

# Relative Salinity Tolerance of 21 Turf-type Desert Saltgrasses Compared to Bermudagrass

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**Abstract.** Relative salinity tolerance of 21 desert saltgrass accessions (*Distichlis spicata* [L.] Greene var. *stricta* (Torr.) Beetle), and one hybrid bermudagrass 'Midiron' (*Cynodon dactylon* [L.] Pers. var. *dactylon* × *C. transvaalensis* Burt-Davy 'Midiron') were determined via solution culture in a controlled-environment greenhouse. Salinity in treatment tanks was gradually raised, and grasses progressively exposed to 0.2, 0.4, 0.6, 0.8, and 1.0 M total salinity in sequence. Grasses were held at each salinity level for 1 week, followed by determination of relative salinity injury. Relative (to control) live green shoot weight (SW), relative root weight (RW), and % canopy green leaf area (GLA) were highly correlated with one-another (all *r* values >0.7), being mutually effective indicators of relative salinity tolerance. The range of salinity tolerance among desert saltgrass accessions was substantial, though all were more tolerant than bermudagrass. Accessions A77, A48, and A55 suffered little visual shoot injury, and continued shoot and root growth at a low level, when exposed up to 1.0 M (71,625 mg·L<sup>-1</sup>); sea water is about 35,000 mg·L<sup>-1</sup>, and therefore can be considered halophytes.

Critical water shortages are occurring in many urbanizing areas due to rapid population growth (Kjelgren et al., 2000). In the western United States, acute water shortages have resulted in strict water use policies, requiring use of nonpotable, saline water sources such as effluent and brackish waters for turf landscape irrigation (State of Arizona, 1995; State of California, 1993).

The primary turfgrasses used in the southwestern, and throughout the southern United States are common bermudagrass (*Cynodon dactylon* [L.] Pers. var. *dactylon*) and hybrid bermudagrass (Duble, 1996; Emmons, 2000). Bermudagrasses are well-adapted to hot arid climates, being tolerant to drought (Carrow, 1996), alkaline soil conditions (Gould, 1993), and moderately tolerant to salinity (Harivandi et al., 1992; Marcum, 1999). However, in the southwestern United States where xeriscaping is prevalent, bermudagrass is considered a high water consumption landscape plant (Southern Nevada Water Auth., 2003; State of Ariz., 1995), and work has begun on development of turf-type halophytic and xerophytic native grass species (Kopec and Marcum, 2001; Mintenko et al., 2002).

Desert saltgrass, native to the Sonoran and Mohave deserts of North America, thrives in

extremely dry, saline environments, including saline and alkali salt flats having soil salinity levels above that of sea water; in these hypersaline environments it is typically a dominant species (Gould, 1993; Nielson, 1956). As such, desert saltgrass has been classified as a halophyte by a number of researchers (O'Leary and Glenn, 1992; Warren and Gould, 1982; Zhao et al., 1989). In addition, it displays aggressive rhizomatous growth, even in anaerobic, high soil-strength sodic soils, and has excellent potential for revegetation of such sites (Pavlicek et al., 1977). Genotypes vary morphologically from upright, tall types to compact, low-growing types. Compact, prostrate types have growth characteristics similar to bermudagrass, and as such, have potential for development into an alternative turfgrass for dry or saline areas, or when saline water sources are used for irrigation (Kopec and Marcum, 2001; Jensen et al., 1988).

Desert saltgrass accessions in this experiment were from two sources. 'A' accessions were initially collected by D. Kopec and T. Koski (Colorado State University) from sites within a 24 km radius of U.S. interstate 25, between Denver and Fort Collins, Colorado. Site locations ranged from infrequently mowed roadsides, to contaminants in turf lawns (home and city park). Seven 'C' accessions, collected by R. Cuany (Colorado State University), were originally selected for tall culms to facilitate seed harvest (Cuany, 1988). 'A' accessions were screened in greenhouse for turf growth characteristics, including shoot density, leaf canopy density, visual quality, shoot rigidity,

and foliage retention (Kopec et al., 1998). Fourteen superior 'A' genotypes were screened for turf growth characteristics with the seven 'C' genotypes in field (Kopec et al., 2001). These 21 genotypes were subsequently screened for salinity and drought tolerance in glasshouse. Results from glasshouse salinity studies are reported in this paper. Research objectives were a) compare relative salinity tolerances of desert saltgrass genotypes in relation to standard bermudagrass, and b) determine suitability of shoot and root growth parameters in predicting relative salinity tolerance in this species.

## Materials and Methods

Twenty-one desert saltgrass accessions, and hybrid bermudagrass 'Midiron' (Table I) were vegetatively propagated by 5 cm rhizome pieces into 7-cm-diameter × 8-cm-deep pots filled with coarse, acid-washed silica (inert, neutral pH) sand. 'Midiron' was chosen as it is commonly used in lower maintenance scenarios (i.e., lawns, parks, sports fields) in the southwestern U.S., and there is salt tolerance data available for this cultivar (Marcum and Pessaraki, 2000). Following initial establishment under mist, pots were suspended over tubs containing 32 L of half-strength, constantly aerated Hoagland's no. 1 solution (Hoagland and Arnon, 1950), modified with Fe-sodium ferric diethylenetriamine pentaacetate (DTPA) chelate to provide 3 mg·L<sup>-1</sup> elemental Fe. Pot bottoms consisted of coarse nylon screen, allowing roots to freely grow into the solutions. Plants were grown in a 29 °C day/18 °C night greenhouse, with maximum photosynthetically active radiation (PAR) levels of 1100 μmol·m<sup>-2</sup>·s<sup>-1</sup>. Light levels were supplemented for 2 h during early morning (after sunrise) and late afternoon (before sunset) with high-pressure sodium lamps (1000 W; Energy Technics, York, Pa.). To ensure complete establishment, plants were grown for 2 months before initiation of salinity treatments.

Salinity levels were increased daily by 0.04 M total salinity in treatment tubs (control tubs received no salt) using a salt mix of 75% NaCl : 25% CaCl<sub>2</sub> (on a molar basis), until 0.2 M total salinity (14,325 mg·L<sup>-1</sup>) was reached. Treatment grasses were held at 0.2 M for 1 week, then pots were visually rated for percent canopy green leaf area (GLA). Following rating, salinity ramping was resumed until 0.4 M total salinity was reached. Salinity was again held at this level for 1 week, followed by rating for GLA. The cycle was repeated at 0.2 M intervals (0.2, 0.4, 0.6, 0.8, and 1.0 M) until 1.0 M total salinity (71,625 mg·L<sup>-1</sup>) was reached. Salinity was again held for 1 week, followed by final rating of GLA. Plant green live shoots and roots were then harvested, dried at 60 °C, and shoot and root dry weights (SW and RW) determined.

Throughout the experiment, grasses were clipped weekly at 5-cm height to maintain turf growing conditions. Solutions were monitored daily for salinity level using a conductivity meter with platinum dip cell (model 2052; VWR Scientific, Chicago), adjusted when necessary, and changed every 14 d to ensure

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Table 1. Relative live shoot dry weight (SW), relative root dry weight (RW), and percent canopy green leaf area (GLA) of 21 desert saltgrass accessions and 'Midiron' bermudagrass following exposure to 1.0 M salinity. Relative growth values are calculated as: (salinized treatment + value) control treatment value) × 100.

Grass	SW	RW	GLA
A77	29.8	78.3	70
A48	24.0	50.0	85
A55	23.0	86.1	88
A138	14.8	64.6	68
A65	14.3	35.3	45
A137	14.0	39.2	63
A40	13.3	41.4	53
A41	12.3	24.3	30
A51	12.0	18.5	15
C92	11.0	24.2	12
A53	10.5	21.9	43
A86	10.0	47.1	31
C12	10.0	25.5	15
C10	9.8	45.0	20
A119	9.5	32.3	46
A72	9.5	28.0	23
C11	9.5	14.1	13
A61	9.3	34.7	18
C56	9.3	11.6	28
C8	8.8	18.2	29
C66	8.8	4.7	18
Midiron	0	15.9	0
LSD <sub>0.05</sub>	7.7	13.2	18

minimal changes in nutrient ion concentrations. To provide uniform starting conditions, roots were clipped back to the bottoms of the pots at the beginning of the experiment.

Experimental design was a randomized complete block with four replications, each solution tub containing all 22 grass entries. Data were analyzed by analysis of variance, with mean separation by protected LSD at  $P = 0.05$ . Growth measurements (RL, SW, and RW) were expressed as percentages, relative to control [(treatment value/control value) × 100]. Growth data were transformed by arcsin before analysis (Steel and Torrie, 1980), but are presented as percentages. Pearson product moment correlation coefficients were used to compare variables.

### Results and Discussion

Relative live shoot and root weights (i.e., yield, relative to control) are primary variables used to determine salinity tolerance in plants (Maas, 1990; van Genuchten and Hoffman, 1984). Following exposure to 1.0 M total salinity, A77, A48, and A55 had the highest SW (LSD,  $P \leq 0.05$ ) (Table 1). Other desert saltgrass accessions were not significantly different from one another. 'Midiron' bermudagrass, significantly different from all other entries,

Table 2. Pearson product moment correlation coefficients, and significance levels, for percent canopy green leaf area (GLA), relative live shoot dry weight (SW), and relative root dry weight (RW).

Parameter	SW	RW
GLA	0.809	0.764
	0.000005	0.000035
SW		0.717
		0.000175

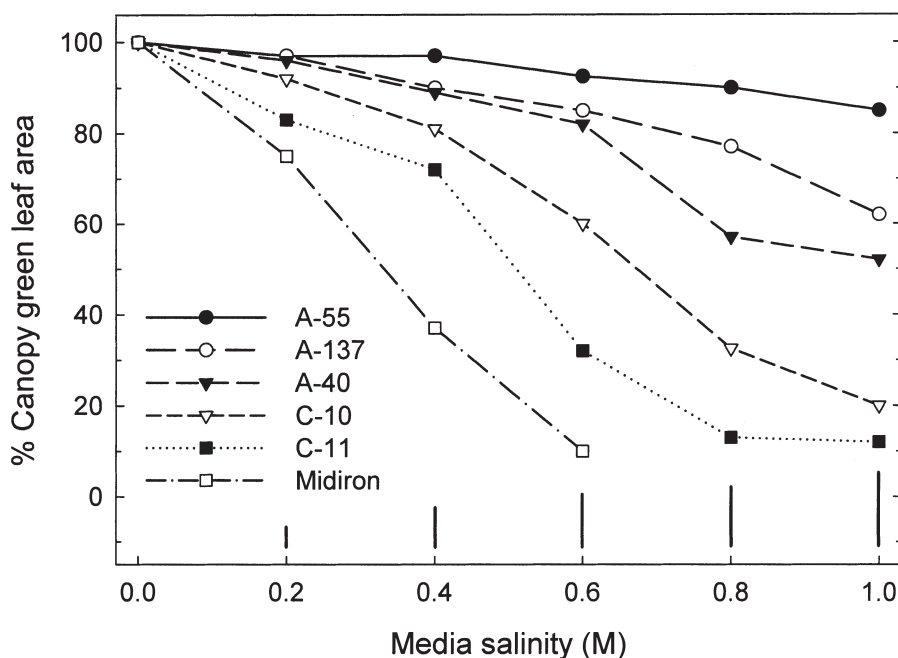


Fig. 1. Percent canopy green leaf area with increasing salinity of five desert saltgrass accessions in comparison to 'Midiron' bermudagrass. Vertical bars represent LSD ( $P < 0.05$ ) values for mean comparison at each salinity level.

was dead at this salinity (all shoots and roots were completely brown and desiccated). In contrast, all desert saltgrasses were still alive, with green shoots and white, fleshy roots. RW was highest in A55 and A77, and lowest in 'Midiron' bermudagrass, C66, C56, and C11 (Table 1), and ranged from 78.3 to 4.7 among desert saltgrasses.

Canopy green leaf area, a primary indicator of turfgrass quality, is of far more importance to the turfgrass manager than shoot yield (Morris and Shearman, 1999). Figure 1 illustrates the extreme differences in salinity tolerance, both among desert saltgrass accessions, and compared to 'Midiron' bermudagrass. At high salinity, GLA ranged from 88% to 12% among desert saltgrasses (Table 1). In contrast, 'Midiron' bermudagrass shoots were completely brown at both 0.8 and 1.0 M salinity (GLA=0), and also had <10% GLA at 0.6 M salinity.

GLA, SW, and RW were highly correlated with one another ( $P > 0.0001$ ) (Table 2), indicating their mutual suitability as relative salinity tolerance indicators. Relative shoot and root growth responses to salinity have been correlated in studies involving other grass species, including *Festuca rubra* L. (Ashraf et al., 1986), *Agrostis palustris* Huds. (Marcum, 2001), and *Poa pratensis* L. (Qian et al., 2001). The large range in GLA, SW, and RW values among desert saltgrass accessions represents excellent genetic variability in these salt tolerance traits, supporting the potential for varietal development.

All desert saltgrass accessions were much more salt tolerant than 'Midiron' bermudagrass, a commonly used cultivar on lawns, parks, and sports fields in the southwestern U.S. However, there was a substantial range in salinity tolerance among desert saltgrass accessions, indicating genetic diversity within the species.

Three accessions, A77, A48, and A55 suffered little visual shoot injury, and continued shoot and root growth at a low level, when exposed up to 1.0 M (71,625 mg·L<sup>-1</sup>) for 1 week in solution culture. These genotypes would be considered true halophytes according to the strict definition of a halophyte: a plant that thrives in full strength sea water (about 35,000 mg·L<sup>-1</sup>) and above (Aronson, 1989; Waisel, 1972). Salt tolerant desert saltgrass genotypes have been reported tolerant of 0.5 to 0.6 M total salinity under dry salt playa conditions (about 36,000-43,000 mg·L<sup>-1</sup>) (Dahlgren et al., 1997; Kemp and Cunningham, 1981), and tolerant up to 1.0 M NaCl under greenhouse conditions (Hansen et al., 1976; Pessaraki et al., 2005; Wrona and Epstein, 1982). Potential value of this species as a halophytic turfgrass is evident, and work is continuing on development of prostrate, densely growing genotypes suitable for high quality turfgrass sites (Kopeck, 2003).

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