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Salinity Tolerance of Ryegrass Turf Cultivars

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***Abstract*. Relative salinity tolerance of 32 perennial (*Lolium perenne* L.) and three intermediate (*Lolium ×hybridum* Hausskn.) ryegrass turf cultivars was determined by measuring turf leaf clipping dry weight, root weight, rooting depth, and percent green leaf canopy area relative to control (non-salinized) plants. After gradual acclimation, grasses were exposed to moderate salinity stress (6 dS·m^{-1}) for 6 weeks through solution culture in a controlled environment greenhouse. Shoot parameters were highly correlated, being mutually effective predictors of salinity tolerance. After 6 weeks of salinity stress, percent green leaf canopy area (GL) was correlated with relative (to control) final week leaf clipping weight (LW_{REL}) (*r* = 0.90) and with linear slope of decline of weekly leaf clipping weight over the 6-week exposure to salinity (LW_{SLOPE}) (*r* = 0.66). Rooting parameters root dry weight (RW) and rooting depth (RD), although significantly correlated with all shoot parameters, were only moderately effective in predicting relative salinity tolerance. 'Paragon' was the most salt-tolerant as indicated by all parameters. Other salt-tolerant cultivars included Divine and Williamsburg. Intermediate ryegrass cultivars (Froghair, Midway, and Transist) were invariably found within the most salt-sensitive category for all parameters.**

Increasing population growth in large urban centers is resulting in critical potable water shortages (Anderson et al., 2005; Kjelgren et al., 2000), a trend progressively worsening as a result of droughts related to global climate change (Barnett et al., 2005; Pearman et al., 2003). Demand on limited potable water resources is resulting in government-mandated water use restrictions, which limit use of potable water while requiring use of reclaimed or other secondary saline water sources for irrigation of turfgrass landscapes (Arizona Department of Water Resources, 2003; California State Water Resources Control Board, 2006; Council of Australian Governments, 2004; Florida Department of Environmental Protection, 2006); therefore, the need for salt-tolerant turfgrasses is increasing (Harivandi et al., 2008).

Ryegrasses are among the most widely used C_3 turfgrasses in cool regions as well as the most commonly used species for winter overseeding of dormant C_4 turf in warm regions (Christians, 2007; Duble, 1996). Ryegrasses generally used for turf are of three species: perennial (*Lolium perenne*), annual or Italian (*Lolium multiflorum* Lam.), and intermediate (*Lolium ×hybridum*), an interspecific hybrid of the two. Of these, perennial and intermediate ryegrasses are generally used in modern turf landscapes as a result of their higher quality (Turgeon, 2005).

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Perennial ryegrass has been ranked moderate in salinity tolerance, tolerating soil ECe (saturated paste extract) ranging from 4 to 8 dS·m^{-1} (Harivandi et al., 1992) with annual and intermediate ryegrasses ranked more salt-sensitive, tolerating soil ECe from 3 to 5 dS·m^{-1} (Marcum, 2006). In a field trial in which turfgrasses were grown on a saline soil with average ECe 11 dS·m^{-1}, six perennial ryegrass accessions or cultivars tended (no statistical analysis was done) to maintain equivalent visual quality to 11 kentucky bluegrass (*Poa pratensis* L.) cultivars and better quality than six red fescue (*Festuca rubra* L.) and three colonial bentgrass (*Agrostis capillaris* L.) cultivars (Gibeault et al., 1977). In a pot study comparing different C_3 turf species irrigated periodically with either fresh or saline water (soil salinity not controlled), salinity tolerance, again determined as visual quality, decreased in the order creeping bentgrass (*Agrostis stolonifera* L.) cv. Seaside > perennial ryegrass cvs. Common and NK 200 = kentucky bluegrass cvs. Park, Pennstar, and Nugget > rough bluegrass (*Poa trivialis* L.) accession (Greub et al., 1985). Salinity tolerance, measured as relative (to control) shoot dry weight reduction in plants exposed to 300 mM NaCl for 2 weeks, was greater in perennial ryegrasses than in an accession of annual ryegrass; however, there was no significant difference among three perennial ryegrass cultivars tested (Marcar, 1987). Little information is available regarding the range in salinity tolerance present among ryegrass turf cultivars. The goal of this study was to determine the degree and range of salinity tolerance present among a broad selection of modern ryegrass turf cultivars.

Materials and Methods

Thirty-two perennial and three intermediate ryegrass cultivars (Table 1) were seeded at a rate of 35 g·m^{-2} into 7-cm-diameter × 8-cm-deep pots with coarse plastic screen bottoms filled with coarse, acid-washed silica sand. Cultivars were chosen based on extent of use by the turfgrass industry. Grasses were germinated under mist and then transferred to constantly aerated solution culture tanks using a previously developed solution culture protocol (Marcum and Pessarakli, 2006). Temperatures were maintained at 28 to 32 °C day/20 to 24 °C night with maximum photosynthetically active radiation levels of 950 μmol·m^{-2}·s^{-1}. To minimize differential shading effects of greenhouse support beams during early morning and late afternoon, light levels were supplemented for 2 h daily: 1 h during early morning (immediately after sunrise) and 1 h during late afternoon (immediately before sunset) with high-pressure sodium lamps (1000 W; Energy Technics, York, PA).

Turfgrasses were established for 2 months before initiation of salinity treatments. Salinity levels were increased daily by 1 dS·m^{-1} in treatment tanks (control tanks received no salt) using a 3:1 ratio by weight of NaCl:$CaCl_2$ salts until 6 dS·m^{-1} was reached. Data collection began 1 week after reaching final treatment salinity levels. Grasses were held at 6 dS·m^{-1} for 6 weeks, during which relative leaf clipping dry weight, calculated as (treatment leaf dry weight/control leaf dry weight) × 100, and percent GL were recorded weekly. Solutions were monitored daily for salinity level using a Model 2052 conductivity meter with a platinum dip cell (VWR Scientific, Chicago, IL), adjusted when necessary, and changed every 10 d to ensure minimal changes in nutrient ion concentrations.

Grasses were clipped twice per week at 2-cm height. Biweekly clippings were dried at 60 °C and combined for weekly dry weight determination. RD, i.e., distance from the crown to the longest extending root, and RW were measured at the end of the experiment. To ensure uniform starting conditions, roots were clipped back to the bottoms of the pots at the beginning of the experiment.

The experimental design was a randomized complete block with six replications, each solution tank containing all 35 cultivars. Data were analyzed by analysis of variance using least significant difference separation of treatment means. Weekly relative leaf clipping dry weights were regressed against time to obtain the LW_{SLOPE}. GL and relative leaf clipping weight data were transformed by arcsine before analysis (Steel and Torrie, 1980) but are presented as percentages. Pearson product moment correlation coefficients were used to compare all variables. Data analysis was performed using SAS (Der and Everitt, 2001).

Results and Discussion

Plant tolerance to a given stress is the product of stress level and duration (Levitt,

1980) with duration (exposure time) a more sensitive indicator for subtle differences in stress tolerance, particularly at the intraspecies or cultivar level (Chen et al., 1982). In this study, plants were held under a moderate stress level of 6 dS·m^{-1}, this reported to be a critical level of salinity tolerance for perennial ryegrass (Harivandi et al., 1992).

Because turfgrass is an aesthetic landscape plant, visual quality, indicated as percent GL, is of primary importance (Morris and Shearman, 1999). After 6 weeks exposure to 6 dS·m^{-1}, GL ranged from 67% to 0%, indicating a broad range of salinity tolerance in ryegrasses (Table 1). 'Paragon' was significantly more salt-tolerant than other cultivars followed by 'Williamsburg' and 'Divine' in the second statistical group. Least salt-tolerant cultivars included all intermediate ryegrasses as well as perennial ryegrass cultivars Lowgrow II, Pace, Monterey, Linedrive, and Manhattan III. All intermediate ryegrasses had died after 3 weeks of salinity exposure, and perennial ryegrass cultivars LineDrive and Manhattan III died within 4 to 5 weeks of exposure.

Relative shoot dry weight, an indicator of plant vigor under stress relative to control conditions, is a commonly used indicator of salinity tolerance (Shannon, 1997; van Genuchten and Hoffman, 1984). After 6 weeks of exposure to 6 dS·m^{-1}, LW_{REL} ranged from 61% to 0% (Table 1). 'Paragon' was again the most salt-tolerant cultivar followed by 'Divine' in the second and 'Jiffie', 'Express', 'Caddieshack', and 'Essence' in the third statistically significant group. Least salt-tolerant cultivars included all intermediate ryegrasses as well as nine perennial ryegrass cultivars.

Changes in relative shoot dry weight with level or time of exposure, indicated by slope, is also a commonly used salt tolerance indicator (Maas, 1990). LW_{SLOPE} decreased linearly with time of exposure to salinity (Fig. 1). This indicates the glycophytic (low to moderately salt-tolerant) nature of ryegrasses in contrast to curvilinear growth response of halophytic (highly salt-tolerant) plants (Flowers, 1985). All shoot parameters were highly correlated (Table 2), indicating their mutual effectiveness in predicting salinity tolerance.

Root dry weight was highest in cvs. Paragon, Pinnacle, Spyglass, Superfly, Sunshine, and Top Gun and lowest in the three intermediate ryegrasses (Table 1). For RD, the highest significant group included 'Paragon' and the lowest group included all intermediate ryegrasses (Table 1). Both rooting parameters were significantly, although not highly correlated with shoot tolerance parameters (Table 2), thus only moderately effective in predicting salinity tolerance.

A wide range of salinity tolerance was found among 35 modern ryegrass turf cultivars, indicating the genetic potential for improvement in this genus. Shoot parameters GL, LW_{REL}, and LW_{SLOPE} were highly correlated and equally effective in predicting salinity tolerance, although root parameters RW and RD were less effective. Salt-tolerant cultivars included Paragon, Divine, and Williamsburg. Intermediate ryegrasses were invariably the least salt-tolerant across all measurement parameters.

Table 1. Salinity tolerance parameters of 35 ryegrass (*Lolium* spp.) turf cultivars after 6 weeks of exposure to 6 dS·m^{-1} root media salinity.[z]

Cultivar	GL (%)	LW_{REL} (%)	LW_{SLOPE}	RW (g)	RD (cm)
Paragon	67	61.4	–0.99	1.50	8.1
Williamsburg	37	22.9	–1.89	1.25	5.9
Divine	33	39.9	–1.53	1.10	6.6
Jiffie	23	28.5	–1.79	0.91	0.7
Pinnacle	20	17.6	–2.05	1.36	4.0
Spyglass	20	16.7	–1.93	1.37	3.7
Express	17	32.3	–1.72	0.91	6.2
Caddieshack	17	28.5	–1.79	0.96	5.5
Essence	17	25.8	–1.84	1.01	0.5
Cutter	17	23.3	–1.80	1.07	3.7
Majesty	17	21.8	–1.96	1.26	1.3
Wilmington	17	14.7	–2.08	1.14	4.2
Achiever	17	9.6	–2.21	0.91	3.2
Gator II	13	19.7	–2.19	0.96	4.0
Legacy II	13	13.2	–2.02	1.03	5.6
BlackHawk	13	5.8	–2.24	0.61	4.6
Fiesta III	10	19.7	–2.01	0.99	0.8
Laredo	10	17.5	–2.16	0.92	5.5
Top Hat	10	12.3	–2.30	0.91	3.3
Superfly	10	10.2	–2.18	1.29	3.3
Ascend	7	15.0	–2.32	1.26	3.3
Premier III	7	10.6	–2.13	1.14	3.0
Calypso II	7	8.0	–2.33	0.92	6.6
Sunshine	7	7.1	–2.19	1.29	0.5
Peak	7	6.3	–2.29	1.07	5.8
Platinum	7	5.2	–2.38	1.06	7.8
Top Gun	7	5.0	–2.36	1.36	4.4
Lowgrow II	3	9.0	–2.46	0.79	0.3
Pace	3	3.9	–2.39	0.90	1.5
Monterey	3	2.8	–2.62	0.89	2.4
LineDrive	0	0	–3.13	1.01	6.0
Midway (hybridum)	0	0	–2.84	0.22	1.4
Manhattan III	0	0	–3.91	0.80	0.2
Transist (hybridum)	0	0	–4.63	0.26	0.1
Froghair (hybridum)	0	0	–4.89	0.10	0.1
$LSD_{0.05}$	6	7.4		0.21	1.8

[z]Shoot parameters include percent green leaf canopy area (GL), final week relative leaf clipping dry weight (as percent of control) (LW_{REL}), and linear slope of decline of weekly clipping dry weight over the 6 weeks of exposure to salinity (LW_{SLOPE}). Rooting parameters are root dry weight (RW) and rooting depth (RD). Intermediate ryegrasses are designated as (hybridum).
LSD = least significant difference.

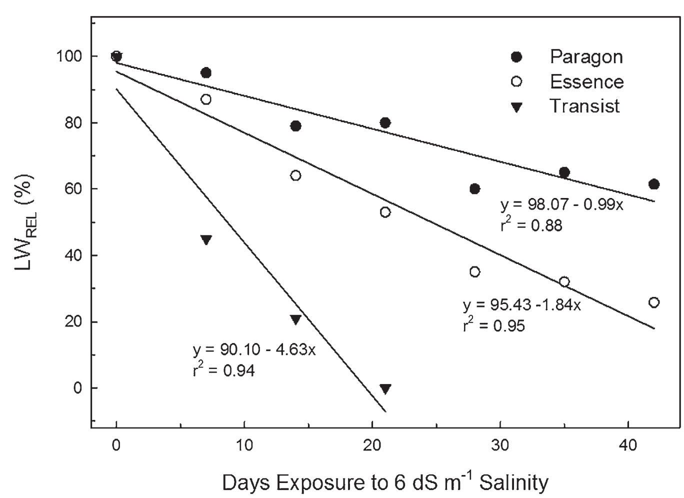

Fig. 1. Linear regressions of relative leaf clipping weight (LW_{REL}) versus days exposure to salinity. Data means of six replications are indicated as points.

Table 2. Pearson product moment correlation coefficients and associated probability levels for percent green leaf canopy area (GL), relative leaf clipping weight (LW_{REL}), linear slope of decline of weekly clipping weight (LW_{SLOPE}), root dry weight (RW), and rooting depth (RD) after 6 weeks of exposure to 6 $dS \cdot m^{-1}$ root media salinity.

Variable	GL	LW_{REL}	LW_{SLOPE}	RW
LW_{REL}	0.90			
	0.0001			
LW_{SLOPE}	0.66	0.71		
	0.0001	0.0001		
RW	0.52	0.48	0.73	
	0.001	0.004	0.0001	
RD	0.48	0.40	0.49	0.43
	0.004	0.018	0.003	0.011

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