Potential for the Improvement of Turf Quality in Crested Wheatgrass for Low-maintenance Conditions

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Abstract. With the exception of the undesirable characteristic of summer dormancy and the accompanying low aesthetic value, crested wheatgrass has many desirable characteristics in semiarid environments, making it a promising candidate for lower water use turf. Using a population of 27 half-sib families, this study characterized the underlying genetics of turf quality (based on a 1–9 rating scale) of crested wheatgrass and compared the performance of crested wheatgrass turf with traditional control cultivars (‘Cody’ buffalograss, ‘Gazelle’ tall fescue, ‘Manhattan 3’ perennial ryegrass, and ‘Midnight’ Kentucky bluegrass) over 2 years under space-planted conditions. Heritability estimates were generally high ($h^2 = 0.44$ to 0.84) and suggested a strong additive genetic component for crested wheatgrass turf quality throughout the summer months. Genotypic correlations among the monthly turf quality scores were very high (greater than 0.90) indicating a strong commonality for the genetics underlying turf quality during any point in the growing season. Thus, a breeding program aimed at improving turf quality in this population of crested wheatgrass would stand a good chance for success. However, primarily as a result of summer dormancy, the crested wheatgrass turf performed poorly compared with the control cultivars during late spring and early summer. Turf quality scores in early July were $>3$ for the crested wheatgrass half-sib families compared with scores between 5 and 6 for the traditional turf species. Thus, crested wheatgrass, for the near future, will likely be a viable turf candidate only in situations in which turf aesthetics are secondary to a desire for low-input requiring species.

Materials and Methods

Plant materials. Plant materials consisted of 27 half-sib crested wheatgrass families and six control cultivars representing various turfgrass species. The half-sib families came from the polycross nursery of 27 crested wheatgrass genotypes selected from ‘RoadCrest’ crested wheatgrass (Asay et al., 1999). Selection criteria were spreading ability, short growth stature, and fine leafiness. The six control cultivars were ‘Cody’ buffalograss [Buchloe dactyloides (Nutt.) Engelm.], ‘Fults’ weeping alkali grass [Puccinellia distans (L.) Parl.] (identified by S.E. Metsker in 1979), ‘Gazelle’ tall fescue [Festuca arundinacea Schreb.], ‘Manhattan 3’ perennial ryegrass [Lolium perenne L.] (Rose-Fricker et al., 2002), ‘Midnight’ Kentucky bluegrass (Poa pratensis L.) (Meyer et al., 1984), and ‘RoadCrest’ crested wheatgrass.

Experimental design. The study location was the Utah Agricultural Experiment Station Evans Farm in Millville, UT (41°45′ N, 111°8′ W; 1350 m above sea level; Nibley silty clay loam [fine, mixed, mesic Aquic Argorthods]). The experimental design was a randomized complete block design with four complete blocks. Transplanting of the control cultivars and half-sib families occurred in Apr. 1999. Individual plots consisted of 10 plants. Spacings were 1 m between rows and 0.5 m between plants within a row. Although sward plots would have been preferable to space-planted plots for the evaluation of turf quality, the polycross used to derive the half-sib families did not result in sufficient seed production for a sward plot study. Thus, seed limitations required the utilization of space-planted plots. Space-planted plots have been used previously to characterize turf quality (Hanks et al., 2005).

Throughout the study, irrigation occurred weekly from April to October at 50% evapotranspiration (ET\textsubscript{0}) replacement. Approximate ET\textsubscript{0} values for turfgrass at Millville, UT, were: April, 48 mm; May, 87 mm; June, 109 mm; July, 121 mm; August, 107 mm; September, 68 mm; and October, 29 mm for turfgrass. However, the study also identified high levels of broad-sense heritability for turf quality and suggested that breeding efforts aimed at increasing crested wheatgrass turf quality would be successful (Hanks et al., 2005). Although high broad-sense heritabilities suggest the importance of genetic as compared with environmental factors (Holland et al., 2003; Nyquist, 1991), they are not indicative of the potential that can be made in a breeding program.

The objective of this study was the estimation of genetic variation and narrow-sense heritability for turf quality in a population of half-sib families. These families represent breeding materials used in ongoing efforts at improving turf-quality traits in crested wheatgrass for low-maintenance turfgrass conditions.
(Hill and Kopp, 2002). Throughout the evaluation, plots were mowed at a height of 7.62 cm (3.0 in) with a rotary mower at an interval that removed \( \approx 33\% \) of growth at each mowing. The clippings were left on the ground and 49 kg ha\(^{-1}\) of nitrogen (1 lb 1000 ft\(^{-2}\)) was applied in early June and again in September.

**Phenotypic data collection and analysis.** Data collection took place from April through October in both 2000 and 2001. However, data were not collected during May 2001. Turf quality was measured monthly and twice in July during these time periods. The turf quality assessment combined visual ratings of color intensity, leaf texture, and tiller density (Gibeault et al., 1989; Skogley and Sawyer, 1992). Ratings followed a 1 to 9 scale. A score of 9 was given to the plot with the highest turf quality in the study and indicated a plot with solid green color, fine leaves, and dense sod with solid groundcover. A score of 5 was given to plots with acceptable turf quality and indicated a plot with uniform, mostly green color, acceptable leaf fineness, and a uniform sod with little open-ground area. A score of 1 was given to plots with unacceptable turf quality and indicated a plot with brown color, coarse leaves, and an open canopy. Other values were given to plots with characteristics intermediate to these descriptions.

Using the MIXED (Littell et al., 1996) and IML procedures of SAS (SAS Institute, 2006), variance components andheritabilities with their standard errors were computed with control genotypes removed from the analysis (Holland et al., 2003) based on a split-plot-in-time modification of the randomized complete block design with four complete blocks. The model used was appropriate for the analysis of genetic variation and heritability in a set of half-sib families (Nguyen and Sleper, 1983) based on entry means and was as follows:

\[
h^2 = \frac{\sigma^2_{HF}}{\sigma^2_{HF} + \sigma^2_{HF yr} + \sigma^2_{HF yr} + \sigma^2_e} \]

where,

\[
\sigma^2_{HF} = \text{variation among half-sib families;}
\]

\[
\sigma^2_{HF yr} = \text{variation resulting from the half-sib family-by-year interaction;}
\]

\[
\sigma^2_{HF yr} = \text{variation resulting from the half-sib family-by-replication interaction;}
\]

\[
\sigma^2_e = \text{residual variation;}
\]

and \( y \) and \( r \) were the number of years and replications, respectively.

To compare the performance of the half-sib families with that of the control cultivars, a second model was used to calculate mean scores for each entry. This model considered genotypes (half-sib families and cultivars), years, and the genotype-by-year interaction to be fixed effects and block effects and interactions to be random. Genotypic correlations (with corresponding standard errors) between the monthly turf quality scores were also calculated using the MIXED and IML procedures of SAS and with the control cultivars removed from the analysis (Holland, 2006).

**Results and Discussion**

**Genetic variation and heritability of turf quality.** Although the main effect resulting from year was generally a significant term in the model, the half-sib family-by-year interaction only differed from zero during the late July rating period (Table 1) and in that instance was roughly three times smaller than the corresponding half-sib family variation estimate. Thus, genotype-by-environment (half-sib family-by-year) interaction was negligible or nonexistent in this study, and all further discussion and conclusions are based on data combined across years. Additionally, there was no indication that pest damage played a role in the characterization of turf quality and, thus, is not further discussed.

Variation among the half-sib families (additive genetic variation) was present during each of the months except April (Table 1). Although there was no test for determining differences among the monthly half-sib family variation values, generally, the variation among half-sib families increased from the spring to summer and then decreased during the fall. The numerically highest values occurred in August and September (Table 1). Apparently, the maximization of genetic differences among the half-sib families required more stressful, hotter summer months with smaller differences during the less stressful spring and fall time periods.

Monthly turf quality heritability estimates were low to moderate based on a plot basis but were moderate to high on the entry mean basis (Table 1). As would be expected based on the trend in half-sib family variation values over the course of the summer, heritability estimates increased from the spring to summer and then decreased going into fall with August being the month with the numerically highest heritability (\( h^2 = 0.84 \)). Across the entire growing season, heritabilities were suggestive of strong genetic control of turf quality with only June and October having estimates less than 0.60. These high estimates of turf quality heritability are well in line with previous high estimates of broad-sense heritability of turf quality in crested wheatgrass (Hanks et al., 2005) and high estimates of turf trait heritabilities in other species such as bermudagrass [\( \text{Cynodon dactylon} \) (L.) Pers.; Wofford and Baltensperger, 1985] and perennial ryegrass (Waldron et al., 1998).

The high turf quality heritability estimates suggested that turf quality, at least in this population of half-sib families under the conditions of this study, was under very strong genetic as opposed to environmental control. Thus, selection for improved crested wheatgrass turf quality in this population of half-sib families should be successful. However, testing at additional locations is necessary before genotype-by-environment interaction can be completely disregarded.

**Comparison of half-sib families to control cultivar turf quality.** Although generally lower than the control cultivars, the mean turf quality of the crested wheatgrass half-sib families performed favorably with the control cultivars during the months of April, September, and October (Table 2). The main problem with crested wheatgrass turf quality occurs during the hotter summer months when, despite irrigation and fertilization, crested wheatgrass enters dormancy (Bushman et al., 2007; Robins et al., 2006). This was illustrated in this study by low turf quality scores of the half-sib family means during the June to August/September time period (Table 2). During these months particularly, the performance of the half-sib families was much lower than that of most of the control cultivars. However, the crested wheatgrass half-sib families always outperformed, at least numerically, the more typical low-maintenance turf cultivars, ‘Fulst’ alkaligrass and ‘RoadCrest’ crested wheatgrass (Table 2). This result suggested the success of selecting for improved turf traits in this crested wheatgrass population because these half-sib families originated from ‘RoadCrest’.

Eight of the half-sib families had higher turf quality scores than the mean half-sib family score in at least one of the months of the study (Table 2). Two half-sib families,
The study investigated the relationship among the monthly turf quality scores using genotypic correlations. If genotypic correlations were sufficiently high among the monthly turf quality scores, then the likelihood of success of a selection program based on a single, or a few, time points rather than the entire growing season would be substantially improved.

Genotypic correlations indicate the extent that the underlying genetics influencing each of the traits are the same (Falconer and Mackay, 1996). In this study, with the exception of April, likely as a result of April’s nonsignificant estimation of genetic variance, genotypic correlations between monthly and overall mean scores were very high (data not shown) with the smallest estimate being 0.95 between early and late July. Therefore, it was apparent that the genetics underlying turf quality in this crested wheatgrass population had a very high level of commonality from month to month. The high genotypic correlations among each of the monthly scores and among the monthly scores and the overall mean scores suggested that selection during any of the months, except April, would result in improved turf quality during each of the months and for the overall turf quality across the entire summer. Thus, selection for improved crested wheatgrass turf quality could take place during any of the months of the growing season.

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