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Breeding CWG-R Crested Wheatgrass for Reduced-Maintenance Turf

Justin D. Hanks, Blair L. Waldron,* Paul G. Johnson, Kevin B. Jensen, and Kay H. Asay

ABSTRACT

Using reduced-maintenance turfgrass as an alternative to current high-maintenance turfgrass species would conserve resources, reduce labor, and potentially reduce pollutants in the environment. CWG-R is an experimental population of crested wheatgrass [*Agropyron cristatum* (L.) Gaertn.] from Iran that has shown potential as a low-maintenance turf. The objective of this research was to estimate the genetic variation for turf traits within the CWG-R population when evaluated under a reduced-maintenance regimen. Ninety CWG-R clonal lines were established in 1998 near Logan, UT, as spaced-plant plots in a RCB design with four replicates. Maintenance of 50% ET₀ replacement, 97.74 kg of nitrogen ha⁻¹ yr⁻¹, and mowing at 7.62 cm was approximately 40% lower than typical for high-input Kentucky bluegrass (*Poa pratensis* L.) turf. Critical turf traits, including spring regrowth, season-long (March–October) and mid-summer (June–July) turf quality, color, and rhizomatous spread were evaluated in 1999 and 2000. Significant genetic variation among clonal lines was evident with broad-sense heritabilities of 0.65, 0.76, 0.45, and 0.76 for spring regrowth, season-long turf quality, color, and rhizomatous spread, respectively. Several clonal lines remained green throughout the summer months and maintained acceptable turf quality and color ratings during the critical mid-summer period. The high broad-sense heritability estimates within this population indicate potential for successful improvement of critical turf traits by phenotypic selection. These results indicate that that CWG-R could be an important low-maintenance turf-type crested wheatgrass germplasm.

SIGNIFICANT LANDSCAPE ACREAGE that has been planted to high-maintenance turf could be replaced with low-maintenance turf species or cultivars (Wu and Harivandi, 1988). Low-maintenance turf is a relative term describing areas that receive reduced or no inputs of irrigation, fertilizer, herbicides, and mowing, and can withstand weed invasion (Dernoeden et al., 1994; Meyer, 1989) and thus help conserve natural resources and reduce pollutants.

Conservation of water is a primary goal for low-maintenance turfgrass development and management in the western USA. In many areas, where drought is a periodic or constant threat, ordinances or governmental mandates are imposed to limit water consumption on landscapes (Pleban, 1993) and projected to be implemented throughout many areas of the western U.S. (Garrot and Mancino, 1994). However, demands for more recre-

ational areas in urban communities continue to increase even as population growth places new burdens on limited water resources. To meet both needs, strategies need to be developed to maintain aesthetically acceptable turf, in spite of diminishing water resources (Garrot and Mancino, 1994). The selection and development of species and cultivars of turfgrasses that resist drought stress and require minimal inputs of supplemental irrigation is a viable strategy to conserve water.

Each turfgrass area has unique aesthetic and functional requirements (Riordan, 1991), requiring varying levels of inputs and maintenance (Emmons, 2000). Main criteria for low-maintenance turf have often been defined as soil stabilization, uniform appearance, and persistent stand that can compete against unwanted species (Dernoeden et al., 1994). However, there are reduced-maintenance areas where turf quality is a major priority, as well as the expectations listed above. Reduced-maintenance areas include highway medians, cemeteries, and low-use sections of parks and schools, and golf course roughs and fairways. Acceptable turf quality is defined as meeting the appearance expectations for a particular area and includes traits such as green color, fine leaf texture, high tiller density, and overall aesthetic appeal.

Crested wheatgrass is well adapted to the cold, semi-arid climate of the northern Great Plains and the Intermountain West (Asay and Jensen, 1996). This species is winter hardy, withstands weed competition, tolerates insect depredation, produces long-lived stands (>20 yr), is easily established, is adapted to a wide variety of soils, and can cope with severe drought stress (Allred, 1940; Asay and Jensen, 1996). Cultivars of crested wheatgrass used for low-maintenance turf include 'Fairway', 'Ruff', 'Ephraim', and 'RoadCrest'. RoadCrest is a recent "turf-type" crested wheatgrass cultivar specifically developed for use as low-maintenance turf (Asay et al., 1999). RoadCrest, like Ephraim, originated from Turkey and is noted for its rhizome development as opposed to the typical caespitose growth habit of crested wheatgrass. RoadCrest and other crested wheatgrass cultivars are usually recommended for use on roadsides and other very low-maintenance areas where soil stabilization is the major criteria, and turf quality is of lower importance (Asay et al., 1999). Turf-type crested wheatgrass cultivars were not selected for high aesthetic turf quality, and can exhibit unacceptable quality, especially during mid-summer months where they tend to go dormant. It would be of great benefit to have a crested wheatgrass cultivar that was functionally and aesthetically acceptable in reduced-maintenance landscape areas. Development of such turf-type crested wheatgrass cultivars may be possible by selection for turf quality traits including color, leaf texture, density, and short stature, as well as, rhizomatous spread, drought tolerance, and persistence.

CWG-R is an experimental population of crested

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wheatgrass that originated from Iran. The original population showed variability in important turf-type characteristics including plant texture, plant height, maturity date, and most notably rhizome development (Dewey and Asay, 1972). Before this experiment, CWG-R had undergone four cycles of recurrent selection for low growth, rhizomatous habit, and fine leaf texture and was characterized as having coarser leaves, remaining green later in the summer, and expressing more rhizome development than RoadCrest. CWG-R could be a valuable germplasm for developing low-maintenance turf cultivars, providing the population still exhibited genetic variation for turf quality and other important turf traits. The primary goal of this research, therefore, was to evaluate the CWG-R population for genetic variation of important turf traits when grown under a reduced-maintenance regimen.

MATERIALS AND METHODS

Experimental Design

In 1997, 90 individual CWG-R plants were selected from a 2000 plant nursery and clonally propagated. In the spring of 1998 the clones were transplanted to the Utah State University, Evans Experimental Farm, approximately 2 km south of Logan, (41°45' N, 111°8' W, 1350 m above sea level) for evaluation. Soil at the site was a Nibley silty clay loam (fine, mixed, mesic Aquic Argiustolls). Clones were planted in a randomized complete block design (four replicates) with five plants (clones) per plot. Clones were spaced 1.0 m between rows and 0.5 m within rows.

Throughout the evaluation, plots were mowed at a height of 7.62 cm (3.0 inches) with a rotary mower at an interval that removed approximately 33% of growth at each mowing. The clippings were left on the ground and 49 kg of nitrogen per hectare (1 lb/1000 ft²) was applied in early June and again in September. Weather data were obtained from a weather station at the Greenville Farm (North Logan, UT) to determine estimated evapotranspiration. The plots were irrigated weekly (April–October) at 50% ET₀ replacement. This represents a 33% increase in cutting height, 50% decrease in fertilization, and 38% decrease in irrigation as compared to high-maintenance Kentucky bluegrass turf.

Traits Evaluated

Evaluations were conducted in 1999 and 2000 for turf quality, color, regrowth (height), and rhizomatous spread. Turfgrass quality was visually rated monthly or bimonthly during the evaluation period from March to October. Turfgrass quality is a composite visual rating of characteristics including color, texture, density, growth habit (e.g., uprightness and leaf angle), and overall turf appeal (Skogley and Sawyer, 1992; Morris, 2001). Turf quality was rated on a scale from 1 to 9. A score of "9" represented the highest turf quality found within the CWG-R population for the given year, a score of "5" indicated the minimal acceptable rating for a turfgrass, and a score of "1" indicated a very poor turf quality (brown color, low tiller density, or mortality). Color was rated monthly from March to October on a scale from 1 to 9, with a "9" being the darkest color found within the CWG-R population that year, and a score of "1" being brown. The representative height of each plot (regrowth) was measured before each mowing. However, only regrowth measurements during the spring months of April and May, a time when crested wheat-

grass is rapidly growing, were used in the analyses. The average rhizomatous spread of each plot was also evaluated annually during late summer with both visual ratings and measurements. A visual scale of 1 to 9 was used with a rating of "9" representing the greatest rhizomatous spread and "1" indicating no spread. The representative diameter of each plot was measured to get a quantitative rating.

Statistical Analysis

Data were analyzed across years, and variances were estimated, using the MIXED procedure (SAS Institute Inc., 1999). Broad-sense heritability values were determined on an entry-mean basis using the ratio:

$$H_B = \sigma_c^2 / [\sigma_c^2 + (\sigma_{cy}^2/y) + (\sigma_e^2/ry)]$$

where σ_c^2 represents variance among clonal lines, σ_{cy}^2 represents clonal line \times year variance, σ_e^2 represents error variance, and c , r , and y represent number of clonal lines, replications, and years, respectively (Fehr, 1991). Spearman rank correlations were estimated to determine the strength of the relationship between any two of the evaluated traits. A base index was used to facilitate simultaneous multiple trait selection. A base index weights each trait, based on its importance, and has the form of $I = a_1P_1 + a_2P_2 + \dots + a_nP_n$, with a representing the economic weight and P representing the phenotypic value (Baker, 1986). Economic weights that were chosen, giving turf quality highest priority, were 1.5 for season-long turf quality averaged over the year, 1.5 for mid-summer turf quality during June through August, 0.5 for color, 0.5 for spread, and 0.5 for reduced spring regrowth.

RESULTS AND DISCUSSION

Heritability

Significant genetic variation existed among CWG-R clonal lines for evaluated turf traits (Table 1). Broad-sense heritabilities were 0.76 for season-long turf quality (March–October), 0.61 for mid-summer turf quality (June–July), 0.45 for color (March–October), 0.76 for rhizomatous spread, and 0.65 for spring regrowth (March–May) (Table 1). These high broad-sense heritabilities indicate that improvements should be possible through direct phenotypic selection. Lower heritability for turf quality in June and July, compared to the heritability for overall turf quality, suggests that it may be more difficult to improve mid-summer turf quality as opposed to overall season-long average turf quality. However, because of the positive correlation between season-long and mid-summer turf quality ($r = 0.75$, $P < 0.001$), selection for overall turf quality should also result in increased mid-summer turf quality. High broad-sense heritabilities, coupled with large differences between the population mean and best clonal lines (Table 1; Fig. 1) indicated potential for substantial genetic gain. Heritabilities were likely affected by the prior selection within this population; however, they are still valid parameters for predicting general gain in selection for the next several cycles (Hallauer and Miranda, 1988). The broad-sense heritabilities may also have been inflated because of the inability to separate the non-additive genetic variation from the overall genetic variation.

Ability to select for reduced spring regrowth, reduced summer dormancy, and improved turf quality will be

Table 1. Top 18 (20%) CWG-R crested wheatgrass clonal lines identified using a base selection index, and their corresponding rank and mean season-long and mid-summer turf quality, color, spread, and spring regrowth. Also shown is the variation among clonal lines and resulting broad-sense heritability. Clonal lines were evaluated 1999–2000 for turf traits under low-maintenance near Logan, UT.

Base index†		Season-long turf quality‡		Mid-summer turf quality‡		Color§		Spread¶		Regrowth#	
Entry	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank
39	1	7.8	1	7.1	1	6.3	1	5.8	19	7.8	17
70	2	7.0	2	6.6	2	6.1	5	5.7	22	7.0	9
68	3	6.3	5	5.3	6	6.0	6	5.6	24	7.0	4
55	4	6.7	3	5.4	3	6.2	4	5.3	40	8.1	22
69	5	6.5	4	4.7	11	6.2	3	5.2	41	7.2	15
47	6	5.4	10	5.3	5	5.5	10	5.3	36	8.2	33
63	7	5.0	15	4.1	13	5.5	11	6.0	18	7.1	11
34	8	6.1	7	4.0	14	5.4	13	4.7	55	7.9	3
18	9	5.5	9	3.5	23	5.3	19	7.0	5	7.4	24
66	10	5.6	8	5.3	4	5.4	14	5.1	43	7.6	51
17	11	4.9	18	4.7	9	5.4	16	6.3	8	7.5	40
85	12	4.3	23	4.7	10	5.4	15	7.8	1	6.5	1
81	13	4.6	27	3.9	16	5.3	18	7.5	2	7.2	12
15	14	5.1	14	4.7	8	5.6	9	5.6	25	7.8	65
14	15	6.3	6	4.4	12	5.5	12	5.3	37	7.9	69
57	16	4.9	19	3.8	17	4.7	39	6.3	12	7.3	18
92	17	4.8	23	5.1	7	6.3	2	6.3	10	8.1	86
45	18	5.0	16	3.5	20	5.0	28	5.3	33	7.6	30
Population mean		4.1		3.1		4.8		5.1		7.6	
Index top 10% mean		6.3		5.1		5.9		5.6		7.4	
Index top 20% mean		5.7		4.8		5.6		5.9		7.4	
Pop range		7.7–2.5		7.1–1.3		6.4–3.6		7.4–2.4		6.5–8.6	
LSD (0.05)		0.77		1.84		0.97		1.54		0.55	
σ^2_{cl} ††		0.99**		0.74**		0.36**		0.74**		0.11**	
H_b ‡‡		0.76 ± 0.12		0.61 ± 0.15		0.45 ± 0.09		0.76 ± 0.16		0.65 ± 0.13	

** Variance estimates significantly different than zero at the 0.01 probability level.

† Traits included in base index and their economic wt were: season-long turf quality (1.5), mid-summer turf quality (1.5), color (0.5), spread (0.5), and regrowth (-0.5).

‡ Turf quality estimated on a visual scale of 1–9: 1 = dead brown turf, 9 = dark green, dense, fine leaf, healthy turf. Season-long turf quality is average from March to October. Mid-season is scores from June through July.

§ Color estimated on a visual scale of 1–9: 1 = brown turf, 9 = dark green turf.

¶ Spread estimated on a visual scale of 1–9: 1 = no rhizomatous spread or horizontal growth, 9 = exceptional spread.

Regrowth (height) was measured in cm. at time of cutting.

†† σ^2_{cl} = variance among clonal lines.

‡‡ H_b = Broad-sense heritability (± standard error) computed on an entry-mean basis.

particularly important for this population. Correlations between traits indicated the potential of simultaneously improving most of the turf traits with the exception of

reduced growth. We compared a 10 versus 20% selection intensity within the base index, by examining the mean of the selected clonal lines. The mean value of

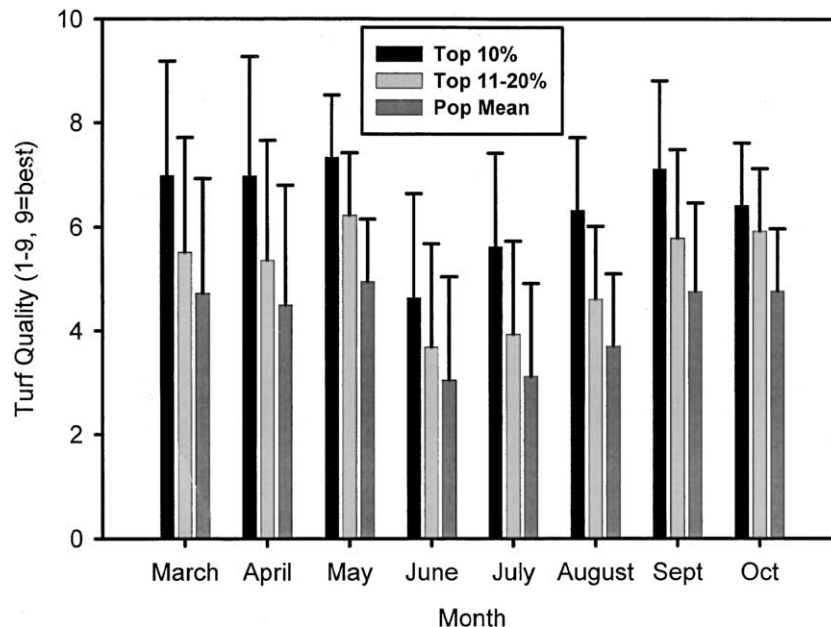


Fig. 1. Monthly turf quality mean of the overall CWG-R crested wheatgrass population and the corresponding average values from clonal lines representing the highest 10% and highest 11–20% of the population. Turf quality visually evaluated in 1999 and 2000 on spaced-plants near Logan, UT. Error bars show the LSD(0.05) value within each individual month.

selected lines increased under the more stringent selection intensity for turf quality and color but resulted in lower spread and no change in spring regrowth (Table 1). Because improved turf quality is a major emphasis of this breeding program, the higher potential gain from more stringent selection probably outweighs the potential loss of rhizomatous spread.

Traits

Season-long (March–October) average turf quality ranged from clonal lines that were aesthetically acceptable as reduced-maintenance turfgrass, to those that lacked most of the desirable turf-type traits, with values from 2.5 to 7.7, and a population mean of 4.1 (Table 1). Many superior clonal lines had much higher turf quality ratings than the population mean, throughout the growing season (Fig. 1). The mean turf quality rating of the top nine entries identified by the base index entries was 6.4, and all of them were in the top 20% of the population for turf quality. Many of these high turf quality entries were also top ranking in several, if not all the turf trait evaluations.

Considerable variation was evident among clonal lines for turf quality in the mid-summer months (June–July) with a range of 1.3 to 7.1, and mean of 3.1 (Table 1). The majority of the clonal lines went dormant (e.g., browning and senescence of leaves) in early June. Some postponed dormancy, and some came out of dormancy earlier than others. A few clonal lines, such as #39, 70, and 68, had reduced summer dormancy and maintained an acceptable turf quality throughout the summer months and high turf quality during the spring and fall. The mean mid-summer (June–July) turf quality rating for the top nine base index entries was 5.1.

The correlation coefficient between season-long versus mid-summer turf quality of 75% indicated that most clones with superior year round turf quality also did well during the critical summer months. Because summer dormancy is a critical limiting factor in the CWG-R population, it was encouraging that eight out of nine index-selected (10% selection intensity) entries were also in the top 20% for June–July turf quality (Table 1). Several of these selected clonal lines remained green throughout the summer months and maintained an acceptable turf quality and color rating throughout the year. The clonal lines in the population ranged in color from light to dark green, and to dark grayish-green. The population mean for yearly color was 4.8 and ranged between 3.6 and 6.4 (Table 1). The mean color rating for the top nine index-selected entries was 5.9, and eight of them were in the top 20% for color. Similar to turf quality, ratings for color were highest in the spring, declined in early and midsummer, and recovered in late summer. These findings are similar to Cook's (2000) evaluation of turf-type crested wheatgrasses where he used seeded plots to compare CWG-R to the precursor of RoadCrest and found that they were quite similar for overall and seasonal patterns of turf quality and color.

Clonal lines differed substantially in rhizomatous spread ranging from 35.7 to 53.8 cm in diameter, with

a population mean of 42.6. The visual rating ranged from 2.4 to 7.4, with a population mean of 5.1 (Table 1). Some more aggressive clonal lines produced abundant rhizomatous offshoots, and filled in the gaps creating a more uniform turf appearance. However, most of the highly rhizomatous clonal lines, such as #22 and 80, had poor quality because of “forage-like” characteristics such as broad leaf texture, low tiller density, and tall, open growth habit. This explains why only two of nine index-selected clonal lines were on the list of the top 18 entries for spread and why there was only a moderate correlation ($r = 0.41$, $P < 0.001$) between spread and turf quality. The mean spread of the top nine entries identified by the base index was 5.6, only slightly higher than the overall population mean (Table 1).

Clonal lines also differed in spring regrowth ranging from heights at cutting of 6.5 to 8.6 cm. Small to zero correlations were found between reduced spring regrowth and turf quality ($r = 0.09$, $P < 0.001$), color ($r = 0.11$, $P < 0.001$), and spread ($r = 0.26$, $P < 0.001$). The mean height at cutting for the top nine entries in the base index was 7.5 cm, and not significantly different from the population mean (Table 1). This suggests that using the multiple trait selection index will probably not result in reduced spring regrowth in the CWG-R population.

Growth habit, leaf texture, and tiller density are other important components of overall turf quality. These traits were not considered separately in the base index, but were integral in the overall turf quality ratings. Limited data were taken for these traits and showed the presence of variation among clonal lines for each trait. Many clonal lines had fine leaf texture and high tiller density, while others were more “forage-like.”

In conclusion, we found that there were high levels of heritable genetic variation in the CWG-R population for important turf traits. These high broad-sense heritabilities indicated potential for substantial gain from selection. Several superior clonal lines had much higher turf quality ratings than the overall mean of the population, further indicating significant potential improvement from selection. Rapid spring regrowth and reduced mid-summer turf quality appear to be the most limiting characteristics in the population; however, the average mid-summer (June–July) turf quality of the top nine entries identified by the base index was acceptable for reduced-maintenance turf. Overall, the results support the potential to improve turf quality, color, and spread within the germplasm through further cycles of selection, or possible introgression with other crested wheatgrass. We conclude that CWG-R could be an important germplasm for future reduced-maintenance turfgrass breeding projects and plans are underway to make it publicly available.

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