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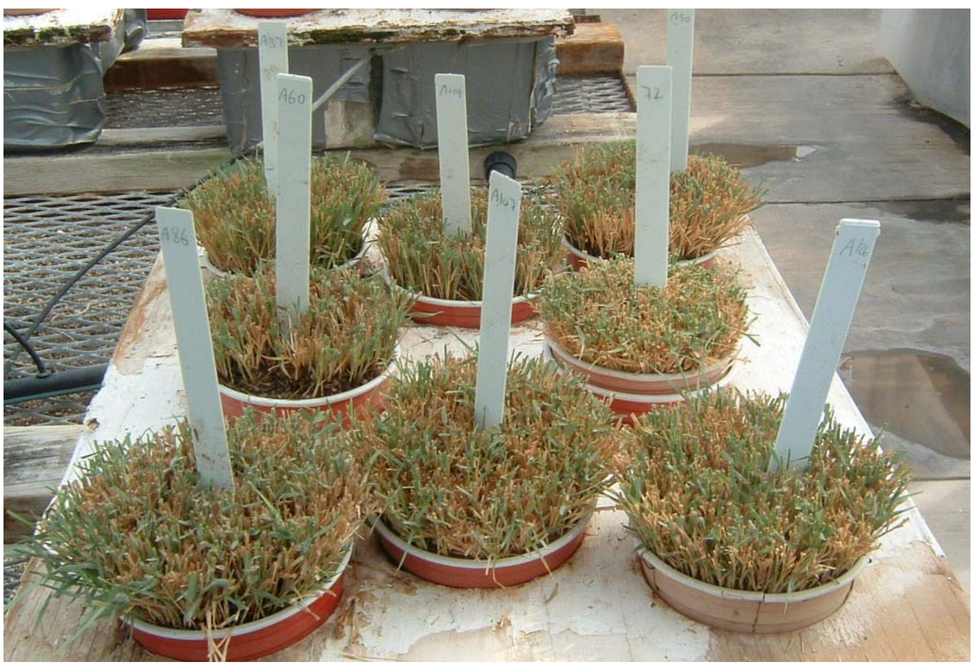

University of Arizona scientists continue to evaluate saltgrass (*Distichlis spicata*) for its ability to grow under saline conditions. The results of this study show that all clones of saltgrass are able to accumulate significant levels of nitrogen even under high salt stress.

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PURPOSE

The purpose of *USGA Turfgrass and Environmental Research Online* is to effectively communicate the results of research projects funded under USGA's Turfgrass and Environmental Research Program to all who can benefit from such knowledge. Since 1983, the USGA has funded more than 350 projects at a cost of $29 million. The private, non-profit research program provides funding opportunities to university faculty interested in working on environmental and turf management problems affecting golf courses. The outstanding playing conditions of today's golf courses are a direct result of ***using science to benefit golf***.

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Growth Responses of Saltgrass (*Distichlis spicata*) Under Sodium Chloride (NaCl) Salinity Stress

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SUMMARY

The USGA sponsored research studies are ongoing at Karsten Turfgrass Research Facility, Department of Plant Sciences, College of Agriculture and Life sciences, the University of Arizona. This specific experiment was conducted in a greenhouse to evaluate growth responses, in terms of shoot and root lengths, fresh and dry matter (DM) weights, as well as nitrogen uptake, of various saltgrass clones collected from different southwestern states of the US under sodium chloride (NaCl) salinity stress conditions. The results can be summarized as follows:

- The results of this experiment, confirmed that saltgrass has a high salt tolerance, and is a true halophyte.
- Although shoot growth numerically decreased under salinity stress compared with the control plants, the growth reduction at this level of salinity, which is considered moderate for saltgrass growth, was statistically not significant.
- Root length, root fresh weigh., and root dry weight in plants grown under saline condition increased.
- The amount of dry matter produced is the most significant result as it is a direct representation of saltgrass' ability to grow under highly saline conditions.
- Based on the results of this experiment, each of the tested varieties had a high degree of salt tolerance.
- Based on the partial results of the ^{15}N analysis, all the clones accumulated significant amounts of nitrogen in their tissues under salinity stress condition.

Saltgrass (*Distichlis spicata*) is a warm-season turfgrass species that has the ability to grow under highly saline conditions and with limited available water sources (2, 3, 4, 6, 7, 8, 11, 12). This characteristic could prove to be beneficial in certain turfgrass areas requiring low maintenance in arid regions with saline soils and limited available water resources. Use of this species could be important to aid in conservation of water and use of salt-affected soils. Tests of the species' ability to grow under highly saline conditions and with low available water sources are needed before it can be applied to a turfgrass system.

The objective of this study was to compare growth responses of saltgrass in terms of shoot and root lengths, as well as fresh and dry weights of various clones grown under salt stress condition. ^{15}N was also added to this experiment to determine saltgrass' ability to take up nitrogen during salt stress.

Materials and Methods

Saltgrass genotypes (A37, A49, A50, A60, 72, A86, A107, A126, A136, A138, 239 and 240) collected from several southwestern states of the United States (5) were studied in a greenhouse to evaluate their growth in terms of shoot and root lengths, fresh and dry matter weights, as well as nitrogen uptake of the various clones grown under

Dr. Mohammad Pessarakli inspects the growth of saltgrass clones. His research re-confirms saltgrass as a true halophyte.

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saline (NaCl) conditions at EC of 20 dSm^{-1} using a hydroponic technique.

Plants were grown in cups, 9-cm diameter and 7-cm height. Silica sand was used as the plant anchor medium. Each cup was fitted into one of the 9-cm holes cut in a rectangular plywood sheet 46 cm x 37 cm x 2 cm. The plywood sheets served as lids for the hydroponic tubs and supported the cups above the solution to allow for root growth and were placed on 42 cm x 34 cm x12 cm polyethylene tubs containing half-strength Hoagland solution (1).

Grasses were grown in a randomized complete block (RCB) design in this experiment. Four replications of each clone and each treatment were grown in this experiment. During this period, the plant shoots (clippings) were harvested weekly in order to allow the grass to reach full maturity and develop uniform and equal size plants. The harvested plant materials (clippings) were discarded. One week prior to the first harvest, all roots and shoots were cut to have uniform roots and shoots prior to the initiation of the salt stress study.

Salinity stress started by adding NaCl to the culture solution to raise the EC of the growth medium 5 dS m^{-1} per day to reach the final salinity level of 20 dS m^{-1}. Ammonium sulfate $[(^{15}NH_4)_2SO_4$ containing 5% $^{15}N]$ was added to the nutrient solution to provide 25 mg ^{15}N L^{-1} of the culture solution per week.

After the completion of the salinity treatment and ^{15}N addition, the plant shoots (clippings) were harvested weekly for the evaluation of dry matter (DM) production. At each harvest, both shoot and root lengths were measured and recorded. After the fresh weight determination, the harvested plant materials were oven-dried at 60º C and DM weights were measured and recorded. Six harvests were made in this experiment. At the termination of the experiment, plant roots were also harvested. After the fresh weights determination, the harvested roots were also oven-dried at 60º C and DM weights were measured and recorded. The data were subjected to Analysis of Variance, using SAS statistical package (SAS Institute, 1991). The means were separated using Duncan Multiple Range test.

Grass ID	Average Shoot Length (cm)		Average Root Length (cm)	
	Control	EC 20 dS/m	Control	EC 20 dS/m
A37	14.49a	12.57a	9.48ab	6.00bc
A49	13.30a	12.05a	8.60ab	6.72bc
A50	13.28a	11.26a	13.84a	5.26bc
A60	12.65a	12.15a	12.62a	13.44a
72	12.18a	10.39a	15.90a	13.16a
A86	12.22a	11.70a	7.96ab	12.08a
A107	11.65a	10.95a	3.76c	4.30c
A126	12.99a	11.29a	6.08bc	7.38b
A136	16.80a	14.08a	10.70a	12.95a
A138	11.34a	9.90a	7.10b	9.60ab
239	7.23b	6.09b	10.10a	12.85a
240	7.86b	7.08b	8.40ab	17.85a

*Shoot values are average of 4 replications and 6 harvests.
*Root values are average of 4 replications at the final harvest.
*** The values followed by the same letters in each column are not statistically different at the 0.05 probability.

Table 1. Shoot and root lengths of saltgrass under control and NaCl salinity stress

Grass ID	Average Shoot Fresh Weight (g) Control	Average Shoot Fresh Weight (g) EC 20 dS/m	Average Root Fresh Weight (g) Control	Average Root Fresh Weight (g) EC 20 dS/m
A37	1.24ab	0.86ab	0.99ab	0.46b
A49	1.02ab	0.86ab	0.07c	0.34bc
A50	1.32 ab	0.88ab	0.58b	0.24bc
A60	1.22ab	0.90ab	0.77b	0.50b
72	1.95a	1.73a	1.62a	1.20a
A86	0.77 b	1.09ab	0.67b	0.79ab
A107	0.95b	0.76b	0.41bc	0.46b
A126	1.21ab	0.92ab	0.11c	0.19c
A136	2.54a	1.01ab	0.09c	1.13a
A138	1.82a	0.74b	n/a*	n/a*
239	1.35ab	0.69b	n/a*	n/a*
240	1.69a	1.15ab	0.17c	0.82ab

*Shoot values are average of 4 replications and 6 harvests.
**Root values are average of 4 replications at the final harvest.
*** The values followed by the same letters in each column are not statistically different at the 0.05 probability.
*Note: Varieties A 138 and 239 did not produce recordable results for root dry weight.

Table 2. Shoot and root fresh weights of saltgrass under control and salinity stress

Results and Discussion

Shoot Length

The data from the average shoot length per week showed numerically a decrease in all varieties of plants grown under saline conditions compared to control. Clones 239 and 240 had statistically the lowest shoot lengths under either control or salinity stress condition (Table 1).

Root Length

The data from the total root length for the duration of the experiment showed increased root growth of 8 of the 12 varieties grown under saline condition when compared to control plants (Table 1). These 8 varieties were A60, A86, A107, A126, A136, A138, 239 and 240. Clones 239 and 240, which had statistically the lowest shoot lengths under either control or salinity stress conditions, were among the clones with the highest root lengths, especially under salinity stress conditions (Table 1).

Shoot Fresh Weight

The results showed that all varieties, except A86, produced a higher weekly average fresh weight for control plants than those grown under saline conditions (Table 2). Clones 72, A136, A138, and 240 had the highest shoot fresh weights under control condition, and clone 72 had the highest fresh weight under salinity stress condition. A86 and A107 clones had the lowest shoot fresh weights under control condition, and clones A107, A138, and 239 had the lowest fresh weights under salinity stress conditions.

Root Fresh Weight

The results of the final fresh weight of the roots showed an increase in 6 of 10 of the varieties (A49, A86, A107, A126, A136 and 240) for the plants grown under saline conditions (Table 2). Two of the varieties, A138 and 239, did not produce recordable results for root fresh weight. Among all the clones, clone 72 had the highest root fresh weights under both control and the

Grass ID	Average Shoot DM Weight (g) Control	Average Shoot DM Weight (g) EC 20 dS/m	Average Root DM Weight (g) Control	Average Root DM Weight (g) EC 20 dS/m
A37	0.4723ab	0.3417bc	0.0841bc	0.0760ab
A49	0.3859b	0.4103ab	0.0309c	0.1370a
A50	0.5558ab	0.4390a	0.4730a	0.0740ab
A60	0.4631ab	0.4236ab	0.0498c	0.0074c
72	0.7156a	0.5049a	0.0848bc	0.1393a
A86	0.3082b	0.4690a	0.0675bc	0.0819ab
A107	0.3900b	0.3612b	0.0723bc	0.0771ab
A126	0.5501ab	0.4529a	0.0173c	0.0478b
A136	0.8292a	0.3720b	0.2520b	0.0813ab
A138	0.9620a	0.2873c	n/a*	n/a*
239	0.4542ab	0.2856c	n/a*	n/a*
240	0.5894ab	0.4681a	0.0066c	0.0723ab

*Shoot values are average of 4 replications and 6 harvests.
**Root values are average of 4 replications at the final harvest.
*** The values followed by the same letters in each column are not statistically different at the 0.05 probability level.
****Note: Varieties A 138 and 239 did not produce recordable results for root dry weight.

Table 3. Shoot and root dry matter (DM) weights of saltgrass under control and NaCl salinity stress

NaCl salinity stress conditions followed by clone A136 under salinity stress.

Shoot Dry Weight

The average shoot dry weight showed an increase in 10 of the 12 varieties (A37, A50, A60, 72, A107, A126, A136, A138, 239, and 240) in the control plants in comparison to those grown under saline conditions (Table 3). There was a wide range of variations in shoot and root DM weights of the various clones under either control or salinity stress condition. Clones 72, A136, and A138 had the highest DM weights among all the clones under control. Clones A49, A86, and A107 had the lowest DM weights among all the clones under control condition. Under the NaCl stress, clones 72, A50, A86, A126, and 240 had the highest DM weight with the DM of clone 72 numerically the highest. In contrast with the previous reports (6, 7, 9,10,13), clones A138 and 239 had the lowest DM weights under salinity stress condition (Table 3).

Root Dry Weight

Root dry weight averages showed an increase in 8 of the 10 varieties (A49, A50, 72, A86, A107, A126, A136 and 240) grown under saline conditions (Table 3). As mentioned before and shown in Table 2, two of the varieties, A138 and 239, did not produce recordable results for root fresh weight and consequently no dry weights were recorded. A50 had the highest root DM weight among all the clones under control condition, but clones A49 and 72 had almost equal and the highest root DM weights under salinity stress condition (Table 3).

Shoot Succulence

The results showed, except for clone 72, a slight numerical increased in succulence (shoot fresh weight/shoot dry weight) of the other 11 varieties under control compared to those grown under saline condition (Table 4). Under control conditions, the range among the shoot succulence

Grass ID	Shoot Succulence (fw/dw) Control	EC 20 dS/m
A37	2.6	2.5
A49	2.6	2.1
A50	2.4	2.0
A60	2.6	2.1
72	2.7	3.4
A86	2.5	2.3
A107	2.4	2.1
A126	2.2	2.0
A136	3.1	2.7
A138	3.0	2.4
239	3.0	2.4
240	2.9	2.5

*Values are average of 4 replications.

Table 4. Shoot succulence (fresh wt./dry wt.) of saltgrass under control and NaCl salinity stress

of the 12 clones was between 2.2 to 3.1. However, this range was between 2 to 2.7 for the clones under salinity stress condition (Table 4). As indicated by these values (Table 4), the differences between the lower ranges of the control and salinized plants is only 0.2, and this difference for the upper ranges of the control and salinized plants is only 0.4, which is insignificant in either case.

Nitrogen Concentration in Plant Tissues

The partial results of the ^{15}N analysis (Table 5) show a substantial increase in nitrogen concentration of the plant tissues under salinity stress condition. This indicates that saltgrass is a true halophyte and accumulates the extra N in its tissues which can be gradually available to the growing parts of the grass.

Conclusion

Based on the results of this experiment, it was reconfirmed that saltgrass has a high salt tolerance. The results show increased shoot length, shoot fresh weight, shoot dry weight, and an insignificant increase in shoot succulence in the plants grown under control condition. However, the results also show increased root length, root fresh weight, root dry weight, and nitrogen concentration (both total and ^{15}N) in the plants grown in the saline (EC 20 dS m^{-1}) condition. This indicates high salt tolerance because the results pertaining to root growth were all increased under the saline condition. This shows the plant's ability to produce sufficient root growth under saline condition in order to support adequate shoot growth.

The amount of DM produced is the most significant result as it is a direct representation of saltgrass' ability to grow under saline conditions. The DM results show saltgrass' tolerance to salt stress because it represents the total shoot and root mass produced by the plants. Therefore, based on the results of this experiment, it is concluded that each of the tested varieties has a high salt tolerance.

Grass ID	Total N (mg/g)	^{15}N (%)
A37	33.8	2.94
A49	30.7	2.26
A50	31.1	2.60
A60	31.6	2.77
72	27.3	2.78
A86	33.0	2.65
A107	27.9	2.16
A126	28.3	2.21
A37	27.9	2.61
A49	29.2	2.25
A50	31.5	2.54
A60	29.6	2.55
72	31.6	2.24
A86	31.1	2.33
A107	27.7	2.11
A126	27.7	1.95
A136	31.8	2.90
A138	32.9	2.65
239	33.9	2.33
240	37.7	2.58
A136	29.4	2.40
A138	30.3	2.68
239	33.5	1.91
240	38.3	2.52

Table 5. Partial results of the saltgrass tissue ^{15}N analysis. ^{15}N (%) are means from two runs.

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