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Using Bermudagrass (*Cynodon dactylon* L.) In Urban Desert Landscaping and as a Forage Crop for Sustainable Agriculture in Arid Regions and Combating Desertification

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Abstract: Bermudagrass (*Cynodon dactylon* L.), cv. Arizona Common, was studied in a greenhouse experiment to evaluate its growth responses in terms of shoot and root lengths, shoot and root fresh and dry weights and percentage of grass visual green cover under control and salt stress conditions viz., sodium chloride (NaCl). Plants were grown under control (distilled water) and four levels of salt (75, 150, 225 and 300 mM NaCl equivalent to 4.38, 8.77, 13.15 and 17.53 g L^{-1} sodium chloride, respectively), using a hydroponics system. Results showed that the adverse effect of salinity on the root length started to appear from the third harvest, generally at the higher levels of salinity and it was more pronounced as the exposure time to salinity progressed. Shoot length was more severely affected under salt stress compared to root length. The effect of salinity on shoot length was shown from the first harvest. Generally, for any harvest, only the highest NaCl level significantly reduced the shoot fresh and dry weights compared to that of the control or any other salinity levels. The root fresh and dry weights were decreased under salinity stress compared with the control treatment, while there was no significant difference detected between the root fresh or dry weights of different salinity treatments. All the grasses showed excellent recovery when transferred into the normal 1/2 strength Hoagland solution after the termination of the salinity stress period. Bermudagrass proved to have a satisfactory growth under the salinity levels of the experiment higher than the soil salinity of the harsh desert conditions. This indicates that Bermudagrass can effectively be used for cultivation under desert saline soils. Therefore, this grass could be recommended for sustainable production under harsh desert conditions with high soil salinity levels, limited water resources and drought conditions and effectively combating desertification processes.

Key words: Bermudagrass · Combating desertification · Sustainable agriculture

INTRODUCTION

Continuous desertification of the arable lands due to urbanization, global warming and shortage of water mandates use of marginal lands and saline soils and low quality/saline water, particularly associated with desert regions, for irrigation and cultivation of plant species with high degrees of salt and drought tolerance, especially in regions experiencing water shortage. Cultivation and agricultural practices on saline soils and using low quality/saline water for irrigation imposes more salt stress on plants which are already under stress in these regions characterized with saline soils and shortage of water. Thus, there is an urgent need for finding salt/drought tolerant plant species to survive/sustain under such stressful conditions. Since the native plants are already growing under such conditions and are adapted to these stresses, these plants are the most suitable candidates to be manipulated under the minimum cultural practices and minimum inputs (water, fertilizer and other agrichemicals) for use under these stressful conditions. If stress tolerant species/genotypes/ cultivars of these native plants are successfully identified, there would be a substantial savings in cultural practices and inputs in using these plants by the growers and will result in substantial savings in the local, regional and the national currencies

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of the countries. In previous investigations [1-4] indicated that Bermudagrass (*Cynodon dactylon* L.) is a halophytic grass species that has a great potential to be used under harsh and stressful environmental conditions, characterized with arid regions, yet perform very satisfactory growth. This grass has multiple usages, including animal feed, soil conservation and stabilization against erosion and use for lawns/parks/ recreation areas as desert landscaping plant.

One strategy to enhance plant survival and recovery from salt stress is to use cultivars with superior salinity tolerance [5-9]. However, development of salt-tolerant cultivars is not simple because the trait is quantitative (controlled by many physiological mechanisms and genes) [10, 11] and lacks a standardized screening protocol at both intra- and inter-species levels [5, 7, 12]. Therefore, reliable selection criteria are fundamental for developing salt-tolerant cultivars.

Grasses along with various other kinds of plants often have to endure environmental stresses, with salinity issues being one of the most common stresses they encounter [2-4, 13-21]. Salinity stress can stunt growth, dehydrate, cause chemical imbalances and make the plants susceptible to injury.

Some grasses deal with salinity better than other species [2-4, 13-21]. To help aid in salinity tolerance, cultivars are selected and bread for having increased tolerance. For a grass to be considered tolerant to the saline conditions, it must meet some basic criteria such as having acceptable quality, reasonable growth and persistence at various levels of salinity. With that been said, assessment of salt tolerance in grasses should be evaluated under control (no salt), low, moderate and high salt levels. Factors to look for could be overall visual appeal, shoot length, root length and biomass production.

Perennial vegetation coverage in desert regions must maintain adequate growth and persistence under variable levels of soil salinity or salinity-laden water over several years. Successful assessment of salinity tolerance of perennial, halophytic plants, 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 plant species exposed to combined biotic or abiotic stresses [5, 6, 22].

Salt problems in agricultural sites, especially in desert regions, are continually becoming more common. Therefore, halophytic plants such as Bermudagrass (*Cynodon dactylon* L.) need to be evaluated at salinity regimes up to sea-water salinity level [4, 6, 16] to select the best genotype.

Bermudagrass grows worldwide as a turf grass/landscaping plant, forage/pasture grass, or as a sustainable desert cover grass species for soil erosion control in a wide range of climates, soils and environmental conditions. It is a warm-season grass species, a common major turfgrass/ landscaping plant or sustainable desert grass species used in the Southwest USA and other arid regions. The species is very tolerant to salinity, drought and heat stress, all characteristics of the Southwest or other desert areas. Despite its fairly well stress tolerance, the species is vigorously studied to find more tolerant cultivars with more efficient nutrient and water use [1, 23, 24]. These characteristics can be beneficial for this plant species growth in arid and semi-arid regions where the soils are usually saline/sodic and water is limited for irrigation and other agricultural uses.

The objectives of this study was to evaluate growth and performance of Bermudagrass, a warm-season desert species, in terms of shoot and root length as well as shoot (clippings) and root fresh and dry weights under control treatment (no salt) and various levels of salinity (sodium chloride) stress, characteristics of arid region soils, for use under such harsh and stressful desert conditions for sustainable agriculture and combating desertification processes.

MATERIALS AND METHODS

Bermudagrass, cv. Arizona Common was used in a greenhouse experiment to evaluate its shoot and root growth as well as its fresh and dry weights under control and salt (NaCl) stress conditions, using a hydroponics technique.

Plants were grown as vegetative propagules in cups, 9 cm diameter and 7 cm height, followed the procedures used by Marcum and Pessarakli [2, 13], Marcum *et al*. [14], Pessarakli [15, 23], Pessarakli and Touchane [4, 16], Pessarakli and Kopec [17, 18, 24] and Pessarakli *et al*. [19-21]. Silica sand was used as the plant anchor medium. Each cup was fitted into one of the 9 cm diameter holes cut in a rectangular plywood sheet 52 cm x 40 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 48 cm x 36 cm x 18 cm Carb-X polyethylene tubs containing 1/2 strength Hoagland solution No. 1 [25]. Four replications of each treatment were used in a randomized complete block design (RCBD) in this study.

Plants were allowed to grow in this nutrient solution for six weeks. During this period, the plant shoots (clippings) were harvested weekly in order to allow the

Bermudagrass to reach full maturity and develop uniform and equal size plants. The harvested plant materials (clippings) were discarded. The culture solutions were changed biweekly to ensure adequate amount of plant essential nutrient elements for normal growth and development. At the last harvest (6th week), the roots were also cut to 0.5 cm length ensuring that all plants had uniform roots and shoots for the stress phase of the experiment.

The salt treatments were initiated by adding 50 mM, 2.922 g NaCl per liter of the culture solution per day. Five treatments were used, including control (no salt addition), 75, 150, 225 and 300 mM salinity levels. The culture solution levels in the tubs were marked at the 10 liter volume level and maintained at this level by adding water as needed. After the final salinity level was reached (day 6 after the initiation of the salt treatment), the shoots (clippings) were harvested and the harvested plant materials were discarded for the last time.

After the completion of the salt treatments, plant shoots were harvested weekly for the evaluation of the fresh and dry matter (DM) production. At each weekly harvest, both shoot and root lengths were measured and recorded. The harvested plant materials were oven dried at 65° C and DM weights were measured and recorded. The recorded data were considered the weekly plant DM production. The shoot succulence was also calculated by the ratio of the shoot fresh weight to dry weight. At the termination of the experiment, the last harvest, plant roots were also harvested, oven dried at 65° C and DM weights were determined and recorded.

Electrical conductivity (EC) of the culture solutions were initially measured and recorded. At the end of the experiment, the EC of the culture solutions were also measured and recorded (Final EC). By subtracting the final EC from the initial EC values, the quantity of the salts removed by the plants from the culture medium was estimated.

Statistical Analysis: The data were subjected to Analysis of Variance, using SAS statistical package [26]. The means were separated, using Duncan Multiple Range test.

RESULTS AND DISCUSSIONS

Root Length: The effects of salinity stress on the cumulative length of roots are shown in Tables 1 and 2. The weekly effects of salinity stress on roots are shown in Table 3. Table 1, cumulative root length, shows that root length significantly decreased at all salinity levels compared with the control treatment. However, statistically, there was not any significant difference found between the cumulative root lengths at different salinity levels (Table 1). Table 2 shows the root and shoot lengths and dry weights calculated based on the percent of the control values. The adverse effect of salinity on the root length started to show from the third harvest generally at the higher levels (225 and 300 mM) of salinity. This decrease was more pronounced as the exposure time to salinity progressed. As shown in Table 3, salinity stress did not have any significant effect on the weekly root lengths of the grasses.

Shoot Length: The shoot length was more severely affected under salt stress compared to the root length (Tables 1 and 2 for the cumulative values and Table 3 for the weekly values). The effect of salinity stress on shoot length was shown from the first harvest at all salinity levels, including the lowest (75 mM) NaCl level. However, Pessarakli *et al*. [19] found that the effect of salinity on Saltgrass (*Distichlis spicata* L.) shoot length was statistically significant at 200 mM or more salinity levels compared to the control and the low (100 mM) level of NaCl. This is an indication of the difference in salt tolerance of these two grass species (Bermudagrass vs. Saltgrass).

Shoot Fresh Weight: The cumulative shoot fresh weights presented in Table 1 show that, generally, for any harvest, only the high (300 mM) level of NaCl significantly reduced the shoot fresh weight compared to the control or any other levels of salinity. However, Pessarakli *et al*. [19] found that there was no significant difference detected on the salt grass shoot fresh weights between the high (400 mM) salinity level compared with the low (100 mM) NaCl stress and the control treatment. They also found that as the stress period progressed, the medium (200 mM) sodium chloride stress enhanced the salt grass shoot fresh weight. Pessarakli [27] also reported enhancement of Cotton (*Gossypium hirsutum* L.), a salt tolerant plant, growth and protein synthesis under low level of NaCl stress.

The decrease in plant biomass production due to high level of salinity found in the present study may be attributed to the low medium water potential, specific ion toxicity, or ion imbalance as reported by Greenway and Munns [28].

Shoot Dry Matter (DM) Weight: Shoot dry weights essentially followed the same pattern as the shoot fresh weights. Generally, for any harvest, only the high (300 mM) level of NaCl significantly reduced the shoot

Table 1: Bermudagrass growth responses (cum.)* to NaCl stress

	Length (cm)*		Fresh Wt. (g)*		Dry Wt. (g)*		Shoot/Root*
NaCl (mM)	Root	Shoot	Root	Shoot	Root	Shoot	ratio
Control	55.6a** 83.9a	0.71a	16.64a	0.47a	7.6a	16.2c	
75	47.4b	69.0b	0.51b	15.66a	0.34b	6.9a	20.3b
150	48.7b	69.6b	0.44b	17.22a	0.29b	7.0a	24.1a
225	43.8b	60.7c	0.48b	15.00a	0.32b	6.2a	19.4b
300	45.9b	54.8c	0.44b	11.82b	0.29b	4.6b	15.9c

*The values are the averages of 4 replications of each treatment.

**The values followed by the same letters in each column are not statistically different at the 0.05 probability level.

Table 2: Bermudagrass growth responses (based on the% of the control) to NaCl stress

	Length (cm)		Dry Wt. (g)	
NaCl (mM)	Root	Shoot	Root	Shoot
Control	100	100	100	100
75	85	82	72	91
150	88	83	62	92
225	79	72	68	82
300	83	65	62	61

Table 3: Bermudagrass weekly growth responses* to NaCl stress

	Length (cm)*		Dry Wt. (g)*		Shoot/Root*
NaCl (mM)	Root	Shoot	Root	Shoot	ratio
Control	6.2a**	9.3a	0.05a	0.84a	16.8c
75	5.3a	7.7b	0.04a	0.77a	19.3c
150	5.4a	7.7b	0.03a	0.78a	26.0a
225	4.9a	6.7bc	0.03a	0.69ab	23.0b
300	5.1a	6.1c	0.03a	0.51b	17.0c

*The values are the averages of 4 replications of each treatment.

**The values followed by the same letters in each column are not statistically different at the 0.05 probability level

dry weight compared to the control or any other levels of salinity (Tables 1 and 2 for the cumulative shoot dry weights and Table 3 for the weekly shoot dry weights). However, Pessarakli *et al*. [19] found that there was no significant difference detected on the salt grass shoot dry weights between the high (400 mM) salinity level compared with the low (100 mM) NaCl stress and the control. They also found that as the stress period progressed, the medium (200 mM) sodium chloride stress enhanced the Saltgrass shoot dry weight. Pessarakli [27] also reported enhancement of Cotton (*Gossypium hirsutum* L.), a salt tolerant plant, growth and protein synthesis by this plant under low level of NaCl stress. In the present study, the difference between the average shoot (clippings) weights of the highest level (300 mM) of salinity stressed plants and the other treatments was wider as the exposure time to stress progressed.

Root Fresh Weight: The root fresh weight essentially followed the same pattern as the root length. It was reduced at all salinity levels compared with the control (Table 1). However, there was no significant difference between the average root fresh weights of the different salinity treatments. Marcum and Pessarakli [2, 13], Marcum *et al*. [14], Pessarakli [15], Pessarakli and Kopec [17, 18] and Pessarakli *et al*. [20, 21] also found that the adverse effects of salinity stress were more pronounced on shoot than the root growth.

Root Dry Matter (DM) Weight: The root dry weight essentially followed the same pattern as the root length and root fresh weight. It was reduced at all salinity levels compared with the control treatment (Tables 1 and 2 for the cumulative root dry weights and Table 3 for the weekly root dry weights). However, there was no significant difference detected between the average root dry weights of the different salinity treatments either for the cumulative root dry weights or for the weekly root dry weights. Marcum and Pessarakli [2, 13], Marcum *et al*. [14], Pessarakli [15], Pessarakli and Kopec [17, 18] and Pessarakli *et al*. [20, 21] also reported that the adverse effects of salinity stress were more pronounced on shoot than the root growth.

Table 4: Bermudagrass succulence (Fr.Wt./Dry Wt.) response to salinity

	Shoot succulence	
NaCl (mM)	(F.W./D.W.)	(Based on% of Cont.)
Control	2.19	100
75	2.27	104
150	2.46	112
225	2.42	111
300	2.57	117

Table 5: Bermudagrass percentage of green cover under salinity stress

	Percentage of Green Cover*								
	Week								
NaCl (mM)	1	2	3	4	5	6	7	8	9
Control	100a**	100a	100a	100a	100a	100a	100a	100a	100a
75	100a	100a	99a	99a	98a	97a	95a	92a	83b
150	98a	98a	96a	96a	95a	93a	92a	90a	78c
225	94a	93a	92a	90a	87b	83b	80b	76b	62d
300	81b	78b	74b	71b	68c	64c	59c	53c	42e

*The Values are means of 4 replications of each treatment.

**The values followed by the same letters in each column are not statistically different at the 0.05 probability level.

Shoot to Root Ratio: The shoot to root ratio of the grasses significantly increased under salinity stress levels up to 225 mM NaCl compared with that of the control plants (Table 1 for the cumulative data and Table 3 for the weekly values). There was no difference between the shoot to root ratios of the grasses at the highest level of salinity stress (300 mM NaCl) compared to the control plants (Table 1 for the cumulative data and Table 3 for the weekly values).

Shoot Succulence: Shoot succulence (Fresh Wt./Dry Wt.) was increased as salinity stress increased from control to 300 mM NaCl salinity (Table 4). These values (average of all the harvests) were 2.19, 2.27, 2.46, 2.42 and 2.57 for the control, 75,150, 225 and 300 mM NaCl treated plants, respectively.

Percentage of Grass Green Cover: The grass percentage of green cover significantly decreased at the highest salinity level (300 mM NaCl) compared to the control or any other salinity level at any evaluation week (harvest) (Table 5). As shown in this Table (Table 5), at the low and medium salinity levels (75 and 150 mM NaCl), the difference between the grasses, except for the last evaluation week (harvest), was not significant compared to the control plants. At the higher level of salinity stress (225 mM NaCl), the difference between the grasses percentage of green cover was not significant at the first 4 evaluation weeks (harvests 1-4) compared with the control and the 75 and 150 mM NaCl treatments (Table 5). Starting on week 5 to the end of the experiment, the percentage of the green cover of the grasses significantly decreased at this high level of salinity (225 mM NaCl) compared to the control and the 75 and 150 mM NaCl treatments (Table 5).

Salt Removal by the Plants from the Culture Medium: The quantity of the salts removed by the plants from the culture medium was estimated by subtracting the final electrical conductivity (EC) of the culture medium from the initial EC values of the salinized nutrient solutions (Table 6).

As shown in Table 6, at each NaCl salinity level, Bermudagrass removed substantial amount of salts from the culture medium. Therefore, this halophytic grass species would be effective in biologically reclaiming desert saline soils. There was no difference between the quantity of the salts removed from the culture media among the 75, 150 and 225 mM NaCl treatments, indicating that although the levels of salinity stress were increased, the grass removed the same quantities of the salts from the culture medium. Only at the highest level of salinity treatment (300 mM NaCl), the amount of the salts removed from the culture medium was significantly lower than that at the 150 and 225 mM NaCl treatments, while statistically the same as that at the lowest level of salinity (75 mM NaCl). Pessarakli and Touchane [4] also reported a substantial amount of salts removed from the culture

Table 6: Salt removal by Bermudagrass from the culture medium under various levels of NaCl application rates

	Electrical Conductivity (EC)			
Salinity (NaCl) treatment	Initial (mM)	Final (g/l)	Salt Removed* from Culture Soln.	
	--------------------(dS/m)------------------------		---------------------(g/l)----------------------------	
Control (0)	Control (0)	0.87	0.82	------
75	4.383	7.60	5.33	1.453ab**
150	8.766	14.45	11.86	1.658a
225	13.149	21.13	18.74	1.530a
300	17.532	27.92	26.80	1.222b

*The Values are means of 4 replications of each treatment.

**The values followed by the same letters in the last column are not statistically different at the 0.05 probability level.

medium by two halophytic grass species (Bermudagrass and Seashore paspalume). Furthermore, Pessarakli and McMillan [29] also found a substantial amount of salt removed from the culture medium by two cultivars of Seashore paspalume (Aloha and Sea Dwarf). These results show that, these halophytic grass species could be effectively used in biologically reclaiming desert saline soils and combating desertification processes, especially in arid regions.

CONCLUSIONS

Shoot length was decreased as NaCl levels increased. Root length was stimulated by NaCl at early harvests, but as the stress period progressed, root length decreased, especially at the higher NaCl levels. Shoot dry weights generally decreased as NaCl levels increased, but shoot fresh weights significantly decreased only at the highest NaCl level. Considering these results, performance of Bermudagrass at these relatively high levels of salinity stress indicate that Bermudagrass is a very high salt tolerant halophytic plant species that can easily tolerate high salinity levels of soils and waters in the arid regions and would be a suitable grass species for cultivation under harsh arid regions and effectively combat desertification processes.

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