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Turf Quality Characteristics of Crested Wheatgrass (*Agropyron cristatum* (L.) Gaertner.) Specimens Native to Iran

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Abstract

Crested wheatgrass (*Agropyron cristatum* (L.) Gaertner.) is a potential source of low-maintenance turf species for use in areas with less water. The main goal of this study was to evaluate turf quality characteristics of 24 crested wheatgrass specimens collected from different locations of Iran as low-maintenance turfgrass. The experimental design was a randomized complete block design with 3 replications. The results showed significant variation among specimens for turf quality and turf quality components and there were 15 specimens with an average turf quality rating of 6.0 or higher, indicating adequate quality performance. Mowing quality were higher than 6 for all specimens and ranging from 6.30 (210 M) to 7.28 (4049). Habitats of samples varied in performance for all traits and different geographical regions may offer germplasm with high turf quality performance. There were significant positive correlation between turf quality and mowing quality (r = 71**) and also turf quality and tillering (r = 57**). Based on the results of cluster analysis, the specimens were assigned to 3 clusters and the single specimen from cluster 2 had the highest ratings for turf quality (7.95), mowing quality (7.28), color (7.27) and leaf texture (7.10). These results indicated that crested wheatgrass specimens native to Iran could be an important resource for use as low-maintenance turfgrass.

Keywords: Cluster analysis, Correlation, Low-maintenance, Mowing quality, Native grass.

INTRODUCTION

Water is becoming a more and rarer resource in arid and semi-arid regions in Iran which is characterized by little rainfall, high solar radiation and high temperatures in summer (Madani, 2014). In recent years turf grass has been extensively used in urban landscape and water demand for the irrigation of turfgrass will also increase substantially. One strategy to mitigate irrigation demands for turfgrass is to identify species and cultivars that maintain better qualities with less water for low-maintenance situations (Feldhake *et al*., 1983; Clark and Watkins, 2010).

Extensive landscape areas planted with 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 (Meyer, 1989; Dernoeden *et al.*, 1994) and thus help conserve natural resources and reduce pollutants. Moreover, maintenance costs of turfgrass in many areas could be reduced by planting low-maintenance turfgrass that need limited irrigation and mowing (Feldhake *et al.,* 1983; Clark and Watkins, 2010).

Crested wheatgrass (*Agropyron cristatum*) is a potential source of turf germplasm for arid and semi-arid regions. The genus is originated from central Asia, including parts of Iran, Turkey, Afghanistan, Russia, and China (Dewey and Asay, 1975) and includes 150 species, of which more than 20 species are distributed in different areas in Iran (Mozaffarian, 1996). Crested wheatgrass is a persistent, long-lived perennial and its properties include excellent seeding and well drought and cold resistance. It withstands weed competition, tolerates insect depredation, establishes easily and is adapted to a wide variety of soils (Asay and Jensen, 1996; Asay *et al.*, 1999). Although crested wheatgrass is normally bunch-type growth habit. Specimens with varying degrees of rhizome development have also been acquired from Iran and Turkey (Hanks *et al.*, 2005).

Several studies have investigated the potential (Robins *et al*., 2006; Bushman *et al.*, 2007; Robins and Waldron, 2007; Watkins *et al.*, 2011) and breeding (Asay *et al*., 1999; Hanks *et al*., 2005) of crested wheatgrass for turf use. Robins and Waldron (2007) reported that crested wheatgrass had a high genetic variation and heritability estimates for turf quality and revealed that crested wheatgrass might have promise for low maintenance situations. Hanks *et al.* (2005) identified the rapid spring growth and reduced summer turf quality as the most limiting characteristics of crested wheatgrass for turfgrass.

Development of turf-type crested wheatgrass cultivars may be possible by selection for turf quality traits including color, leaf texture, density and uniformity, as well as, drought tolerance and persistence. Genetic differences among cultivars could be employed by turf breeders as selection process in breeding programs. There was no information about the potential of native Iranian specimens of crested wheatgrass for use as low-maintenance turf species. The objectives of this study were to (1) evaluate the specimens for turf quality traits under low-maintenance conditions and (2) identify key geographical locations for future germplasm collection efforts and breeding programs.

MATERIALS AND METHODS

Plant material and experimental design

Seeds of twenty four native Iranian specimens of crested wheatgrass (*Agropyron cristatum*) (Table 3) were collected from different geographical regions by the Rangelands and Forestry Research Institute and the experiment was conducted at research farm of Department of Horticultural Science in Ferdowsi University Mashhad, Mashhad (36º16N, 59º38E; 989 m latitude), Iran during 2013-2014. The meteorological data of the experimental site were shown in Table 1. The grass seeds were sowed directly on 7 October 2013. The experimental design was a randomized complete block design with 3 replications. Individual plots consisted of 10 plants and spaced 50 cm between rows and 30 cm between plants within a row. The experiment soil was a loamy texture, pH= 7.1 and 0.9% organic matter. Throughout the study, irrigation occurred weekly from May to September at 60% evapotranspiration (ET0) replacement. Plots were weeded by hand or using hoes as needed throughout growing season. Following establishment, plots were mowed twice weekly to 8.0 cm.

Measurements

Turf characteristics including turfgrass quality, color, summer color, fall color and leaf texture were rated visually using a 1-9 scale (9 = best turf quality) following the guidelines provided by National Turfgrass Evaluation Program (NTEP) (Turgeon, 1996). A rating of 6.0 or higher indicates acceptable performance for traits. A similar scale was utilized to score mowing quality, i.e. the amount of leaf shredding (9 = no shredded leaf tips). Lateral spread (diameter [cm] at 4 cm above the soil) was measured at the widest expanse of the crown in one direction. Numbers of tillers were also recorded.

Statistical analysis

Analysis of variance (ANOVA) for all the variables was carried out using the JMP8 software and LSD test at 5% levels was used for mean comparison. Ward's method based on Euclidean distance grouped all 24 specimens using measured characters (Ward, 1963) made by the Minitab software.

RESULTS AND DISCUSSION

The results of analysis of variance showed significant differences ($P<0.01$) for turfgrass quality, color, summer and fall color, leaf texture, lateral spread and number of tillers within specimens (Table 2). Block was not significant for all of the traits except number of tillers (Table 2).

Mean separation analysis for measured traits was shown in Table 3. Specimens 4049 (7.90) and 210 M (4.67) had the highest and lowest turf quality, respectively. There were 15 specimens that received an average turf quality rating 6.0 or higher, indicating adequate turf quality performance. Mowing quality were higher than 6 for all specimens and ranging 6.30 (210 M) to 7.28 (4049). The highest ratings for leaf color (7.28) and texture (7.10) were obtained from 4049. The highest ratings for summer (6.78) and fall (6.37) color were observed from 4049 M and 2854, respectively (Table 3).

These results are similar to Cook (2000), Robins *et al.* (2006), Bushman *et al*. (2007), Robins and Waldron (2007) and Watkins *et al*. (2011) evaluations of turf-type crested wheatgrasses for overall and seasonal patterns of turf quality and color. The range of variation among specimens indicates that there is potential for developing crested wheatgrass specimens for use as low-input turf. The number of individual specimens with adequate turf performance and other traits suggests that these species should be the target of germplasm improvement efforts for use as a low-input turf.

Table 1. Monthly average temperatures and precipitation at the experimental station during October 2013 to December 2014.

Year	Month	Min. average temperature (◦C)	Max. average temperature (◦C)	Precipitation (mm)
2013	October	11.3	27.1	26.4
	November	4.3	16.2	3.2
	December	0.8	11.8	7.2
2014	January	- 3.5	7.9	5.0
	February	- 4.0	9.4	2.9
	March	9.0	15.0	3.0
	April	5.9	18.2	35.1
	May	14.9	28.9	22.4
	June	17.5	32.6	4.3
	July	20.9	36.4	0.0
	August	19.5	35.6	0.0
	September	16.0	31.5	0.0

Table 2. Analysis of variance for trial characteristics of crested wheatgrass specimens.

Precipitation (mm)	df	Turf quality	Mowing quality	Leaf texture	Color	Summer color	Fall color	Lateral spread	Lateral spread
Replication	2	0.05 ns†	0.04 ns	0.10 ns	0.22 ns	0.09 ns	0.04 ns	46.21 ns	438.05*
Specimens	23	2.43**	0.20*	0.54**	0.30**	0.61**	1.30**	135.13**	565.22**
Error	46	0.14	0.10	0.08	0.10	0.04	0.31	16.78	104.91

† *, ** and ns indicate significance at $P < 0.05$, $P < 0.01$ levels and non-significance, respectively.

Table 3. Origin and mean separation analysis of turf quality, mowing quality, leaf texture, color, summer color, fall color, lateral spread and number of tiller for crested wheatgrass specimens native to Iran.

Specimen	Origin	Turf quality	Mowing quality	Leaf texture	Color	Summer color	Fall color	Lateral spread	Number of tiller
		1-9	1-9	1-9	1-9	1-9	1-9	cm	n
3029	Bojnord	7.34	6.92	5.44	7.23	6.04	5.37	44.53	97.13
1727 P10	Golestan	6.45	6.37	6.00	7.05	5.63	6.33	43.51	40.49
1727 M	Golestan	5.08	6.35	6.76	6.33	4.70	5.67	46.47	41.57
208 M	Esfahan	6.69	7.00	6.43	7.04	6.70	5.33	47.65	67.83
4056	Chadegan	7.31	7.20	6.31	7.22	6.38	5.67	44.06	75.70
2854	Arak	6.30	6.53	6.13	6.30	6.41	6.37	47.62	56.78
1727 P12	Golestan	4.73	6.38	6.94	6.48	6.34	5.80	36.31	32.73
1550	Bojnord	6.79	6.89	5.82	7.12	6.45	5.73	36.74	69.84
619 S	Esfahan	6.41	6.61	5.82	6.96	5.77	6.17	44.73	74.53
208 P2	Esfahan	5.73	6.80	6.62	7.00	6.67	5.33	35.81	64.80
4049	Kerman	7.90	7.28	7.10	7.27	5.66	3.00	23.71	53.84
208 P13	Esfahan	6.69	6.86	6.02	6.61	6.11	5.80	42.20	75.26
619 M	Esfahan	6.56	6.67	6.15	6.96	6.13	5.63	40.31	58.32
4056 M	Chadegan	6.72	6.87	6.21	6.92	6.00	5.57	44.62	60.39
210 M	Hamand	4.67	6.30	5.63	6.79	5.92	5.37	38.03	38.37
619	Esfahan	6.58	6.66	5.76	6.84	6.00	6.00	47.90	68.61
619 P13	Esfahan	6.80	6.77	6.00	6.87	6.10	5.00	43.43	55.23
208 MH	Hamedan	7.44	7.10	6.00	7.19	6.11	5.33	46.35	81.27
1727 P1	Golestan	5.90	6.71	6.45	6.54	5.35	6.07	42.24	36.08
1727	Golestan	5.20	7.00	6.43	6.78	6.21	5.77	21.60	38.29
209 M	Esfahan	5.10	6.66	5.81	6.20	6.00	5.53	44.67	57.37
4050	Lorestan	5.90	6.82	6.01	7.00	6.34	6.33	47.10	55.22
4049 M	Kerman	6.00	6.67	6.15	6.67	6.78	5.33	44.00	59.67
1551	Bojnord	4.98	6.56	5.48	6.33	6.00	5.67	40.67	77.50
	LSD (0.05)	0.61	0.53	0.47	0.55	0.33	0.90	6.99	18.36

Specimens 619 (47.90 cm), 208 M (47.65 cm), 2854 (47.62 cm) and 4050 (47.10 cm) had higher lateral spread among specimens (Table 3). Lateral spread is a measurement of plant vigor and an indicator of the ability to adequately cover the soil surface as a uniform turf. This trait is desirable in turfgrass to fill in gaps of a turf canopy caused by damage or wear. The highest tiller number was observed in 3029 (Table 3). Plant density appeared to be influenced by environmental factors and by genetic factors such growth habit (Clark and Watkins, 2010). The specimens differed substantially in tillering density that will be useful in selecting genotypes with the high density ratings.

Means separation analysis on origin basis showed that collection regions differed in performance for all traits (Table 4). The single accession from Hamedan (208 MH) performed the highest turf quality (7.44), mowing quality (7.10) and color (7.19). All collection origins had acceptable turf quality (higher than 6) except Lorestan (5.90), Hamand (4.67) and Golestan (5.47). The lowest turf quality rating was obtained from Hamand (4.67). The finest (6.62) and coarsest (5.58) leaf texture were observed in Kerman and Bojnord, respectively. The lateral spread and tillering were the highest for collections from Arak (47.62 cm) and Bojnord (81.49), respectively. The single accession from Arak (208 M) performed the highest ratings for summer (6.41) and fall

Table 4. Means separation analysis of turf quality, mowing quality, leaf texture, color, summer color, fall color, lateral spread and number of tiller by origin of crested wheatgrass specimens native to Iran.

Origin	No. specimen	Turf quality	Mowing quality	Leaf texture	Color	Summer color	Fall color	Lateral spread	Number of tiller
		1-9	1-9	1-9	1-9	1-9	1-9	cm	n
Bojnord	3	6.37	6.79	5.58	6.89	6.16	5.59	41.13	81.49
Golestan	5	5.47	6.56	6.52	6.64	5.64	5.93	37.73	37.56
Esfahan	8	6.32	6.75	6.08	6.81	6.18	5.60	43.34	64.69
Chadegan	2	7.02	7.04	6.26	7.07	6.19	5.62	44.39	66.52
Arak	1	6.30	6.53	6.13	6.30	6.41	6.33	47.62	56.78
Kerman	2	6.95	6.97	6.62	6.97	6.22	4.17	33.86	56.75
Hamand	1	4.67	6.30	5.63	6.79	5.92	5.37	38.03	38.37
Hamedan	1	7.44	7.10	6.00	7.19	6.11	5.33	46.35	81.27
Lorestan	1	5.90	6.82	6.01	7.00	6.34	6.28	47.10	55.22
LSD (0.05)		1.21	0.56	0.62	0.65	0.72	1.06	11.61	18.89

Table 5. Correlation coefficients among several turf quality characteristics of crested wheatgrass specimens native to Iran.

	Turf quality	Mowing quality	Color	Leaf texture	Lateral spread	Summer color	Number of tiller	Fall color
Turf quality								
Mowing quality	0.71**†							
Color	0.73**	0.63**						
Leaf texture	- 0.00 ns	0.18 ns	0.00 ns					
Lateral spread	0.10 ns	- 0.27 ns	- 0.15 ns	- 0.42*				
Summer color	0.12 ns	0.31 ns	0.22 ns	- 0.11 ns	- 0.02 ns			
Number of tiller	0.57**	0.47*	0.38 ns	- 0.51*	0.34 ns	0.32 ns		
Fall color	- 0.37 ns	- 0.50*	- 0.34 ns	- 0.38*	0.51*	0.03 ns	- 0.06 ns	

† *, ** and ns indicate significance at P < 0.05, P < 0.01 levels and non-significance, respectively.

(6.33) color. Clark and Watkins (2010) revealed that significant differences among collection regions of prairie junegrass specimens for most traits like turf quality, mowing quality and color that were similar to present results. The analysis of collection regions allowed for the identification of future germplasm collection sites and planning for future turf breeding programs. Collection of specimens from different geographical regions of Iran may offer germplasm with high turf quality performance.

Correlations based on the 24 specimen means were calculated among the turf quality traits (Table 5). As expected, there were generally positive correlations between overall turfgrass quality and the turfgrass quality components. There were significant positive correlation between turf quality and mowing quality (r = 71**) and between turf quality and tillering (r = 57**). Positive correlation was occurred between mowing quality and tillering (r = 0.47*). There were a negative correlation between lateral spreading and leaf texture (r = -0.42*) and significant positive correlation between lateral spreading and fall color (r= 0.51**). Hanks *et al*. (2005) reported that sig-

Table 6. Means of traits used in the identification of three clusters formed from 24 crested wheatgrass specimens native to Iran.

Cluster	Turf quality	Mowing quality	Leaf texture	Color	Summer color	Fall color	Lateral spread	Number of tiller
	1-9	1-9	1-9	1-9	1-9	1-9	cm	n
1	6.64	6.84	6.05	6.97	6.26	5.61	43.53	67.82
2	7.90	7.28	7.10	7.27	5.66	3.00	23.71	53.84
3	5.38	6.54	6.18	6.53	5.84	5.84	40.04	44.81

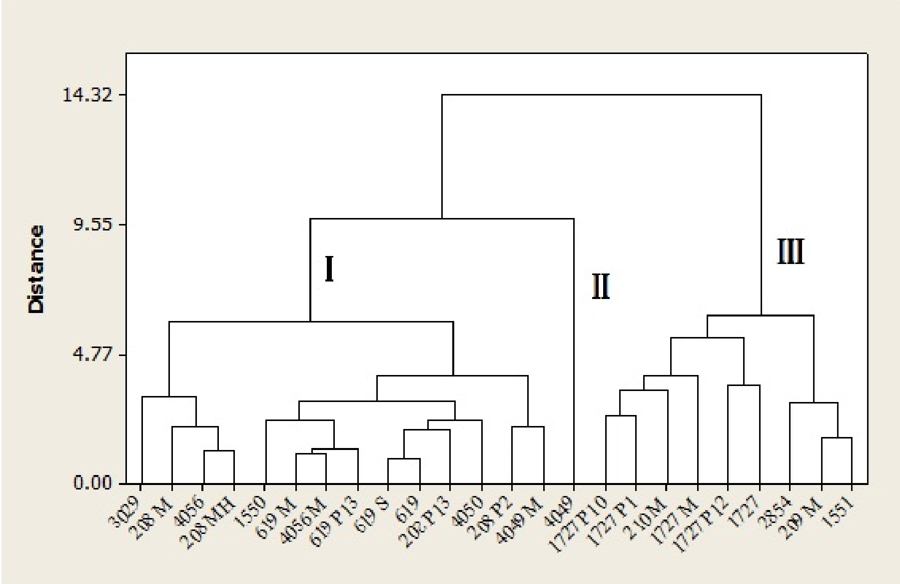

Fig. 1. Ward's cluster analysis classifications of 24 crested wheatgrass specimens native to Iran.

nificant positive correlation between turf quality and mowing quality in population of CWG-R crested wheatgrass in agreement with the present results.

On the basis of the results of cluster analysis, the specimens were assigned to 3 clusters (Fig. 1). Cluster 1, the largest group, included 14 specimens and had the highest lateral spread (43.53 cm), number of tillers (67.82) and summer color (6.26) (Table 6). In cluster 2, contained the single accession and had the highest ratings for turf quality (7.95), mowing quality (7.28), color (7.27) and leaf texture (7.10). Cluster 3 included 9 specimens and fall color rating (5.84) was the highest (Table 6). Cluster analysis has been used to group specimens in genetic diversity studies and examine the relationships among specimens of diverse germplasm (Garcia *et al.,* 1997; Bayuelo-Jimenez *et al.,* 2002; Gazanchian *et al.*, 2006; Oliveira *et al.*, 2008). Cluster 2 had single accession (4049) collected from Kerman was superior for turf quality, mowing quality and color among all of specimens that could be used in future breeding programs. Genetic diversity of cluster 1 could be used for selecting resistance specimens to summer dormancy and reduction of greenness.

CONCLUSION

In the present study, several superior specimens had higher turf quality ratings than the overall mean of the specimens, further indicating significant potential improvement from selection. The variability in turf quality traits observed in the specimens supports their use in a breeding program for the development of low-input turf. The specimens with high mowing quality performance will be important in germplasm improvement of native plant material which does not tolerate mowing. The specimens collected from different geographical regions of Iran may be germplasm with high turf quality and mowing quality ratings. It will be necessary to examine the better performing specimens for turf quality in seeded turf plots.

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