Salinity Effects on Bentgrass Germination

L.B. McCarty and A.E. Dudeck

Department of Environmental Horticulture, Fifield Hall, Box 110670, University of Florida, Gainesville, FL 32611-0670

Additional index words. *Agrostis* spp., overseeding, putting greens, turfgrass

Abstract. Duplicate studies were conducted to determine salt tolerance during germination of eight bentgrass (*Agrostis* spp.) cultivars commonly used for overseeding warm-season turf species, such as bermudagrass (*Cynodon* spp.) putting surfaces. Bentgrass seeds were germinated on agar salinized with 0, 4000, 8000, 12,000, or 16,000 mg·liter⁻¹, with the highest rate approaching one-half seawater salinity. Total germination decreased linearly or quadratically for specific cultivars as salinity increased. Time necessary to reach 50% germination across all salt concentrations was shortest for 'Highland' colonial (*Agrostis tenuis* Sibth) and 'Seaside' creeping (*A. palustris* Huds.) bentgrass (≈3.7 days); intermediate for 'Kingstown' velvet (*A. canina* L.) and 'Streaker' red top (*A. alba* L.) bentgrass (≈4.5 days); and longest for 'Penneagle' creeping, 'Pennncross' creeping, 'Exeter' colonial, and 'Pennlinks' creeping bentgrass (≈5.3 days). Salt concentrations necessary to reduce germination to 90%, 75%, and 50% indicated that 'Streaker' red top and 'Seaside' creeping bentgrass were the most salt-tolerant cultivars. 'Kingstown' velvet, 'Exeter' colonial, and 'Highland' colonial bentgrass were intermediate, while 'Pennlinks', 'Pennncross', and 'Penneagle' creeping bentgrass were the most salt-sensitive cultivars.

Cool-season turfgrasses are overseeded into bermudagrass annually in the southern United States during the fall to provide a green playing surface year-round. Traditionally, perennial ryegrass (*Lolium perenne* L.) has been the major or only component of an overseeding mixture. Interest in using bentgrass for this purpose has increased due to its fine leaf texture, tolerance to low mowing, and stoloniferous growth habit, which enables it to recover from physical damage.

In Florida and other southern states, increased use of effluent and saline water or direct exposure to ocean spray presents serious problems when bentgrass is used as an overseeding species. Youngner et al. (1967) reported the relative saline tolerance based on 50% clipping yield reduction of established mature creeping bentgrass as follows: 'Arlington', 'Seaside', 'Pennlu', and 'Old Orchard' were most tolerant; 'Congressional' and 'Cohansey' were intermediate; and 'Pennncross' was the least tolerant. We found no research on the effects of increasing salinity on bentgrass seed germination. We report herein the rates and total germination of eight bentgrass cultivars widely used for overseeding in response to various saline levels in germination medium.

'Pennncross', 'Penneagle', 'Pennlinks', and 'Seaside' creeping bentgrass; 'Highland' and 'Exeter' colonial bentgrass; 'Kingstown' velvet bentgrass; and 'Streaker' redtop were used in germination studies. These were seeded at

predetermined seed weights to yield ≈100 live seeds per 100-mm-diameter × 15mm-deep petri dish containing 1% Difco Bacto agar salinized with 0, 4000, 8000, 12,000, or 16,000 mg salt mixture/liter dissolved in deionized water to simulate seawater (Svedrup et al., 1959). Dishes were sealed with plastic film and placed in a germinator with a regime of 8 h light at 25C and 16 h dark at 15C. These temperatures and photoperiods are recommended for germinating *Agrostis* spp. (Copeland, 1978). Irradiance was 10 W·m⁻², and the experiment covered 4 weeks. No contamination was observed during either study. Petri dishes were blocked according to replication on separate shelves and were moved three times weekly to minimize possible environmental effects in the germinator. Data were collected on germination rate (Maguire, 1962) based on seedling counts three times weekly during the experiment and on total germination counts after 4 weeks. A seed was considered germinated when the emerged shoot was visible under ×2 magnification. Experimental design was a factorial treatment set of eight cultivars and five salinity levels arranged in a randomized complete block with four replications. The first study was repeated using the same cultivars but different seed lots between years. Data were subjected to analysis of variance. Total germination percentages were transformed using square-root transformations before analyses of variance, but germination rates, which are the sum of the average germination counts per day, were not transformed before analysis (Little and Hills, 1978). Regression analyses within cultivars were conducted to identify growth response models. Inverse regression analyses within cultivar replicates were used to predict 10%, 25%, and 50% reductions in germination rate. Means between grasses were then separated

using the Waller-Duncan k ratio *t* test (*P* = 0.05). A sigmoidal response curve as described by Dudeck and Peacock (1985) was used to compute time to 50% germination.

Total germination was affected by study-cultivar-salt interaction, while germination rate was affected by a study-cultivar interaction (Table 1). One possible explanation for these interactions is that different seed lots were used for the two studies. Germination rate and total germination of most bentgrass cultivars decreased linearly or quadratically with increased salinity (Figs. 1 and 2). Total germination for 'Kingstown' velvet bentgrass and 'Seaside' creeping bentgrass averaged 95% over all salinity levels and was not significantly reduced by increased salinity, while that for 'Streaker' red top was only slightly reduced from 98% to 95% total germination when salinity was increased from 0 to 16,000 mg·liter⁻¹. Total germination in 'Exeter' and 'Highland' bentgrass was 95%, 92%, and 89% and 96%, 88%, and 80% at 0, 8000, and 16,000 mg salt/liter, respectively. 'Penneagle', 'Pennlinks', and 'Pennncross' creeping bentgrasses were least tolerant to salt. 'Penneagle' total germination decreased from 95% in a

Table 1. Mean squares for the analyses of variance on rate and total germination of bentgrass as influenced by salinization in duplicate studies.

Source of variance	df	Germination	
		Rate	Total
Study	1	8.10	192.82**
Error A block (study)	6	7.49	24.88
Cultivar	7	105.42**	1222.19**
Salt	4	1176.66**	2333.81**
Cultivar × salt	28	5.27 **	261.70**
Study × cultivar	7	4.01**	131.58**
Study × salt	4	1.39	32.33
Study × cultivar × salt	28	1.72	44.30**
Pooled error B	234	1.17	22.12

**Significant at *P* = 0.01.

Table 2. Predicted salt levels to effect 90%, 75%, and 50% germination as calculated from inverse regression analysis.

Bentgrass cultivar	Salt level (mg·liter ⁻¹)		
	Germination (%)		
	90	75	50
Streaker red top	6,850 a*	11,100 a	16,000 a
Seaside creeping	6,620 a	10,500 ab	15,000 ab
Kingstown velvet	5,130 b	9,280 bc	14,700 ab
Exeter colonial	4,740 bc	9,210 bc	14,700 ab
Highland colonial	4,510 b-d	8,900 cd	14,200 a-c
Pennlinks creeping	3,320 cd	7,320 de	12,800 bc
Pennncross creeping	3,250 de	7,330 de	13,300 bc
Penneagle creeping	2,460 e	6,030 e	11,800 c

*Significant at *P* = 0.05 using Waller-Duncan's k ratio *t* test. Data are the means of two experiments with four replications per experiment and ≈100 seeds per replicate.

Received for publication 13 Dec. 1991. Accepted for publication 21 Sept. 1992. Florida Agr. Expt. Sta. J. series no. R-01095. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked advertisement solely to indicate this fact.

Fig. 1. Influence of salinity on total germination and germination rate of four creeping bentgrass cultivars: Pennncross (A), Penneagle (B), Pennlinks (C), and Seaside (D). Individual data points are the means of four replications with ≈ 100 seeds per replicate. Total germination (percentage) for Studies 1 (●) and 2 (○). Germination rate (percent per day) for Studies 1 (▲) and 2 (△).

salt-free medium to 61% at 16,000 mg salt/liter. Total germination of 'Pennlinks' and 'Pennncross' decreased from 95%, 93%, and 69% and 98%, 86%, and 74% at 0, 8000, and 16,000 mg salt/liter, respectively (Fig. 1).

Germination rates for all bentgrass cultivars decreased quadratically with increased salinity except for 'Penneagle' and 'Pennncross' creeping bentgrass, which decreased linearly (Figs. 1 and 2). 'Seaside' creeping bentgrass (17.5%), 'Kingstown' velvet bentgrass (17.1%), and 'Streaker' redtop (17%) had the highest germination rate at 8000 mg·l⁻¹. At 16,000 mg·l⁻¹, the highest germination rates were for 'Kingstown' velvet (11.3%), 'Streaker' red top (11.3%), and 'Seaside' creeping bentgrass (10.7%).

'Pennlinks' (12.8%), 'Pennncross' (12.4%) and 'Penneagle' (12.0%) creeping bentgrass had the poorest germination rate at 8000 mg·l⁻¹. At 16,000 mg·l⁻¹, germination rates were lowest for 'Pennncross' (6.8%), 'Penneagle' (5.6%) and 'Pennlinks' (5.0%) creeping bentgrass (Figs. 1 and 2).

Reducing total germination to 90% for 'Streaker' red top and 'Seaside' creeping bentgrass required the highest average salinity concentration (≈ 6700 mg·l⁻¹) (Table 2). 'Kingstown' velvet, 'Exeter' colonial, and 'Highland' colonial bentgrass were intermediate in the salinity level necessary to reduce germination to 90%, requiring an average of ≈ 4800 mg·l⁻¹. 'Pennncross' and 'Penneagle' creeping bentgrass required the least average

salinity (≈ 2900 mg·l⁻¹) for the same germination reduction.

Similar trends were evident to reduce germination to 75% (Table 2). 'Streaker' red top and 'Seaside' creeping bentgrass required the highest average salinity concentration ($\approx 10,800$ mg·l⁻¹) to reduce germination to 75%. 'Kingstown' velvet, 'Exeter' colonial, and 'Highland' colonial were intermediate, while 'Pennncross', 'Pennlinks', and 'Penneagle' creeping bentgrass required the least salinity (≈ 6900 mg·l⁻¹).

An average salt concentration of $\approx 15,000$ mg·l⁻¹, almost one-half the salt concentration of seawater (Svedrup et al., 1959), reduced germination rate by 50% in 'Streaker' red top, 'Seaside' creeping, 'Exeter' colonial, 'Kingstown' velvet, and 'Highland' colonial bentgrass. 'Pennncross', 'Pennlinks', and 'Penneagle' creeping bentgrass required the least average salt concentration ($\approx 12,600$ mg·l⁻¹) to reduce germination to 50% (Table 2).

The time required for bentgrass seed germination to reach a 50% mean over all salt concentrations varied with cultivar (Table 3). 'Highland' colonial and 'Seaside' creeping bentgrass germination was least affected by salinity, requiring <4 days to reach 50% germination. 'Penneagle' creeping, 'Pennncross' creeping, 'Exeter' colonial, and 'Pennlinks' creeping bentgrass required the longest time (>5 days), while 'Streaker' red top and 'Kingstown' velvet were intermediate (≈ 4.5

days) in the time required for 50% germination.

Linear and quadratic decreases in germination rate with increasing salinity were noted. Ahman and Wainwright (1977) indicated that increased osmotic stress associated with salinity was responsible for decreased seed germination rate. Previous work on increasing salinity effects on warm-season turfgrasses indicated that the germination rate and total germination of "common" bermudagrass were unaffected by concentrations up to 5800 mg·l⁻¹ (Peacock and Dudeck, 1989). Salinity levels of ≈ 5500 and ≈ 5100 mg·l⁻¹, respectively, were required to reduce carpetgrass (*Axonopus affinis* Chase) and centipedegrass [*Eremochloa*

Table 3. Time to 50% germination (Germ₅₀) of bentgrass germinal seeds as influenced by salt concentration.

Bentgrass cultivar	Germ ₅₀ (days)
Highland colonial	3.4 ± 1.72
Seaside creeping	3.9 ± 0.75
Kingstown velvet	4.5 ± 0.75
Streaker red top	4.6 ± 0.51
Penneagle creeping	5.1 ± 2.12
Pennncross creeping	5.2 ± 1.59
Exeter colonial	5.4 ± 0.67
Pennlinks creeping	5.6 ± 1.84

*Sigmoidal curves were fitted through the data, and midpoints with the data and 95% confidence limits are indicated. Data are the means of two experiments with four replications per experiment and ≈ 100 seeds per replicate.

Fig. 2. Influence of salinity on total germination and germination rate of bentgrass cultivars: Exeter colonial (A), Highland colonial (B), Kingstown velvet (C), and Streaker red top (D). Individual data points are the means of four replications with ≈ 100 seeds per replicate. Total germination (percentage) for Studies 1 (●) and 2 (○). Germination rate (percent per day) for Studies 1 (▲) and 2 (△).

ophuiroides (Munro) Hack.] germination to 75%, while bahiagrass (*Paspalum notatum* Flugge.) was least tolerant to salt and required only an average of ≈ 3700 mg·liter⁻¹ to reduce germination to 75% (Peacock and Dudeck, 1989).

Low salinity retards germination, and increasing salinity progressively reduces final germination percentage (Ayers, 1952). Dudeck and Peacock (1985) reported that ≈ 4 days was needed to obtain 50% germination of perennial ryegrass for up to 8000 ppm salinity, but 50% germination was reached in 5 days at 10,000 ppm salinity. In our study, 'Highland' colonial and 'Seaside' creeping bentgrass reached 50% germination first. 'Penneagle' creeping, 'Penncross' creeping, 'Exeter' colonial, and 'Pennlinks' creeping bentgrass reached 50% germination last. Youngner et al. (1967) reported that the salt tolerance of mature stands of 'Seaside', 'Arlington', 'Pennlu', and 'Old Orchard' creeping bentgrass was

superior to other cultivars. 'Penncross' bentgrass was least salt tolerant in terms of 50% yield reduction of mature plants. 'Congressional' and 'Cohansey' creeping bentgrass were intermediately tolerant.

We conclude that 'Streaker' red top and 'Seaside' creeping bentgrass were the most salt-tolerant cultivars tested. 'Kingstown' velvet and 'Exeter' and 'Highland' colonial bentgrass had intermediate salt tolerance, while 'Pennlinks', 'Penncross', and 'Penneagle' creeping bentgrass had the least. Our data allow turf and golf course managers to calculate germination time and percentages for different bentgrass cultivars grown under varying salt levels.

Literature Cited

- Ahman, I. and S.J. Wainwright. 1977. Tolerance to salt, partial anaerobiosis, and osmotic stress in *Agrostis stolonifera*. New Phytol. 79:605-612.
 Ayers, A.D. 1952. Seed germination as affected by

- soil moisture and salinity. Agron. J. 44:82-84.
 Copeland, L.O. (ed.). 1978. Rules for testing seed. J. Seed Technol. 3:37.
 Dudeck, A.E. and C.H. Peacock. 1985. Salinity effects on perennial ryegrass germination. HortScience 20:268-269.
 Little, T.M. and F.J. Hills. 1978. Agricultural experimentation, design and analysis. Wiley, New York.
 Maguire, J.D. 1962. Speed of germination-Aid in selection and evaluation for seedling emergence and vigor. Crop Sci. 2:176-177.
 Peacock, C.H. and A.E. Dudeck. 1989. Influence of salinity on warm season turfgrass germination, p. 229-231. In: H. Takatosh (ed.). Proc. 6th Intl. Turfgrass Res. Conf., 31 July-5 Aug., 1989, Jpn. Soc. Turfgrass Sci., Tokyo.
 Svedrup, H.W., M.W. Johnson, and R.H. Fleming. 1959. The oceans, their physics, chemistry, and general biology. Prentice Hall, Englewood Cliffs, N.J.
 Youngner, V.B., O.R. Lunt, and F. Nudge. 1967. Salinity tolerance of seven varieties of creeping bentgrass, *Agrostis palustris* Huds. Agron. J. 59:335-336.