WFL Publisher
Science and Technology
Meri-Rastilantie 3 C, FI-00980
Helsinki, Finland
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Journal of Food, Agriculture & Environment Vol.4 (3&4) : 240-243. 2006 www.world-food.net

Growth responses of bermudagrass and seashore paspalum under various levels of sodium chloride stress

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Received 6 May 2006, accepted 23 August 2006.

Abstract

Bermudagrass (*Cynodon dactylon* L.), cv. Tifway 419 and seashore paspalum (*Paspalum vaginatum* Swartz), cv. Sea Isle 2000 were studied in a greenhouse to evaluate their growth responses in terms of shoot and root lengths, shoot fresh biomass production and shoot and root dry matter (DM) weights under different levels of NaCl salinity. The grasses were grown hydroponically under four levels of NaCl (sodium chloride) salinity treatments. The treatments consisted of Control (no salt); 5,000; 10,000; 20,000 and 30,000 mg/l of NaCl in the culture medium. Four replications of each treatment were used in a randomized complete block (RCB) design in this investigation, using Hoagland solution No. 1. The grass shoots (clippings) were harvested weekly, fresh weights were determined. Then, the materials were oven dried at 60°C and DM weights recorded. Shoot (pre-harvest) and root lengths were also recorded at each harvest. At the last harvest, plant roots were also harvested, oven dried at 60°C and DM weights were determined and recorded. The results show that, for both grass species, shoot and root lengths were stimulated at the low levels (5,000 and 10,000 mg/l) of the NaCl salinity, but substantially decreased at the high levels (especially, at the highest level, 30,000 mg/l) of the NaCl salinity. As the exposure time to salt stress progressed, shoot and root fresh and DM weights were more severely affected than the shoot and root lengths by salinity. These parameters significantly decreased at any levels of NaCl salinity. Bermudagrass was more severely affected than paspalum under any levels of NaCl applications. The above results were observed for both the 4th harvest as well as for the average of all harvests.

Key words: Bermudagrass, seashore paspalum, salinity stress, NaCl, shoot growth, root growth, biomass, dry matter.

Introduction

Water quality and quantity are major problems worldwide, especially in water shortage areas [10, 20, 30]. 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 [2, 16].

One strategy to enhance turfgrass survival and recovery from salt stress is to use cultivars with superior salinity tolerance [1, 7, 9]. However, development of salt-tolerant cultivars is not simple because the trait is quantitative (controlled by many physiological mechanisms and genes) [4, 12, 14] and lacks a standardized screening protocol at both intra- and inter-species levels [1, 7, 15]. Therefore, reliable selection criteria are fundamental for developing salt-tolerant cultivars.

Perennial turfgrasses must maintain cosmetic appeal, adequate growth, and persistence under variable levels of salinity-laden water over several years. Successful assessment of salinity tolerance of perennial, halophytic turfgrasses, therefore, should be based on growth at no saline, intermediate and high salinity levels. In addition to shoot evaluation, root and verdure parameters should be measured in tolerance assessment, especially for grasses exposed to combined biotic or abiotic stresses [1, 6, 17, 18].

Therefore, halophytic turfgrass like seashore paspalum (*Paspalum vaginatum* Swartz) needs to be evaluated at salinity regimes up to sea water level ($EC_w \cong 54$ dS m^{-1} or $\cong 34{,}560$ mg/l) [6] to select the best genotype. Salt problems in turfgrass sites are continually becoming more common.

The objectives of this study were to confirm selection criteria for evaluation of salinity tolerance in halophytic bermudagrass and seashore paspalum, and to determine the influence of increasing salinity level on shoot and root lengths as well as fresh and dry weights of these turfgrass species.

Materials and Methods

Two species of turfgrasses [bermudagrass (*Cynodon dactylon* L., cv., Tifway 419) and seashore paspalum (*Paspalum vaginatum* Swartz, cv., Sea Isle 2000)] were studied in a greenhouse to evaluate their growth in terms of shoot and root lengths as well as fresh and dry matter (DM) weights under various levels [Control (0 = no salt); 5,000; 10,000; 20,000 and 30,000 mg/l] of NaCl salinity in the culture medium, using hydroponics technique.

The grasses were grown as vegetative propagules, followed the procedures used by Pessarakli *et al.* [24] in cups, 9 cm diameter and 7 cm height. Silica sand was used as the plant anchor medium.

The work was partially done during Dr. Touchane's sabbatical leave at the University of Arizona.

Each cup was fitted into one of the 9 cm diameter holes cut in a rectangular plywood sheet of 46 cm x 37 cm x 2 cm dimensions. The plywood sheets served as lids for the hydroponics tubs, supported the cups above the solution to allow for root growth and were placed on 42 cm x 34 cm x 12 cm Carb-X polyethylene tubs containing half strength Hoagland solution No. 1[13]. Four replications of each treatment were used in a randomized complete block (RCB) design in this investigation.

Statistical analysis: The data were subjected to Analysis of Variance, using SAS statistical package [28]. The means were separated using Duncan Multiple Range test.

Results and Discussion

The results for the 4th harvest and the average of all the harvests are presented in Tables 1 and 2, respectively.

Shoot length: The data of the 4th harvest (Table 1) as well as the average of the 4 harvests (Table 2) show that the shoot lengths of both turfgrasses were stimulated at all levels of NaCl salinity, except at the highest level (30,000 mg/l) of the NaCl application rate in the culture medium. The stimulation effect of NaCl was more significant for paspalum compared to bermudagrass. For both grass species, the lowest level of the NaCl salinity (5,000 mg/l) stimulated the shoot length most. The average of the data for all the harvests had essentially the same results as the 4th harvest (Tables 1 and 2). At either the control or any levels of NaCl salinity the shoot length of paspalum was substantially higher than that of the bermudagrass.

Root length: In contrast to the shoot length, the root length was less affected by the NaCl salinity (Tables 1 and 2, Fig. 1). The stimulation effect of the NaCl salinity on the root lengths of both grass species was more than that for the shoots at the lowest level of NaCl salinity (Tables 1 and 2, Fig. 1). This is in agreement with the reports of several investigators [23-25, 27] as well as the common knowledge in plant physiology that under stress conditions (nutrient deficiency stress or lower levels of water in the rhizosphere), roots grow more in search of water and/or nutrients. As was observed for the shoots, the root length of paspalum was substantially higher than that of bermudagrass for the controls or at any levels of salinity.

Biomass production: The shoots and roots of both turfgrasses were sampled, and fresh biomass was determined (Tables 1 and 2). At each salinity level and at each harvest, the fresh weights of shoots and roots of paspalum were significantly higher than that of bermudagrass (Tables 1 and 2). Reduction in biomass production due to salinity stress was more pronounced than reduction in shoot lengths in both bermudagrass and paspalum.

Table 1. Shoot and root lengths, fresh weights and dry weights (harvest # 4) of bermudagrass and seashore paspalum under various levels of NaCl salinity.

Grass species	NaCl (mg/l)	Length (cm)		Shoot weight (g)		Root weight (g)	
		Shoot	Root	Fresh.wt.	Dry wt.	Fresh.wt.	Dry wt.
Bermudagrass	Control (0)	0.91ef	14.53de	0.38cd	0.26b	0.46cd	0.14c
	5,000	1.13cde	16.15cd	0.28cde	0.14cd	0.37cd	0.12c
	10,000	1.00def	13.35de	0.13ef	0.08de	0.25cd	0.10cd
	20,000	0.68ef	12.60de	0.12ef	0.07de	0.21cd	0.07cd
	30,000	0.48f	10.65e	0.03f	0.02e	0.09d	0.03d
Seashore	Control (0)	1.98ab	34.28ab	0.61ab	0.44a	1.74a	0.42a
paspalum	5,000	2.58a	37.75a	0.80a	0.52a	1.92a	0.44a
	10,000	2.05ab	29.25b	0.46bc	0.19bc	1.57a	0.38a
	20,000	1.73bc	21.45c	0.24de	0.15cd	1.10b	0.26b
	30,000	1.59bcd	16.60cd	0.21def	0.13cd	0.58c	0.12c

The values are means of 4 replications of each treatment. The values in each column followed by the same letter are not statistically different at the 0.05 probability level.

Table 2. Shoot and root lengths, shoot fresh and dry weights, shoot succulence (fresh wt./dry wt.) and shoot/root ratio (shoot dry wt./root dry wt.) (average of 4 harvests) of bermudagrass and seashore paspalum under various levels of NaCl salinity.

Grass species	NaCl (mg/l)	Length (cm)		Shoot weight (g)			Shoot wt./Root wt.
		Shoot	Root	Fresh.wt.	Dry wt.	Fresh/Dry	
Bermudagrass	Control (0)	0.95de	3.63cde	0.47bcd	0.32b	1.47c	9.14a
	5,000	1.86abc	4.04cde	0.39cde	0.20bcd	1.95ab	6.67b
	10,000	1.03de	3.34de	0.24def	0.15cde	1.60bc	6.00b
	20,000	0.89e	3.15e	0.16ef	0.09de	1.78abc	5.14bc
	30,000	0.76e	2.66e	0.08f	0.05e	1.60bc	6.67b
Seashore	Control (0)	2.48a	8.07ab	0.71ab	0.51a	1.39c	4.86bcd
paspalum	5,000	2.31ab	9.44a	0.84a	0.55a	1.53c	5.00bc
	10,000	2.23ab	7.31b	0.58abc	0.28b	2.07a	2.95d
	20,000	1.89abc	5.36c	0.35cdef	0.22bc	1.59bc	3.39cd
	30,000	1.63bcd	4.15cd	0.23def	0.14cde	1.64bc	4.67bcd

The values are means of 4 replications of each treatment. The values in each column followed by the same letter are not statistically different at the 0.05 probability level.

The decrease in plant biomass production due to salinity which was found in the present study may be attributed to low medium water potential, specific ion toxicity or ion imbalance as reported by Greenway and Munns [11]. Plant biomass production depends on the accumulation of carbon products via photosynthesis, but elevated salinity has probably adversely affected photosynthesis in the present study as was reported by Munns and Termaat [21] and Macler [19]. Photosynthetic capacity of many plant species is reduced in the presence of salinity which is associated with stomata closure as reported by Seemann and Critchley [29] and Delfine *et al.* [5], damage to photosynthetic systems by excessive energy reported by Flowers *et al.* [8] and structural disorganization suggested by Delfine *et al.* [5], Flowers *et al.* [8] and Romero-Aranda *et al.* [26]. Any or all of these factors combined may have caused a reduction in biomass production in these grass species in the present study.

Shoot dry matter (DM) weight: Shoot DM weight responses followed essentially the same pattern as that of the shoot fresh weights. The values significantly decreased as the levels of the NaCl applications increased. This is clearly shown for the 4th harvest (Table 1) as well as for the average of the 4 harvests (Table 2). However, the effect of the NaCl salinity was more pronounced at the later harvests and at the higher levels of salinity. As was observed for the shoot lengths and shoot fresh weights, bermudagrass was more severely affected by NaCl salinity than paspalum (Tables 1 and 2).

Root dry matter (DM) weight: Root DM weights of both grass species significantly decreased as the level of the NaCl application rates increased (Table 1). The control values were substantially higher than those of any NaCl treatments for both bermudagrass and paspalum. It appears that both grasses readily absorbed the nutrients and water translocated and utilized the absorbed elements for the shoot growth. In the previous hydroponics studies, numerous experiments (Pessarakli and Marcum, unpublished reports) showed very little root growth for some grasses, but substantial shoot growth for the same grass species.

The differences in growth rates among the bermudagrass and paspalum followed similar trends both in the presence and in the absence of NaCl. The higher biomass of shoots and roots of paspalum in comparison with that of bermudagrass (Tables 1 and 2, Fig. 1) may have been due to more vigorous and higher growth rate of the former species under any growth conditions, particularly under salinity stress. The lower transpiration rate of paspalum compared to bermudagrass as reported by Chen *et al.* [3] may be another reason for this phenomenon, particularly under the stress condition.

In short, the genotypic growth difference played the dominant role in determining biomass accumulation of the turfgrasses grown with or without salinity stress as clearly shown in plant succulence (the ratios of the shoot fresh weights to dry weights) of both species (Fig. 2).

The NaC1 salinity at the higher application rates (20,000 and 30,000 mg/l) significantly decreased plant growth, though net photosynthesis rate was probably not affected by 5,000 mg/l NaC1 salinity in the youngest fully expanded leaves. This is supported by Munns *et al.* [22] findings that photosynthesis did not limit growth as the NaC1 levels increased the concentrations of soluble carbohydrate in the elongating tissues of the growing leaves of barley plants, but did not change starch concentrations. This suggests that carbohydrate use, not production, is limiting growth of salinity-stressed plants.

In contrast, root growth was less affected by NaC1 salinity stress than shoot growth, leading to a decrease in shoot to root ratios (Fig. 3) in the early growth phase. Owing to the increased

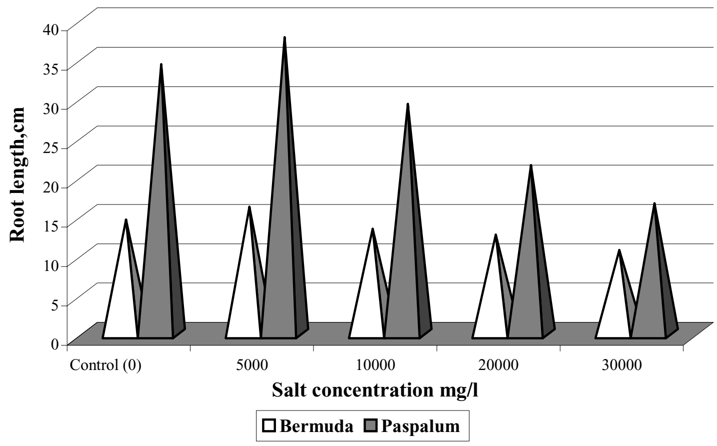

Figure 1. Effects of various levels of the NaCl salinity on the root lengths of bermudagrass and seashore paspalum.

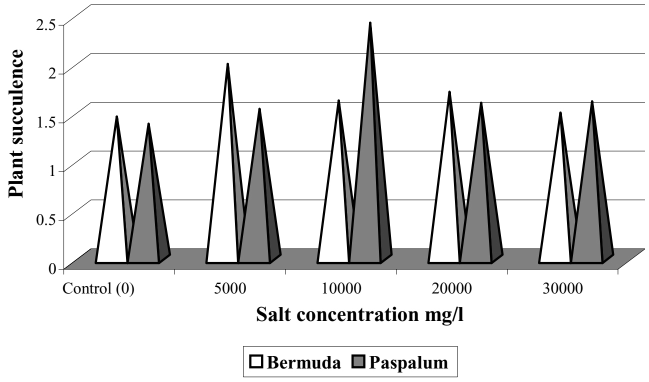

Figure 2. Effects of the NaCl salinity on the shoot succulence (shoot fresh wt./shoot dry wt.) of bermudagrass and seashore paspalum.

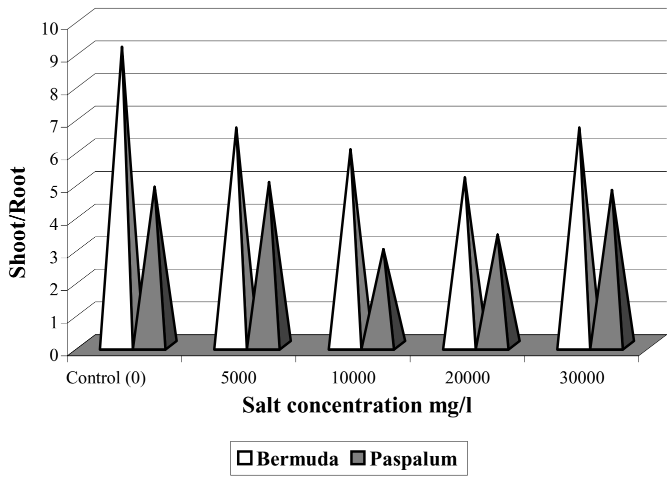

Figure 3. Effects of the NaCl salinity on the shoot/root ratios of bermudagrass and seashore paspalum.

leaf injury in bermudagrass and accelerated senescence caused by salt toxicity in long term, carbohydrate supply for root growth would be limited as was reported by Munns and Termaat [21].

Summary and Conclusions

Two major turfgrass species [bermudagrass (*Cynodon dactylon* L.), cv. Tifway 419 and seashore paspalum (*Paspalum vaginatum* Swartz), cv. Sea Isle 2000] were studied hydroponically in a greenhouse to evaluate their growth responses in terms of shoot and root lengths, shoot fresh biomass production and shoot and root dry matter (DM) weights under various levels of the NaCl salinity in the culture medium, using Hoagland solution No. 1. The grass shoots (clippings) were harvested weekly, fresh weights were determined, the materials were oven-dried at 60°C and DM weights recorded. At each harvest, both shoot and root lengths were measured and recorded. At the last harvest, plant roots were also harvested, oven-dried and DM weights were determined and recorded.

For both grass species, shoot and root lengths were stimulated at the low levels of the NaCl salinity, but substantially decreased at the high levels of NaCl applications. The most pronounced reduction in these parameters occurred at the highest level of NaCl salinity in the culture medium. Shoot and root fresh and DM weights were more severely affected than the shoot and root lengths by salinity stress. For both grass species, shoot lengths and dry matter (DM) weights were more severely affected than those of roots by the NaCl salinity. For any study parameters, at any harvest and at any salinity level, bermudagrass was more severely affected than paspalum by salinity stress.

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