Variation within *Poa* Germplasm for Salinity Tolerance

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Abstract. As competition for water resources in areas of western North America intensify as a result of increasing human populations, the sustainability of turfgrass irrigation with limited water resources is questionable. A potential part of the solution is the use of recycled wastewater for landscape irrigation. However, as a result of high levels of salt, successful irrigation with recycled wastewater will likely need to be coupled with selection for increased salinity tolerance in turfgrass species. Additionally, salinity-tolerant turfgrass will allow production on soils with inherently high salt levels. The study described here characterized the relative salinity tolerance of 93 accessions of *Poa* germplasm from the USDA National Plant Germplasm System (NPGS). Control cultivars of tall fescue [*Lolium arundinaceum* (Schreb.) S.J. Darbyshire], perennial ryegrass (*Lolium perenne* L.), and kentucky bluegrass (*Poa pratensis* L.) were also evaluated for comparison. Kentucky bluegrass accessions exhibited a wide range of LD₅₀ (salinity dosage necessary to kill 50% of plants) values from 811 EC_{days} (PI 369296 from Russia) to 1922 EC_{days} (PI 371768 from the United States). Five kentucky bluegrass accessions exhibited salinity tolerance equal to or better than that of the tall fescue (LD₅₀ = 1815 EC_{days}) and perennial ryegrass (LD₅₀ = 1754 EC_{days}) checks. Thus, there is sufficient variation within this species to develop bluegrass with substantially higher salinity tolerance.

Human population increases lead to greater demands on limited freshwater supplies and associated increased competition for agricultural, environmental, and domestic purposes (Bouwer, 2000). Although the western states comprise the driest region of the United States, this region is experiencing some of the fastest population growth in the country and is facing these problems. Water of acceptable quality is increasingly more difficult to find because water has already been allocated for other purposes (Anderson and Woosley, 2005). Similar issues also plague western Canada (Schindler and Donahue, 2006) and other areas of the world. A possible solution to the need for additional water for landscape irrigation is the use of recycled wastewater (Lazarova et al., 2003). Several

municipalities in the western United States currently use recycled water for nonpotable uses, including irrigation of urban areas (Anderson, 2003; Marcum, 2005). However, use of recycled water can result in increased soil salt levels (Qian and Mecham, 2005; Thomas et al., 2006).

A number of landscape plants, including some turfgrass species, are susceptible to damage from high salt levels. Thus, successful use of recycled irrigation water requires turf plants with sufficient salinity tolerance (Alshammery et al., 2004). Additionally, large areas of the world are characterized by soils with high levels of salt. Oldeman et al. (1991) estimated that ≈80 M ha of arable soil is salt-affected worldwide. Thus, increased salinity tolerance is a priority of a number of C₃ and C₄ turfgrass improvement programs (Horst and Beadle, 1984; Marcum et al., 1998; Qian et al., 2000, 2007).

A major turfgrass species is kentucky bluegrass (KBG; *Poa pratensis* L.), which is grown in most temperate regions, including both rain-fed and irrigated areas of the United States (Huff, 2003). Although variation exists among KBG cultivars for salinity tolerance (Horst and Taylor, 1983; Qian et al., 2001), the salinity tolerance of KBG is low compared with other turfgrasses (Alshammery et al., 2004; Harivandi et al., 1992; Stoutemeyer and Smith, 1936; Torello and Symington, 1984).

Although salinity tolerance is known to vary among KBG cultivars (Horst and Taylor,

1983; Qian et al., 2001), except for annual bluegrass (*Poa annua* L.; Dai et al., 2008), little, if any, information is available regarding salinity tolerance of germplasm sources in the genera *Poa*, and more specifically for KBG. This is in contrast to the extensive evaluation of variation within this species for morphological and genetic diversity (Johnson et al., 2002, 2003; Johnston et al., 1997). The objective of this study was to evaluate a subset of accessions found in the USDA-NPGS *Poa* collection for salinity tolerance. We hypothesized that sufficient variation exists within this collection to improve the salinity tolerance of KBG above current levels and to develop KBG cultivars with salinity tolerance more comparable to that of tall fescue [*Lolium arundinaceum* (Schreb.) S.J. Darbyshire] and perennial ryegrass (*Lolium perenne* L.).

Materials and Methods

Plant materials. The germplasm used in this study consisted of 93 accessions representing kentucky bluegrass (67 accessions), Sandberg bluegrass (*P. secunda* J. Presl; 17 accessions), fowl bluegrass (*P. palustris* L.; six accessions), and texas bluegrass (*Poa arachnifera* Torr.; three accessions) (Table 1). All of the accessions were from the USDA-NPGS collection. Accessions were chosen to provide a broad representation of available *Poa* germplasm, particularly germplasm from arid regions of the world. Twenty-two of the accessions represented the KBG core collection that was developed to represent the diversity of morphological characteristics of the overall KBG NPGS collection in a limited number of accessions (Johnson et al., 2002; Johnston et al., 1997; USDA, ARS, National Genetic Resources Program, 2008). Additional entries included ‘Matador’ tall fescue; ‘Brightstar II’ perennial ryegrass; ‘Midnight’ and ‘Park’ KBG; and ‘Thermal Blue’ kentucky × texas bluegrass hybrid (hybrid bluegrass) for comparison. ‘Matador’ and ‘Brightstar II’ were included as commonly grown control varieties of these species. ‘Midnight’ was included as a commonly propagated variety of KBG, ‘Park’ was included because it was previously shown to be one of the more salt tolerant KBG varieties (Horst and Taylor, 1983), and ‘Thermal Blue’ was included to compare the performance of the included KBG and texas bluegrass accessions with a hybrid between the two species.

Experimental design. The study was conducted according to the methodology of Peel et al. (2004) and replicated twice (Sept. 2006 to Jan. 2007 and Oct. 2007 to Feb. 2008). This method was used because of its high level of run-to-run repeatability (Peel et al., 2004) and its usefulness for identifying salinity-tolerant germplasm in other perennial grass species (Jensen et al., 2005). For each run, seeds of each accession were germinated on blotter paper and transplanted to containers containing 70-grit silica sand (Peel et al., 2004). When seedlings reached the two-leaf

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stage, they were irrigated twice a week by immersing the entire rack into the nutrient solution, which had an electrical conductivity (EC) level of 3 dS·m⁻¹. The nutrient solution contained all essential macro- and micro-nutrients and was amended with sodium chloride (NaCl) and calcium chloride (CaCl₂) to increase the EC level. For a complete description of the solution, see Peel et al. (2004). NaCl and CaCl₂ were added at the appropriate ratios to maintain proper sodium adsorption ratio (Peel et al., 2004). No other irrigation was applied. The EC in the solution was increased by 3 dS·m⁻¹ at weekly or biweekly intervals; EC was increased more rapidly for the 2007–2008 run. Final EC values were 33 dS·m⁻¹ for the 2006–2007 run and 48 dS·m⁻¹ for the 2007–2008 run.

The study ran for 19 weeks during 2006–2007 and 18 weeks during 2007–2008. The solution used in the study was meant to replicate saline irrigation. To compare it with a given source of recycled water is difficult because the salinity and toxicity of recycled water will depend on the source and the salts and elements it contains. However, in our studies, an EC level of 18 dS·m⁻¹ in the solution corresponds to an EC level of 3 dS·m⁻¹ in soil (B.S. Bushman, unpublished data). The greenhouse temperature was maintained at 25 °C throughout the study. Ambient lighting was supplemented with high-intensity greenhouse lights (320 µmol·m⁻²·s⁻¹) to maintain a 16-h daylength.

The experimental design for both runs was a randomized complete block with three replications. Each accession was assigned to one experimental unit per replication. An experimental unit consisted of 15 cones, each containing a seedling from the assigned accession. Thus, each accession was represented by 15 seedlings in each replication. Plants were clipped as needed to maintain a height of ≈63.5 mm. All factors and interactions were considered random.

Data collection and analysis. Before each irrigation event, the number of dead plants was counted and recorded. Plant death was the result of both increasing salinity level and cumulative salt exposure through time. To account for both factors, a value (EC_{days}) was calculated that considered the salt concentration in the solution (EC) and amount of time at each EC level (Peel et al., 2004). The use of EC_{days} allows the data to be analyzed using probit analysis allowing the calculation of LD₅₀ [LD₅₀ = dosage required (EC_{days}) to kill 50% of plants] and LD₇₅ [LD₇₅ = dosage required (EC_{days}) to kill 75% of plants] values for salinity tolerance. The SAS System (SAS Institute, 2006) was used to conduct the probit analysis and corresponding LD₅₀ and LD₇₅ values. These results were then analyzed using the MIXED procedure of SAS to model the results and estimate best linear unbiased predictors (BLUPs) for each accession (Littell et al., 1996). The least significant difference between BLUPs in each run was determined based on Fisher's protected least significant difference (Steel

Table 1. Accession and control variety best linear unbiased predictors for salinity tolerance corresponding to LD₅₀ and LD₇₅ values (EC_{days}) and based on data collected across two runs (2006 and 2007) for salinity evaluations conducted in the greenhouse at Logan, UT.

Accession	Species	Country of origin (province/state)	LD ₅₀	LD ₇₅
W6 19573	<i>P. palustris</i>	Mongolia (Gobi-Altai)	2004	2379
PI 371768 ^z	<i>P. pratensis</i>	USA (Alaska)	1922	2268
Matador	<i>L. arundinaceum</i>	Fraser et al., 1999	1815	2075
PI 440603	<i>P. pratensis</i>	Kazakhstan (Shorthandy)	1780	2132
PI 372742 ^z	<i>P. pratensis</i>	USA (Alaska)	1772	2081
Brightstar II	<i>L. perenne</i>	Rose-Fricker et al., 2002	1754	2024
PI 284249	<i>P. secunda</i>	Sweden	1717	2107
PI 371771 ^z	<i>P. pratensis</i>	USA (Alaska)	1709	1997
PI 578850	<i>P. secunda</i>	USA (Washington)	1680	1966
PI 371775 ^z	<i>P. pratensis</i>	USA (Alaska)	1673	1974
PI 284248	<i>P. secunda</i>	USA	1658	1958
PI 349225 ^z	<i>P. pratensis</i>	USA (Alaska)	1555	1860
PI 250657	<i>P. pratensis</i>	Pakistan (Punjab)	1552	1844
PI 204490	<i>P. pratensis</i>	Turkey (Gumushane)	1530	1830
PI 628714	<i>P. pratensis</i>	Turkey (Çorum)	1525	1817
PI 229774	<i>P. pratensis</i>	Iran (Chaharmahal and Bakhtiari)	1522	1777
PI 230120	<i>P. pratensis</i>	Iran (Chaharmahal and Bakhtiari)	1509	1808
PI 578851	<i>P. secunda</i>	USA (Washington)	1507	1742
PI 232346	<i>P. secunda</i>	USA (Wyoming)	1491	1733
PI 251276	<i>P. pratensis</i>	Iran (Ardabil)	1473	1748
PI 499557 ^z	<i>P. pratensis</i>	China (Xinjiang)	1472	1780
PI 303053 ^z	<i>P. pratensis</i>	Sweden	1470	1708
PI 639806	<i>P. pratensis</i>	Mongolia (Selenge)	1462	1790
PI 298098 ^z	<i>P. pratensis</i>	Hungary	1443	1699
PI 349220 ^z	<i>P. pratensis</i>	USA (Alaska)	1442	1701
PI 229721 ^z	<i>P. pratensis</i>	Iran (Ardabil)	1439	1717
PI 632576	<i>P. palustris</i>	China (Xinjiang)	1436	1734
PI 505898 ^z	<i>P. pratensis</i>	Russia	1423	1672
PI 314736	<i>P. pratensis</i>	Kazakhstan (Almaty)	1404	1658
PI 236898	<i>P. secunda</i>	Canada (Alberta)	1400	1615
PI 440602	<i>P. pratensis</i>	Kazakhstan	1398	1682
PI 440609	<i>P. pratensis</i>	Kazakhstan	1397	1709
PI 236905	<i>P. secunda</i>	Canada (Alberta)	1390	1575
PI 119684	<i>P. pratensis</i>	Turkey (Balikesir)	1385	1656
PI 230128	<i>P. pratensis</i>	Iran (Chaharmahal and Bakhtiari)	1385	1652
PI 283961	<i>P. pratensis</i>	Turkey	1382	1620
PI 237282 ^z	<i>P. pratensis</i>	Denmark	1381	1599
PI 298096	<i>P. pratensis</i>	Hungary	1378	1623
PI 232350	<i>P. secunda</i>	USA (Nevada)	1376	1583
PI 204488	<i>P. pratensis</i>	Turkey (Sivas)	1375	1650
PI 206721	<i>P. pratensis</i>	Turkey (Kars)	1372	1620
PI 505896	<i>P. pratensis</i>	Russia	1371	1604
PI 539057 ^z	<i>P. pratensis</i>	Russia (Altai)	1361	1613
PI 423140	<i>P. pratensis</i>	Spain (Segovia)	1359	1591
PI 255476	<i>P. palustris</i>	Slovenia	1346	1584
PI 227463	<i>P. pratensis</i>	Iran (Fars)	1345	1614
PI 505899	<i>P. pratensis</i>	Russia	1343	1582
PI 355956	<i>P. pratensis</i>	India	1340	1589
Midnight	<i>P. pratensis</i>	Meyer et al., 1984	1335	1576
PI 436002	<i>P. pratensis</i>	Morocco (Tadla-Azilal)	1325	1615
PI 632500	<i>P. arachnifera</i>	USA (Texas)	1323	1594
PI 206725 ^z	<i>P. pratensis</i>	Turkey (Trabzon)	1319	1550
Park	<i>P. pratensis</i>	Minnesota AES, 1957	1305	1528
PI 387931	<i>P. secunda</i>	Canada (Yukon)	1303	1489
PI 632591	<i>P. arachnifera</i>	USA (Texas)	1291	1563
PI 302953	<i>P. pratensis</i>	Spain	1276	1508
PI 227381 ^z	<i>P. pratensis</i>	Iran (Esfahan)	1262	1501
PI 618762	<i>P. pratensis</i>	Turkey (Tokat)	1256	1470
PI 440607	<i>P. pratensis</i>	Kazakhstan (Zhambyl)	1234	1416
PI 349160 ^z	<i>P. pratensis</i>	USA (Alaska)	1233	1425
PI 314734 ^z	<i>P. pratensis</i>	Kazakhstan (Almaty)	1230	1422
PI 229718	<i>P. pratensis</i>	Iran (East Azerbaijan)	1227	1423
PI 423139	<i>P. pratensis</i>	Spain (Avila)	1227	1433
Thermal Blue	<i>P. ar. × P. pr.</i>	The Scotts Company, Marysville, OH	1225	1404
PI 229779	<i>P. pratensis</i>	Iran (Zanjan)	1202	1396
PI 236903	<i>P. secunda</i>	Canada (Alberta)	1198	1331
PI 632539	<i>P. arachnifera</i>	USA (Texas)	1198	1413
PI 269392	<i>P. pratensis</i>	Afghanistan	1188	1398
PI 636573	<i>P. pratensis</i>	Mongolia (Uvs)	1176	1390
PI 236904	<i>P. secunda</i>	Canada (Alberta)	1167	1320
PI 204492	<i>P. pratensis</i>	Turkey (Erzurum)	1163	1347
PI 368241 ^z	<i>P. pratensis</i>	USA (Alaska)	1137	1286

(Continued on next page)

Table 1. (Continued) Accession and control variety best linear unbiased predictors for salinity tolerance corresponding to LD₅₀ and LD₇₅ values (EC_{days}) and based on data collected across two runs (2006 and 2007) for salinity evaluations conducted in the greenhouse at Logan, UT.

Accession	Species	Country of origin (province/state)	LD ₅₀	LD ₇₅
PI 253580	<i>P. pratensis</i>	Spain	1131	1309
PI 221949	<i>P. pratensis</i>	Afghanistan (Kabul)	1127	1299
PI 251278	<i>P. pratensis</i>	Iran (East Azerbaijan)	1118	1306
PI 234484	<i>P. pratensis</i>	Spain (Aragon)	1113	1276
PI 499555	<i>P. pratensis</i>	China (Gansu)	1100	1207
PI 226667 ^a	<i>P. pratensis</i>	Iran (Fars)	1097	1260
PI 277862	<i>P. pratensis</i>	Iran	1096	1278
PI 618751	<i>P. pratensis</i>	China (Xinjiang)	1076	1277
PI 230132 ^a	<i>P. pratensis</i>	Iran (Mazandaran)	1067	1190
PI 232348	<i>P. secunda</i>	USA (Wyoming)	1046	1161
PI 574523 ^a	<i>P. pratensis</i>	USA (Maryland)	1042	1201
PI 618766	<i>P. pratensis</i>	Mongolia (Sükhbaatar)	1035	1181
PI 241066	<i>P. secunda</i>	USA (California)	1028	1163
PI 232347	<i>P. secunda</i>	USA (Montana)	995	1090
PI 610881	<i>P. pratensis</i>	Mongolia (Arkhangai)	989	1113
PI 632488	<i>P. pratensis</i>	Mongolia (Henti)	950	1066
PI 255477	<i>P. palustris</i>	Slovenia	923	1042
PI 232351	<i>P. palustris</i>	USA (Montana)	911	1009
PI 504370	<i>P. secunda</i>	USA (Oregon)	910	1013
PI 598604	<i>P. pratensis</i>	Kazakhstan (Aktobe)	908	1027
PI 236899	<i>P. secunda</i>	Canada (Alberta)	891	986
PI 368233	<i>P. pratensis</i>	USA (Alaska)	887	1017
PI 618771	<i>P. pratensis</i>	Mongolia (Uvs)	886	1030
PI 372738 ^a	<i>P. pratensis</i>	USA (Alaska)	867	955
PI 241067	<i>P. secunda</i>	USA (California)	819	1009
PI 369296	<i>P. palustris</i>	Russia (Novosibirsk)	811	914
Least significant difference (5%)			216	284
Range between high and low accession values			1192	1465

^aCore collection accessions (Johnston et al., 1997).

et al., 1997) using the accession $\times$ run interaction as the error term (Doehlert et al., 2008). The relative importance of the variation resulting from accessions, compared with the accession $\times$ run, and error variation were evaluated with corresponding repeatability estimates (Betrán et al., 2006) because there was no defined family structure among the accessions.

Results and Discussion

Variation and repeatability. Variation existed for salinity tolerance among the accessions across both runs of the experiment for LD₅₀ ($\sigma^2_{ACC} = 80203 \pm 14939$) and LD₇₅ ($\sigma^2_{ACC} = 126921 \pm 23989$) values. There was variation for the accession $\times$ run interaction for LD₅₀ (35716 ± 6567) and LD₇₅ (61538 ± 11072). However, Spearman rank correlations between the LD₅₀ and LD₇₅ values from both runs were high ($r \geq 0.70$). Thus, because there were few substantial changes in rank among accessions between the runs, data represent analyses done across both runs of the study. The accession variation was associated with high repeatability ($R = 0.78 \pm 0.15$ and 0.77 ± 0.15 for LD₅₀ and LD₇₅, respectively). Thus, salinity tolerance in this collection of bluegrass accessions was attributable primarily to variation among the included accessions rather than environmental variation. Wide variation in salinity tolerance among accessions was also expressed by BLUP values for each accession for LD₅₀ and LD₇₅ values (Table 1).

Salinity tolerance of control cultivars. The included control cultivars varied in their response to salinity tolerance, although their corresponding rankings across runs were consistent. Consistent with previous results (Alshammari et al., 2004; Harivandi et al., 1992), ‘Matador’ tall fescue (LD₅₀ = 1815; LD₇₅ = 2075) and ‘Brightstar II’ perennial ryegrass (LD₅₀ = 1754; LD₇₅ = 2024) consistently exhibited the highest level of salinity tolerance for the control cultivars and were among the most tolerant of all accessions (Table 1). Among the KBG and hybrid bluegrass checks, ‘Midnight’ (LD₅₀ = 1335; LD₇₅ = 1576) and ‘Park’ (LD₅₀ = 1305; LD₇₅ = 1528) KBG exhibited the highest values for each trait, but did not significantly differ from ‘Thermal Blue’ hybrid bluegrass (LD₅₀ = 1225; LD₇₅ = 1404) for LD₅₀ or LD₇₅ (Table 1). ‘Park’ previously was found to be one of the more salt-tolerant KBG cultivars (Horst and Taylor, 1983). Earlier evaluation of the salinity tolerance of hybrid bluegrass compared with KBG showed inconsistencies, although KBG tended to be more tolerant (Suplick-Ploense et al., 2002). Although the inclusion of only one hybrid bluegrass entry precludes conclusive findings in our study, our results also suggested that KBG is more tolerant of salinity than hybrid bluegrass.

Salinity tolerance of *Poa germplasm*. *Poa* accessions with high and low salinity tolerance were identified in comparison with the included control cultivars (Table 1). When compared with the tall fescue and perennial ryegrass control cultivars, the majority of the *Poa* accessions exhibited low salinity toler-

ance. However, a few accessions performed as well as or better than ‘Matador’ and ‘Brightstar II’ (Table 1). Ten entries had salinity tolerance equivalent to that of ‘Matador’ (based on corresponding least significant difference) for LD₅₀ and LD₇₅. In no particular order, this group included three *P. secunda* accessions (PI284248, PI284249, and PI578850), five *P. pratensis* accessions (PI 371768, PI 371771, PI 371775, PI 372742, and PI 440603), and one *P. palustris* accession (W6 19573), although W6 19573 is likely alkaligrass (*Puccinellia distans* Parl.) rather than fowl bluegrass. W6 19573, with a higher LD₇₅ value, was the only accession to exhibit significantly higher salinity tolerance than ‘Matador’ for either trait.

Thirteen accessions had significantly lower salinity tolerance than the low control (‘Thermal Blue’) for LD₅₀ and LD₇₅ (Table 1). This group included six accessions of kentucky bluegrass, four accessions of Sandberg bluegrass, and three accessions of fowl bluegrass. All other bluegrass accessions exhibited salinity tolerance that was significantly lower than that of ‘Matador’ and ‘Brightstar II’ but comparable to that of the KBG and hybrid bluegrass checks. However, these remaining accessions appeared to have little promise for improving salinity tolerance of bluegrass.

There was little consistency, as illustrated in the previous paragraph, for the salinity tolerance of the different *Poa* species (Table 1). For each species, representative accessions had widely differing salinity tolerance values. None of the species consistently had all high or low ranking accessions, although texas bluegrass was the only species that had no accessions in the highest or lowest performing groups. Average rankings (rank out of all entries) of accessions representing each species were very similar for all species with values ranging between 48 and 59 (data not shown). The kentucky bluegrass accessions had the highest average ranking for each trait (49 for LD₅₀ and 48 for LD₇₅), whereas the fowl bluegrass accessions had the lowest ranking for each trait (58 for LD₅₀ and 59 for LD₇₅). The fowl bluegrass rankings would be lower if the likely misclassified W6 19573 was removed from the analysis. The key finding was that sufficient variation existed within the kentucky bluegrass accessions for salinity tolerance improvement, and there appeared to be little justification for pursuing interspecific hybrids.

Salinity tolerance of the *Poa pratensis* core collection. Among the 22 accessions representing the *Poa pratensis* core collection, there was wide variability for salinity tolerance (Table 1). Generally, these accessions had comparable salinity tolerance to the KBG and hybrid bluegrass checks. However, PI 372738 was among the accessions with the least salinity tolerance for both traits, and PIs 349225, 371768, 371771, 371775, and 372742 were among the accessions with the highest salinity tolerance.

Along with other entries, the 22 core collection accessions and the varieties ‘Midnight’

Fig. 1. Map depicting sites of origin for *Poa* accessions collected from Alaska.

and 'Park' were also characterized in a previous study for seed production and turf quality (Johnson et al., 2003). Comparing results of the common entries between both studies, there were no significant correlations (Pearson or Spearman) between salinity tolerance and either turf quality or seed yield (data not shown). Although genotypic correlations on a larger number of entries would be preferable for more thoroughly determining trait correlations, the lack of correlation between traits is an initial indication that simultaneous improvement for salinity tolerance and other turf traits is likely possible in kentucky bluegrass. However, the Johnson et al. (2002) study also showed the six previously mentioned core accessions with high and low salinity tolerance to have low seed production and, with the exceptions of PIs 371668 and 371771, low turf quality. Thus, using these accessions to simultaneously improve salinity tolerance and turf traits would likely prove unsuccessful. However, using these accessions as male parents with sexual female plants with high turf quality (Bashaw and Funk, 1987) may be a way to improve salinity tolerance while also improving, or at least maintaining, levels of other important turf traits. As a result of the (facultative) apomictic nature of KBG, individual hybrids from these crosses that exhibit good salinity tolerance and turf characteristics (quality and seed production) may be directly selected and propagated for cultivar development.

Area of origin did not seem to be related to salinity tolerance of the accessions. However, there did appear to be one exception.

Accessions from the southern coastal area of Alaska (PIs 349220, 349225, 371768, 371771, 371775, and 372742) were consistently among the more tolerant to salinity among U.S. accessions (Table 1; Fig. 1). PIs 349225, 371768, 371771, 371775, and 372742 were the previously mentioned accessions from the core collection with the highest salinity tolerance. Earlier evaluation of a variety of morphological traits on the NPGS *Poa pratensis* accessions separated the accessions into clusters and led to the development of the core collection (Johnston et al., 1997). Because the saline-tolerant core collection accessions in this study did not correspond to a common cluster, there did not appear to be specific morphological traits that might help identify clusters of other accessions that may be characterized by higher salinity tolerance. Although these results may be anecdotal, they do suggest that further characterization of Alaskan accessions may lead to further identification of salinity tolerance within the collection.

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