crops according to soil salinity and to water stress day index. Agric. Water Manage. **43:** 99-109.

Kjelgren R, Rupp L and Kjelgren D 2000. Water conservation in urban landscapes. Hort. Sci. **35**:1037-1040.

Lee G, Duncan RR and Carrow RN 2004a. Salinity tolerance of seashore paspalum ecotypes: Shoot growth responses and criteria, Hort. Sci. **39**: 1138-1142.

Lee GJ, Duncan RR and Carrow RN 2004b. Salinity tolerance of selected seashore paspalums and bermudagrasses: Root and verdure responses and criteria. Hort. Sci. **39:** 1143-1147.

Marcum KB 1999. Salinity tolerance mechanisms of grasses in the subfamily *Chloridodeae*. Crop Sci. **39**: 1153-1160.

Marcum KB and Kopec DM 1997. Salinity tolerance of turfgrasses and alternative species in the subfamily C*hloridodeae* (Poaceae). Int. Turfgrass Soc. Res. J. **8**: 735-742.

Marcum KB and Murdoch CL 1990. Growth responses, ion relations, and osmotic adaptation of eleven $C_4$ turfgrasses to salinity. Agron. J. **82**: 892-896.

McCarty LB, Higgins JM and Colvin DL 2003. Selective torpedograss (*Panicum repens*) control in Bermudagrass (*Cynodon* spp.) turf. Weed Technol. **7**: 911-915.

Miyamoto S, Glenn EP and Olsen MW 1996. Growth, water use, and salt uptake of four halophytes irrigated with highly saline water. J. Arid Environ. **32**: 141-159.

Nasser S. Al-Khalifah 2004. Response of some turfgrasses to salinity and environmental conditions of Saudi Arabia. Emir. J. Food Agric. **16**(2): 9-17.

Neumann PM, Volkenburgh EV and Cleland RE 1988. Salinity stress inhibits bean leaf expansion by reducing turgor, not wall extensibility. Plant Physiol. **88**: 233-237.

Qian YL, Engelke MC and Foster MLV 2000. Salinity effects on Zoysiagrass cultivars and experimental lines. Crop Sci. **40**: 488-492.

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

Turgeon AJ 2002. Competition between *Agrostis stolonifera* and *Poa annua* populations in turfgrass communities. Sci. Golf **4**: 643-647.

Westcott DW 1988. Reuse and disposal of higher salinity subsurface drainage water: A review. Agric. Water Manage. **14**: 483-511.

*(Manuscript received on 30 November, 2016; revised on 5 January, 2017)*