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Evaluation of physiological and growing behavior of warm season turfgrass species against salinity stress

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ABSTRACT

The demand for salinity tolerant turfgrasses is increasing due to augmented use of effluent or low quality water for turf irrigation. Fresh water, coupled with soil salinization in many areas has resulted in an increased need for screening of salt-tolerant turfgrasses. Physiological responses to salinity and relative salt tolerance of four C_4 turf grasses *Cynodon dactylon* (Bermuda grass), *Zoysia matrella* (Manilla grass), *Stenotaphrum secundatum* (St. Augustine grass) and *Paspalum notatum* (Bahia grass) were investigated during the study at Division of Floriculture and Landscaping, IARI, New Delhi 2015-2017. Turfgrasses were planted in plastic pots filled with sand: cocopeat: vermiculite (2:1:1) and irrigated with different concentration of salinity levels (50, 100, 200, 300, 400 and 500 mm). Salinity tolerance was evaluated on the basis of leaf firing, shoots and root growth reduction, proline content, total chlorophyll content and relative water content was subjected to analysis of variance. Among the four turfgrass species *S. secundatum* found to be most salt tolerant turf grass followed by *Z. matrella* while *P. notatum* was least tolerant turfgrass against salt stress.

Key words: *Cynodon dactylon, Paspalum notatum, Stenotaphrum secundatum*, Turfgrass, *Zoysia matrella*

Land and water resources are becoming scarce and are insufficient to sustain the increasing population. Salinity is one of the most important abiotic stresses affecting agricultural productions across the world. Cultivation of salt-tolerant turfgrass species may be promising option under such conditions where poor quality water can also be used for these crops.

The relative salt tolerance among most of the widely used turfgrass species and cultivars has not been adequately studied. Those species possessing some level of salt tolerance could provide more acceptable turf in areas where only low quality irrigation water is available or saline soil conditions exist. Many plants can be grown using land and water unsuitable for conventional crops and can provide food, fuel, fodder, fibber, resin, essential oils, and pharmaceutical products and can be used for landscape reintegration. There are a number of potential turfgrass species that may be appropriate at various salinity levels. The goal of this review is to create greater awareness of salt-tolerant turfgrasses, their current and potential uses, and their potential use in developing countries. The future for irrigating turf may rely on the use of moderate-to high-salinity water and, in order to ensure that the turf system is sustainable, will rely on the use of salt-tolerant grasses and an improved knowledge of the effects of salinity on turfgrasses.

Salinity is a major abiotic environmental stress that is reported to be responsible for reducing plant growth across the globe. Salt tolerant turfgrasses are becoming essential in many areas of the world because of salt accumulation on soil, restrictions on groundwater use and saltwater intrusion into groundwater (Hixson *et al*. 2004). Physiological responses to salinity include growth suppression and lowered osmotic potential (Marcum 2006). Salt tolerant plants have the ability to minimize these detrimental effects by producing a series of morphological, physiological and biochemical processes (Jacoby 1999). Sodium chloride (NaCl) is the major compound contributing salinity in soils, and more salt-tolerant turfgrasses are required to cope this problem (Harivandi *et al.* 1992). Therefore, development of salt-tolerant turfgrasses is becoming increasingly necessary in many parts of the world including Malaysia. Salt accumulation in soils, limitations on use of groundwater, and salt water intrusion into groundwater may restrict cultivation of glycophytic crops in these areas. Salinity lowers water potential and restricts of water to plants (Munns and Tester 2008).

Osmotic balance or osmoregulation is certainly a crucial factor for the survival of a plant under salt-stressed conditions. Generally, plants have developed different

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adaptive mechanisms to mitigate salinity under the saline environments (Rhodes and Orczyk 2002, Borsani *et al*. 2003, Sairam *et al*. 2006). Among these, salt exclusion is considered to be the most important adaptive feature of nonhalophytic plants, whilst most tolerant halophytes are salt accumulators (Munns and Tester 2008). Salt-accumulating halophytes are very crucial for osmotic adjustment. It could be achieved in the following ways: (i) by accumulating inorganic osmolyte (K+) and/or (ii) accumulating organic osmolytes such as proline. Therefore, salt-tolerant halophytic plants have the capability to minimize the detrimental effects by morphological means and physiological or biochemical processes (Jacoby 1999). Some of the turfgrass species are halophytic in nature. So salt-tolerant turf varieties would allow landscape development in saline environments and would be ideal in such environments, where limited or no fresh water is available for irrigation and saline water is the only option for irrigation practices. Interestingly, the development of turfgrass industry especially in the coastal areas of India is an emerging field. To the best of our knowledge, published literatures are very scanty on salt tolerance studies in turf grass species, which have been or being conducted in India. Therefore, this study was framed to determine the relative salinity tolerance and growth response of four important turfgrass species to salinity.

MATERIALS AND METHODS

Glasshouse experiment was conducted at IARI, New Delhi during 2015-2017. Plastic pots (40× 15cm) were filled up with a mixture of sand, cocopeat and perlite (2:1:1). The native mixture was washed off the sods, and the sods were then transplanted into the plastic pots and grown for 8 weeks under no saline irrigation to achieve full growth. During this period full strength Hoagland solution has been given to every pot at 50 days interval for proper growth and development of grasses. Three replications have been taken for each treatment and sods were transplanted. All species were narrow leaf (Table 1) and were clipped fortnightly at a cutting height of 5-7 cm. After 8 weeks with fresh water irrigation to ensure establishment, salinity treatments were initiated. Salinity treatments of 0 (T_0), 50 (T_1), 100 (T_2), 200 (T_3), 300 (T_4), 400 (T_5), and 500 (T_6) mM (NaCl + distilled water) were applied. The control grasses were irrigated with distilled water. Salt water Prepared with NaCl was diluted by adding distilled water to achieve different treatments in mili molar. To avoid salinity shock, salinity levels were increased gradually by 8 dS/m/day (88 mM/day) for each treatment until the final salinity levels were achieved. After that, irrigation water was applied daily upto four weeks. Data on leaf firing, proline, chlorophyll, relative water content, shoot and root dry weight were recorded 4 weeks after application of salinity treatment. The data were subjected to CRD with factorial concept by using OPSTAT statistical software.

Determination of relative water content (%): Relative water content (RWC) was estimated using formula given by Barr (1968) and expressed in percentage. 100 mg of leaf tissue was taken and placed in petridish for four hours and turgid weight measured. Relative water content was then calculated using the following formula:

Table 1 Turfgrass species used in this study

Scientific name	Common name
Zoysia matrella	Manila grass
Cynodon dactylon	Bermuda grass
Paspalum notatum	Bahia grass
Stenotaphrum secundatum	St. Augustine grass

$$\text{RWC (\%)} = \frac{\text{(Fresh weight) - (Dry weight)}}{\text{(Turgid weight) - (Dry weight)}} \times 100$$

Determination of leaf firing: Leaf firing was estimated as total percentage of chlorotic leaf area, with 0% corresponding to no leaf firing and 100% for total brown leaves (Alshammary *et al*. 2004).

Determination of shoot and root dry weight: At the end of experiment (four weeks after salt initiation), shoots above the soil surface were harvested and washed with tap water and then distilled water to remove all potting mixture particles. After harvesting the shoots, roots were removed from the pots, washed with tap water, and rinsed with distilled water. The shoot and root samples were then oven-dried to a constant weight at 70°C for 3 days. The dry weight (g/100 cm^2) was recorded for each treatment.

Determination of proline content: Proline was estimated by following method of (Bates *et al*.1973). Fresh leaf tissue (0.5 g) was homogenized in 10ml of 3% sulfosalicylic acid, and the homogenate was filtered through Whatman no. 2 filter paper. Two milliliters of the filtrate were brought to reaction with 2ml acid ninhydrin solution (1.25 g ninhydrin in 30ml glacial acetic acid), 20mL ortho-phosphoric acid (6 M), and 2ml of glacial acetic acid for 1 h at 100◦C. The reaction was terminated in an ice bath. The reaction mixture was extracted with 4mL toluene, mixed vigorously by passing a continuous stream of air for 1-2 min. The chromophore containing toluene was aspirated from the aqueous phase, warmed at room temperature, and the absorbance was recorded spectrophotometrically at 520 nm. The proline concentration was determined from a standard curve and calculated on fresh weight basis as follows:

$$\mu\text{mol proline/g fresh weight} = \frac{\mu\text{g proline/ml} \times \text{ml of toluene}/\ 115.5}{\text{g of sample}} \times 100$$

Determination of total chlorophyll in leaves (mg/g fresh weight): Total chlorophyll was estimated using DMSO method (Hiscox and Israeltsam 1979). 50 mg of fresh leaf samples was weighed, placed into test tubes and 10 ml of DMSO was added. It was kept in oven at 60 °C for 4 hours and reading was taken in spectrophotometer at 645 nm and 663 nm wavelength and absorbance recorded. Total chlorophyll was then calculated using the following formula

$$\text{mg total chl./g f.wt.} = \frac{(20.2 \times \text{A}\,645\,\text{nm}) + (8.02 \times \text{A}\,663\,\text{nm})}{\text{Fresh weight}} \times 1000$$

Table 2 Effect of different concentrations of salt (mM NaCl) for percent relative water content (RWC%) on different turfgrass species

Species	Treatment (Conc. NaCl mM)							
	T_0 (Con)	T_1 (50Mm)	T_2 (100Mm)	T_3 (200Mm)	T_4 (300Mm)	T_5 (400Mm)	T_6 (500Mm)	Mean
Cynodon dactylon	88.073	88.00	75.13	70.090	63.34	55.31	51.08	70.15
Zoysia matrella	85.50	85.42	85.00	83.82	79.70	76.16	75.07	81.53
Stenotaphrum secundatum	85.41	85.00	83.213	81.90	81.48	81.28	80.00	82.61
Paspalum notatum	84.70	75.00	65.207	57.26	50.20	42.30	36.51	58.75
Mean	85.92	83.37	77.14	73.24	68.68	63.77	60.67	
CD (P=0.05)								
Species (S)				0.084				
Treatment (T)				0.111				
Interaction (S × T)				0.222				

where A is absorbance, V is the final volume in ml and f.wt. is fresh weight of tissue in g.

RESULTS AND DISCUSSION

Relative water content (%)

It is clear from the data presented in Table 2 that the effect of treatment, species and interaction was found to be significant with respect to relative water content (RWC). Relative water content of all turfgrass species was significantly influenced by salinity. As salinity increased, RWC decreased. Among the different turfgrass species it was found that the maximum relative water content (%) observed in case of *Stenotaphrum secundatum* (82.61%) followed by *Zoysia matrella* (81.53%) and minimum RWC found in case of *Paspalum notatum* (58.75%). Among the concentration of salt (NaCl mM) it was observed that maximum RWC (%) recorded in $T_{0, \text{ i.e.}}$ control (85.92%) and minimum was recorded in treatment T_6 at 500mM (60.67%) Nacl salt concentarion. Perusal of data in Table 2 shows that interaction among species and NaCl concentration resulted and species were ranked at the highest level of salinity in the treatment T_6 (500 mM NaCl) as *Stenotaphrum secundatum* (80.00%), *Zoysia matrella* (75.07%) then *Cynodon dactylon* (51.08%) and *Paspalum notatum* (36.51%).The percentage relative water content (RWC) was determined as an indicator of osmotic status of turfgrass species studied. Salinity stressed plants certainly face osmotic challenges. This is in agreement with several previous reports (Munns and Tester 2008, Lee *et al*. 2004) which concur that osmotic adjustment is the main mechanism for survival and growth of plants under salinity stress. Plants osmotic adjustment subjected to salt stress can occur by the accumulation of high concentration of either inorganic ions or low molecular weight organic solutes. Our studies indicated that salinity tolerance in relation to relative water content was better in *Stenotaphrum secundatum* followed by *Zoysia matrella*. These new salt tolerant species provide an opportunity to use very brackish sources of water (Uddin and Juraimi 2013).

Leaf firing

It is evident from the data in Table 3 that the effect of treatments, species and interaction of salinity and species had significant effect on leaf firing percent. Regardless of salt concentration minimum leaf firing (%) was recorded among the species in *Stenotaphrum secundatum* (4.38%) while maximum leaf firing (%) was found in *Paspalum notatum* (53.33%). However, there were less noticeable salinity injury in *Stenotaphrum secundatum* and *Zoysia matrella*

Table 3 Effect of different concentrations of salt (mM NaCl) for percent leaf firing on different turfgrass species

Species	Treatment (Conc. NaCl mM)							
	T_0 (Con)	T_1 (50Mm)	T_2 (100Mm)	T_3 (200Mm)	T_4 (300Mm)	T_5 (400Mm)	T_6 (500Mm)	Mean
Cynodon dactylon	0.00	0.00	18.33	38.33	51.66	63.33	80.00	35.95
Zoysia matrella	0.00	0.00	0.00	5.00	10.66	16.66	21.66	7.71
Stenotaphrum secundatum	0.00	0.00	0.00	0.00	5.00	10.66	15.00	4.38
Paspalum notatum	0.00	23.33	36.66	51.66	73.33	88.33	100.00	53.33
Mean	0.00	5.83	13.75	23.75	35.16	44.75	54.16	
CD (P=0.05)								
Species (S)				1.141				
Treatment (T)				1.509				
Interaction (S × T)				3.019				

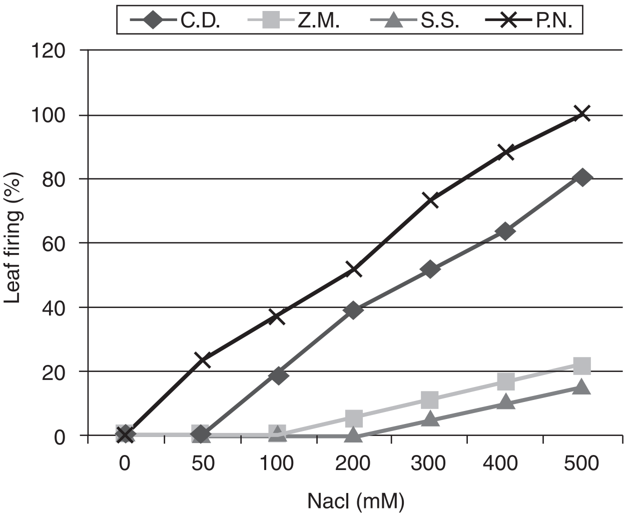

Fig 1 Different concentrations of salt (mM NaCl) on percent leaf firing on different turfgrass species

at all salinity levels compared to other grasses. Among the treatments of salt concentration (NaCl mM) it was observed that maximum leaf firing (%) recorded (54.16%) in T_6, i.e 500mM salt level and minimum was recorded (0.00%) in treatment T_0 (control). There was no injury (0%) recorded in all species up to 50 mM salinity level except *Paspalum notatum* (23.33%) while up to 200mM salt concentration 0% leaf firing recorded in *Stenotaphrum secundatum* and very light injury or leaf firing (5%) was recorded in *Zoysia matrella*. At the highest salinity level of 500 mM the least leaf firing was observed in *Stenotaphrum secundatum* (15.00%) compared to100% leaf firing in *Paspalum notatum*. Thus leaf firing of different varieties increase in respect to increasing concentration of salt (Fig 1), these findings are in accordance with the earlier report by Uddin *et al*. (2011). Assessment of salinity tolerance using percent leaf firing has been reported in previous studies also (Marcum and Murdoch 1994). In fact, leaf firing has been considered as an important criterion of turfgrass assessment under salt stress because leaf firing is easily noticed on turfs and also easily measured.

Leaf chlorophyll content

It is clear from the data presented in Table 4 that the effect of treatment, species and interaction was found to be significant with respect to total chlorophyll content. Chlorophyll content of all turfgrass species was significantly influenced by salinity. As salinity increased, chlorophyll content decreased. Among the different turfgrass species it was found that the maximum chlorophyll content observed in *Zoysia matrella* (2.98 mg/g fw) followed by *Stenotaphrum secundatum* (2.82 mg/g fw) and minimum was found in *Paspalum notatum* (0.73 mg/g fw). Among the concentration of salt (NaCl mM) it was observed that maximum chlorophyll content recorded in control (2.81 mg/g fw) and minimum was recorded in 500mM (1.87 mg/g fw). Perusal of data in Table 4 shows that interaction among species and Nacl concentration resulted and species were ranked at the highest level of salinity in the treatment T_6 (500 mM NaCl) as *Stenotaphrum secundatum* (2.75 mg/g fw), *Zoysia matrella* (2.64 mg/gfw) then *Cynodon dactylon* (2.11 mg/gfw) and *Paspalum notatum* (0.00 mg/g fw). Thus *Stenotaphrum secundatum* and *Zoysia matrella* maintained comparatively higher amounts of total chlorophyll under salt stress with marginal reductions compared to other turf species. Chlorophyll degradation is the primary cause of photosynthetic degeneration or leaf firing and a main biochemical factor for the observed growth reduction (Everard *et al*. 1994). The NaCl induced decrease in chlorophyll level is widely reported in both glycophytes and halophytes (Abdullah *et al*. 2001, Shabala *et al*. 2005). Salinity-induced chlorophyll reduction may be related either to Mg deficiency and/or chlorophyll oxidation since reactive oxygen species (ROS) generation is common in salinity stressed conditions (Moradi and Ismail 2007). Similar findings were reported in salt-sensitive rice cultivars had lower chlorophyll content than salt-tolerant rice cultivars (Pushpam and Rangasamy 2002).

Leaf proline content: The data for proline content was analysed and presented in Table 5. It is clear from data that the shoot proline content of all grasses increased with increasing salinity. Regardless of salt concentration

Table 4 Effect of different concentrations of salt (mM NaCl) for total chlorophyll content (mg/g fw) on different turfgrass species

Species	Treatment (Conc. NaCl mM)							
	T_0 (Con)	T_1 (50Mm)	T_2 (100Mm)	T_3 (200Mm)	T_4 (300Mm)	T_5 (400Mm)	T_6 (500Mm)	Mean
Cynodon dactylon	3.37	3.37	3.17	2.88	2.51	2.28	2.11	2.81
Zoysia matrella	3.24	3.24	3.13	3.00	2.92	2.71	2.64	2.98
Stenotaphrum secundatum	2.89	2.88	2.82	2.82	2.79	2.76	2.75	2.82
Paspalum notatum	1.74	1.54	1.02	0.55	0.28	0.00	0.00	0.73
Mean	2.81	2.76	2.53	2.31	2.13	1.99	1.87	
CD (P=0.05)								
Species (S)				0.024				
Treatment (T)				0.031				
Interaction (S × T)				0.063				

Table 5 Effect of different concentrations of salt (mM NaCl) for proline content (µmole/gfw) on different turfgrass species

Species	Treatment (Conc. NaCl mM)							
	T_0 (Con)	T_1 (50Mm)	T_2 (100Mm)	T_3 (200Mm)	T_4 (300Mm)	T_5 (400Mm)	T_6 (500Mm)	Mean
Cynodon dactylon	3.72	5.57	8.11	17.42	25.5	33.04	38.44	18.83
Zoysia matrella	5.44	7.51	12.33	20.51	36.4	51.41	63.94	28.22
Stenotaphrum secundatum	5.57	7.58	13.71	26.71	49.46	57.74	70.17	33.03
Paspalum notatum	3.46	5.33	7.49	13.43	17.72	21.74	25.47	13.52
Mean	4.55	6.56	10.41	19.52	32.27	40.98	49.50	
CD (P=0.05)								
Species (S)				0.43				
Treatment (T)				0.57				
Interaction (S×T)				0.113				

maximum proline content was recorded among the species in St. Augustine grass (33.03 µmole/gfw) while minimum was found in Bahia grass (13.52 µmole/gfw). Among the treatments of salt concentration (NaCl mM) it was observed that maximum proline content recorded (49.50 µmole/gfw) in 500 mM salt level and minimum was recorded (4.55 µmole/gfw) in control. The interaction data shows that the proline concentration of all the species significantly increasing in respect to the increasing salt concentration. All the grasses exhibited lower proline content at control condition but it increased as salinity level increased from control to 500 mM salt concentration. The maximum proline content observed in St. Augustine grass (70.17 µmole/gfw) followed by Manila garss *(*63.94 µmole/gfw) at 500mM salt concentration while minimum was recorded in Bahia grass (25.47 µmole/gfw). Some compatible solutes that show an increase in concentration under salinity stress may also play significant role in osmotic adjustment, and these include proline, glycine betaine, and sugars (Storey and Jones 1979). Glycine betaine and proline protect enzymes (proteins) from damages caused by salinity or dehydration stress (Paleg *et al*. 1984, Smirnoff and Cumbes 1989) interestingly, significant proline accumulation generally occurs only after exceeding a threshold of drought or salt

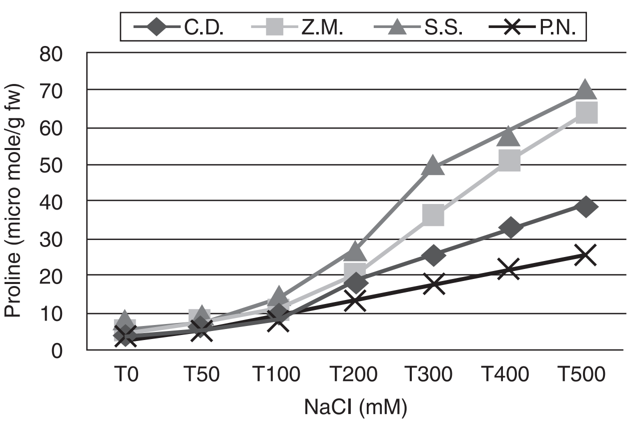

Fig 2 Different concentrations of salt (mM NaCl) on proline content (µmole/g fw) on different turfgrass species.

stress (Cavalieri and Huang 1979). In the current study, salinity triggered proline synthesis in response to salinity to turgor maintenance (Table 5). Osmotic adjustment through synthesis of organic compounds has been postulated to have a significant role in salt tolerance in St. Augustine grass reported by Marcum (1994). St. Augustine grass would contribute substantially to osmotic adjustment, however, the high shoot succulence of St. Augustine grass (Marcum and Murdoch 1990) may result in a dilution effect on a whole-cell basis.

Shoot dry weight: It is clear from the data presented in Table 6 that the effect of treatment, species and interaction was found to be significant with respect to shoot dry weight. Among the different turf grass species it was found that the maximum shoot dry weight observed in case of *Zoysia matrella* (1.69g/100cm^2) followed by *Stenotaphrum secundatum* (1.59/g/100 cm^2), i.e. 15.50% and 8.62% reduction in shoot dry weight respectively with respect to control whereas minimum shoot dry weight was recorded in *Paspalum notatum* (0.73 g/100 cm^2), i.e. 39.16% reduction in shoot dry weight. Among the concentration of salt (NaCl mM) it was observed that maximum shoot dry weight recorded in $T_{0,\ \text{i.e.}}$ Control (1.70 g/100 cm^2) and minimum was recorded in treatment T_6 at 500mM (0.95 g/100 cm^2) NaCl salt concentration which represents 44.11% reduction in shoot dry weight. The interaction data shows that the shoots dry weight of all the species significantly decreasing with respect to the increasing salt concentration. At the highest salinity level (500 mM NaCl) maximum shoot dry weight was found in case of *Stenotaphrum secundatum* (1.34 g/100 cm^2) while minimum shoot dry weight was recorded in *Paspalum notatum* (0.25g/100cm^2) which represent 22.9% and 79.16% reduction in shoot dry weight respectively with respect to control. A common response of plants to salinity is shoot dehydration and loss of cell turgor, resulting in reduced growth rate (Neumann *et al.* 1988). High shoot growth rates of St. Augustine grass at the highest salinity level may have resulted from maintenance of shoot tissue succulence. Rather than comparing absolute growth rates under salt stress, salinity tolerance is better expressed as relative shoot growth reduction (as a percent

Table 6 Effect of different concentrations of salt (mM NaCl) for shoot dry weight (g/100 cm^2) on different turfgrass species

Species	Treatment (Conc. NaCl mM)							
	T_0 (Con)	T_1 (50Mm)	T_2 (100Mm)	T_3 (200Mm)	T_4 (300Mm)	T_5 (400Mm)	T_6 (500Mm)	Mean
Cynodon dactylon	1.87	1.80	1.61	1.44	1.22	1.10	0.94	1.42
Zoysia matrella	2.00	1.97	1.80	1.71	1.61	1.47	1.29	1.69
Stenotaphrum secundatum	1.74	1.74	1.69	1.64	1.57	1.45	1.34	1.59
Paspalum notatum	1.20	1.14	0.95	0.73	0.51	0.33	0.25	0.73
Mean	1.70	1.66	1.51	1.38	1.23	1.08	0.95	
CD (P=0.05)								
Species (S)				0.004				
Treatment (T)				0.006				
Interaction (S×T)				0.012				

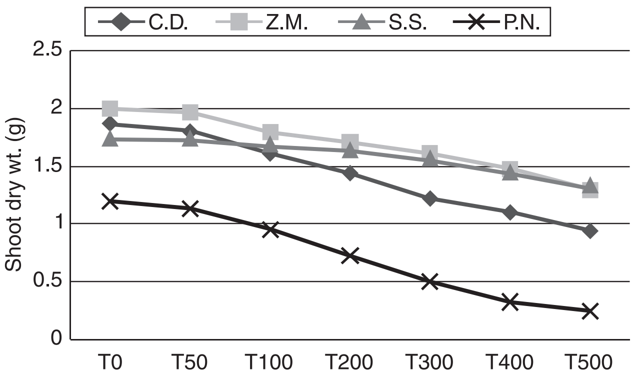

Fig 3 Different concentrations of salt (mM NaCl) on shoot growth reduction on different turfgrass species.

of control) with increased salinity, which is an indication of relative plant vigor under stress (Maas and Hoffman 1977). Using 50% relative yield reduction as a criteria St. Augustine grass, Manila grass, and Bermuda grass were most salt tolerant. These findings are in accordance with the earlier reports by Marcum (1994).

Root dry weight: It is clear from the data presented in Table 7 that the effect of treatment, species and interaction was found to be significant with respect to root dry weight. Root dry weight of all turf grass species was significantly influenced by salinity. Among the different turf grass species it was found that the maximum root dry weight observed in *Zoysia matrella* (3.69 g/100 cm^2) followed by *Stenotaphrum secundatum* (3.56 g/100 cm^2) i.e. 7.98% and 3.78% reduction in root dry weight respectively with respect to control whereas minimum root dry weight was recorded in *Paspalum notatum* (1.94 g/100 cm^2) i.e.39.37% reduction in root dry weight. Among the concentration of salt (NaCl mM) it was observed that maximum root dry weight recorded in T_0, i.e. Control (3.70 g/100 cm^2) and minimum was recorded at 500mM (2.34 g/100 cm^2) NaCl salt concentration which represent 36.75% reduction in root dry weight. The interaction data shows that the roots dry weight of all the species significantly decreasing with respect to the increasing salt concentration. At the highest salinity level(500 mM NaCl) maximum root dry weight was found in case of *Stenotaphrum secundatum* (3.34 g/100 cm^2) while minimum root dry weight was recorded in *Paspalum notatum* (0.51 g/100 cm^2) which represent 9.72% and 84.06% reduction in root dry weight respectively with respect to control. Growth parameters, such as root mass (Marcum and Kopec 1997) has been reported to be excellent criteria to determine salinity tolerance among turf grasses.

Table 7 Effect of different concentrations of salt (mM Nacl) for root dry weight (g/100 cm^2) on different turfgrass species

Species	Treatment (Conc. NaCl mM)							
	T_0 (Con)	T_1 (50Mm)	T_2 (100Mm)	T_3 (200Mm)	T_4 (300Mm)	T_5 (400Mm)	T_6 (500Mm)	Mean
Cynodon dactylon	3.88	3.81	3.62	3.43	3.20	3.10	2.20	3.32
Zoysia matrella	4.01	3.96	3.81	3.71	3.60	3.45	3.30	3.69
Stenotaphrum secundatum	3.70	3.70	3.64	3.59	3.53	3.45	3.34	3.56
Paspalum notatum	3.20	3.14	2.23	1.91	1.53	1.08	0.51	1.94
Mean	3.70	3.65	3.32	3.16	2.96	2.77	2.34	
CD (P=0.05)								
Species (S)				0.010				
Treatment (T)				0.013				
Interaction (S×T)				0.027				

Growth limitation at high salinity may be due to depletion of energy that is needed for growth and the loss of turgor (Marcum 2006). *Stenotaphrum secundatum,* the highest salinity tolerant species could be selected as popular species for cultivation in a salt-affected land (Uddin *et al*. 2011).

Conclusion

The development of turfgrass industry in the salt affected area is challenging due to scarcity of fresh water for irrigation. Appropriate, realistic physiological criteria are essential to define the salinity tolerance and growth responses of turfgrass species. In the present study, salinity tolerance was evaluated on the basis of leaf firing, shoot and root growth reduction, proline content, chlorophyll content and relative water content. It was observed that *Stenotaphrum secundatum* (St. Augustine grass) was highly salt tolerant at salinity level followed by *Zoysia matrella* (Manila grass) while *Cynodon dactylon* (Bermuda grass) was moderate tolerant species, whereas *Paspalum notatum* (Bahia grass) was least tolerant. The conclusion is based on responses of four turfgrass species to salinity tolerance. Many of the principles can be incorporated to discuss issues related to development of better selection criteria for other turfgrass species also.

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