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Evaluation of Alternative Turfgrass Species for Low-input Golf Course Fairways

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***Abstract*. As restrictions on water use, fertilization, and pesticide applications continue to increase, golf course superintendents will need to use grass species that require reduced inputs. The objective of this study was to evaluate alternative turfgrass species under low-input fairways conditions. In 2005, 17 species were established on native soil in St. Paul, MN. Each species was evaluated at three levels of traffic (zero, three, or six passes per week using a drum-type traffic simulator) and two mowing heights (1.90 and 2.54 cm). Data collected included turfgrass quality and percent living stand density. In 2006, velvet bentgrass (*Agrostis canina* L.), colonial bentgrass (*Agrostis capillaris* L.), and creeping bentgrass (*Agrostis stolonifera* L.) maintained acceptable quality in all treatment combinations. In 2007, Chewings fescue (*Festuca rubra* L. ssp. *fallax*) and sheep fescue (*Festuca ovina* L.) were the top-performing species regardless of treatment. Hard fescue (*Festuca brevipila* Tracey) performed poorly in Year 1 and well in Year 2. All other species did not perform at an acceptable level during the study. The results of this study indicate that sheep fescue, Chewings fescue, colonial bentgrass, and velvet bentgrass should be studied further for use on low-input golf course fairways in the northern United States.**

The environmental impact of golf courses has been studied increasingly in recent years. King et al. (2007) studied storm runoff from a golf course in Texas and found that although nitrogen concentrations in runoff were not a concern, phosphorus levels of water exiting the course were above U.S. Environmental Protection Agency (EPA) recommendations for streams not discharging into lakes. Winter and Dillon (2006) found that nutrient load in streams draining golf courses was greater than that of streams that drained forested areas. Lewis et al. (2002) evaluated the effect of a coastal golf course complex on water quality, algae, and seagrass in wetland and near coastal areas; they found very little adverse effect and suggested that the runoff from golf courses into near coastal areas may be less of a problem than that from agricultural areas. The results from these and other studies have not proven or disproven that golf courses are a significant hazard to the environment.

Nevertheless, local, state, and national restrictions are limiting use of chemical and water inputs. In Minnesota, phosphorus applications to turf are restricted throughout the state (State of Minnesota, 2008). In Canada, the use of lawn and garden pesticides and fertilizers has been the subject of public debate for years with municipalities and provinces restricting or banning use altogether because of concern about possible health effects on humans (Government of Quebec, 2006). The EPA has recently defined irrigation water use standards that limit the amount of irrigation water that can be applied to turfgrass (USEPA, 2009). As restrictions continue to increase, golf course managers will need options for managing turf that are not viewed as risks to the environment.

Increasing energy costs, human health concerns, and environmental awareness are making turfgrass managers consider lower input, sustainable turfgrass maintenance practices (Cisar, 2004; Pioppi, 2008). Nationally, golf courses comprise an estimated 908,342 ha of which 67% is maintained as turf (Lyman et al., 2007). Of the maintained areas, ≈85% is kentucky bluegrass (*Poa pratensis* L.), bermudagrass (*Cynodon dactylon* L. × *C. transvaalensis* Burtt-Davy), perennial ryegrass (*Lolium perenne* L.), creeping bentgrass, or annual bluegrass (*Poa annua* L.) (Lyman et al., 2007). In the cool-season region of the United States, golf courses traditionally grow creeping bentgrass on putting greens and creeping bentgrass, kentucky bluegrass, and/or perennial ryegrass on fairways (Christians, 1998; Lyman et al., 2007; Warnke, 2003). These species are desirable because they can tolerate low mowing heights. However, when managed as a fairway turf, creeping bentgrass, annual bluegrass, kentucky bluegrass, and perennial ryegrass typically require significant amounts of nitrogen fertilization, irrigation, and pesticides (Beard, 2002).

Researchers have investigated several options for reducing inputs on golf course fairways such as biological control of disease (Hardebeck et al., 2004); application of plant growth regulators for reduced clipping production (Stier et al., 2000); reducing nutrient runoff through irrigation timing (Shuman, 2002); use of transgenic, disease-resistant cultivars (Guo et al., 2003); and deficit irrigation strategies (DaCosta and Huang, 2005).

A more sustainable, effective strategy to deal with the potential risks associated with inputs such as fertilizers, pesticides, and water on golf courses may be the use of alternative turfgrass species. Several turfgrass species that are not currently used for golf course fairways in the northern United States may have the potential to be used for low-input fairways. Low-input turf must be able to survive and perform adequately under conditions of little or no supplemental irrigation, high traffic, no pesticides, and reduced fertility (≈49.0 $kg\cdot ha^{-1}$ nitrogen or less).

Information about low-input golf course fairway turfgrasses is limited because most research on low-input turfgrasses has focused on high-cut turf (Diesburg et al., 1997; Mintenko et al., 2002; Watkins et al., 2008). Horgan et al. (2007) evaluated fine fescue and colonial bentgrass mixtures for low-input fairways and suggested that under extremely low-input conditions, Chewings fescue would provide the most acceptable turf. In Europe, fine fescue species have long been used for golf courses and sport turf uses (Ruemmele et al., 2003).

Traffic tolerance under typical high-input conditions has been evaluated for creeping and velvet bentgrass (Samaranayake et al., 2008) and kentucky bluegrass (Shortell et al., 2004). Fine fescue species have been evaluated for wear tolerance at low mowing heights in the United Kingdom (Newell and Jones, 1995; Newell and Wood, 2003); however, these evaluations were conducted under conditions in which nitrogen was not a limiting factor (between 83 and 100 $kg\cdot ha^{-1}$ N) and pesticides were used. Identifying grass species that can perform adequately under extremely low-input conditions will allow golf course superintendents to reduce inputs, conserve resources, and improve environmental quality. Therefore, the objective of this study was to evaluate alternative turfgrass species performance under low-input fairway conditions.

Materials and Methods

Plots were seeded in Sept. 2005 in St. Paul, MN, at the Turfgrass Research, Outreach, and Education Center at the University of Minnesota. The soil was a Waukegan silt loam (fine-silty over sandy, mixed, mesic Typic Hapludoll) with a pH of 6.9. Before seeding, the plot area was treated with the soil fumigant dazomet (Basamid Granular; BASF, Ludwigshafen, Germany). After seeding, a starter fertilizer [69.8 $kg\cdot ha^{-1}$ N (9N–7.9P–14.9K)] was applied and the trial was

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covered with Curlex (Excelsior fiber) erosion matting (American Excelsior Company, Arlington, TX). Additional fertilizer applications were made during the fall establishment period as follows: 49.0 kg·ha^{-1} N 3 weeks after seeding using 18N–1.3P–14.9K, 24.5 kg·ha^{-1} N 6 weeks after seeding using 21N–0.0P–17.4K, and 49.0 kg·ha^{-1} N 9 weeks after seeding using 46N–0.0P–0.0K. In 2006, only one fertilizer application was made in late fall (49.0 kg·ha^{-1} N using 22N–0.0P–18.3K). No fertilizer was applied in 2007. Plots were irrigated during establishment. No irrigation was used in 2006, and only one irrigation event occurred during 2007 in August.

The trial consisted of 17 cool-season grass species (Table 1). The experimental design was a randomized complete block with a split–split plot restriction on replication. The experiment included four replications. Mowing height (1.90 or 2.54 cm) was the main plot (59.2 m^2), traffic level (zero, three, or six passes per week) was the subplot (19.7 m^2), and species was the sub-subplot (1.16 m^2).

To simulate golf cart traffic, plots were trafficked with a custom-built golf cart traffic simulator towed behind a turf utility vehicle. The traffic simulator consisted of two 454-kg traffic units on an axle containing five golf cart tires. Traffic was applied 3 d each week beginning 1 May and ending 30 Sept. during each year of the study. Plots received zero, one, or two passes of traffic on each day for a total of zero, three, or six passes of traffic each week.

Plots were evaluated for overall turfgrass quality at least one time each month during both the 2006 and 2007 growing seasons using a visual 1 to 9 scale with 9 representing the optimum quality and 5 representing lowest acceptable quality for a low-input golf course fairway turf. Quality components included density, uniformity, color, and leaf texture. Because there were no major disease or weed problems in either of the 2 years, no ratings were taken for these factors. In Fall 2007, percent living stand density of the originally seeded species was determined using the grid intersect method (100 grid intersections). Percent living stand density has been found to be an effective quantitative method for determining wear tolerance in cool-season turfgrasses (Shearman and Beard, 1975). Weather data were recorded daily throughout the duration of the trial (Fig. 1).

Data from each year were analyzed separately using the MIXED procedure of SAS (Version 9.1; SAS Institute, Cary, NC). Cultivar differences were determined using LSMEANS with the PDIFF option and were considered to be significantly different at $\alpha = 0.05$.

Results

For both 2006 and 2007 average turf quality ratings, significant main effects included traffic ($P \leq 0.0001$ and $P = 0.0122$, respectively) and species ($P \leq 0.0001$ for both years). For both 2006 and 2007 average turf quality data, the traffic × species interaction was significant ($P = 0.0004$ for both years), whereas the mow × species interaction was not significant (Table 2).

Because species performance did not differ between mowing height treatments but did differ between traffic treatments, data were analyzed across mowing heights at each level of traffic (Table 3). In 2006, velvet and colonial bentgrass with no traffic and velvet bentgrass under high traffic had significantly higher average turfgrass quality than the other species. In the high traffic treatment, sheep fescue had turfgrass quality ratings that were significantly lower than seven other species, including velvet, colonial, and creeping bentgrass; supine bluegrass (*Poa supina* Schrad.); kentucky bluegrass; perennial ryegrass; and tall fescue [*Schedonorus phoenix* (Scop.) Holub.] (Table 3).

In 2007, sheep fescue had significantly better turfgrass quality than any other species under all three traffic treatments (Table 3). Under high traffic, colonial bentgrass was the only species that had percent living stand density ratings superior to sheep fescue at the end of 2007. Sheep fescue was able to maintain acceptable quality (greater than 5.0) throughout the summer stress period of 2007, whereas colonial bentgrass had a quality rating of 1.3 during July of that year (Fig. 3). The colonial bentgrass decline in quality appeared to be primarily the result of the onset of drought-induced dormancy. Colonial bentgrass was able to recover once cooler fall temperatures arrived and the summer stress period was complete. Average turfgrass quality under high traffic for all species other than sheep and Chewings fescue was not acceptable (less than 5.0) in 2007.

A closer examination of the treatment with mowing height at 1.90 cm and six passes of traffic each week is useful because it imposed the most stress on the turf (Table 4; Figs. 2 and 3). In 2006, velvet bentgrass had significantly higher average turfgrass quality than any other species (Table 4). Other species that had acceptable turfgrass quality (greater than 5.0 average) in 2006 included creeping bentgrass, colonial bentgrass, kentucky bluegrass, supine bluegrass, perennial ryegrass, and tall fescue. All fine fescue species had significantly lower turfgrass quality ratings than the velvet, creeping, or colonial bentgrass. Several species {weeping alkaligrass [*Puccinellia distans* (Jacq.)], timothy [*Phleum pratense* L.], redtop [*Agrostis gigantea* Roth], Canada bluegrass [*Poa compressa* L.], tufted hairgrass [*Deschampsia cespitosa* (L.) P. Beauv.], perennial-type annual bluegrass [*Poa annua* L. var. *reptans* Hausskn.], and rough bluegrass [*Poa trivialis* L.]} did not perform at an acceptable level under this or any treatment combinations.

In 2007, under the high stress treatment of 1.90-cm mowing height and six passes of traffic each week, sheep fescue and Chewings fescue performed significantly better than the other species (Table 4). The next statistical grouping included hard fescue and colonial bentgrass; however, these and all other species each had an overall average rating of less than 5.0, which indicated that they did not perform adequately during the second year of the trial. Species exhibiting the best percent living stand density were colonial bentgrass, Chewings fescue, and sheep fescue, whereas rough bluegrass, alkaligrass, and annual bluegrass plots each had stand density below 5%.

Temperature and precipitation differed between the 2 years of the study (Fig. 1). In 2006, monthly mean temperature was above recent historical averages (since 1960) in April through August. In 2007, monthly mean temperature was above average in April through July. The monthly mean temperature for April, July, and August was greater in 2006 than 2007. The average temperature during July 2006 (25.6 °C) was higher than July 2007 (23.7 °C). Average monthly precipitation for May, June, July, and August was greater in 2006 when compared with 2007. The total precipitation for Aug. 2006 (21.8 cm) was the highest recorded monthly precipitation at our research site since 1960 (University of Minnesota, 2009).

Discussion

In this study, the fine fescue species showed the greatest potential for use on low-input golf course fairways. To our knowledge, this is the first report of sheep fescue being a successful fairway turf in the United States.

Table 1. Turfgrass species planted in a low-input fairway trial in St. Paul, MN.

Common name	Scientific name	Cultivar/selection
Creeping bentgrass	*Agrostis stolonifera*	L-93
Colonial bentgrass	*Agrostis capillaris*	Tiger II
Velvet bentgrass	*Agrostis canina*	Vesper
Redtop	*Agrostis gigantea*	Streaker
Kentucky bluegrass	*Poa pratensis*	Award
Annual bluegrass	*Poa annua* var. *reptans*	4337
Rough bluegrass	*Poa trivialis*	Sabre II
Supine bluegrass	*Poa supina*	Supranova
Canada bluegrass	*Poa compressa*	Barpressa
Tall fescue	*Schedonorus phoenix*	Corgi
Tufted hairgrass	*Deschampsia cespitosa*	SR6000
Hard fescue	*Festuca brevipila*	SR3100
Chewings fescue	*Festuca rubra* ssp. *fallax*	Jamestown 2
Sheep fescue	*Festuca ovina*	Quatro
Perennial ryegrass	*Lolium perenne*	Gator 3
Weeping alkaligrass	*Puccinellia distans*	Fults
Timothy	*Phleum pratense*	Barvanti

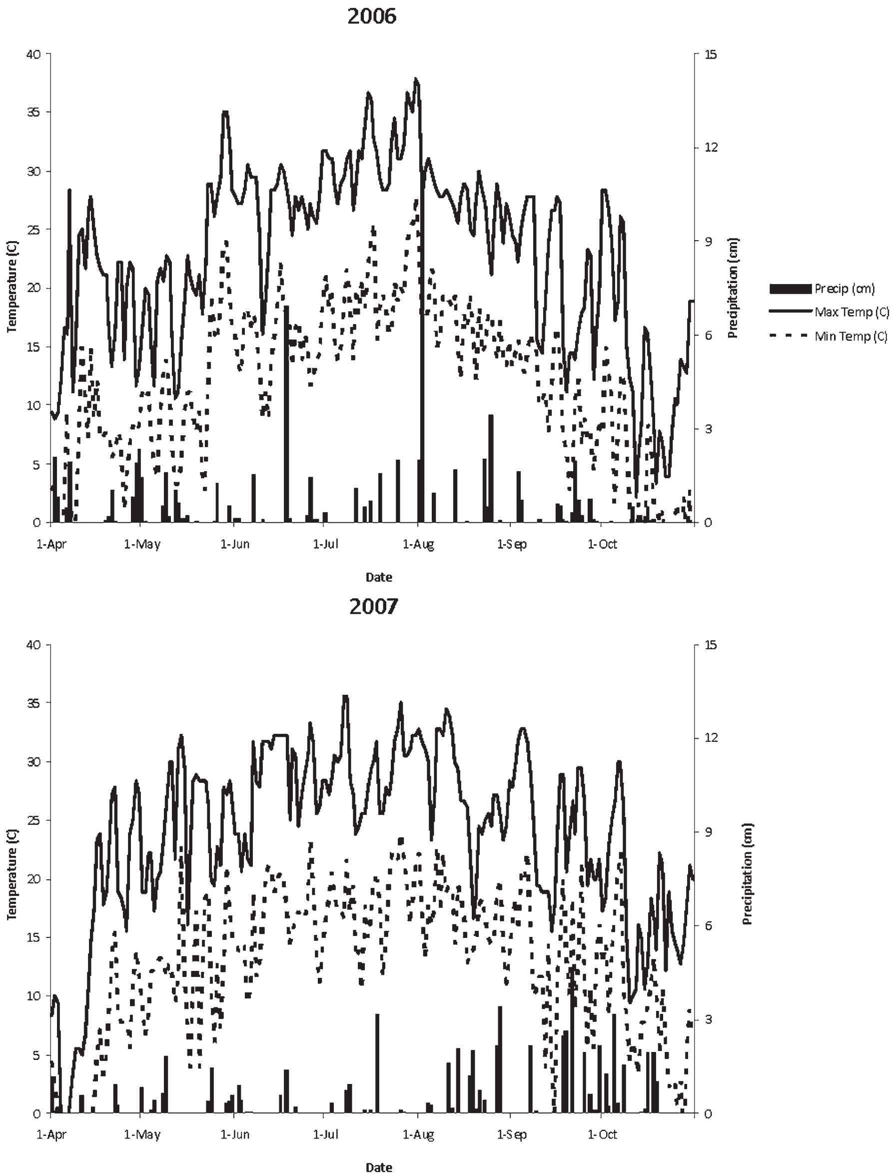

Fig. 1. Weather data for St. Paul, MN, for 2006 and 2007.

Table 2. Analysis of variance for turf quality and percent living stand density for a low-input fairway trial in St. Paul, MN, established in Sept. 2005.

			2006 Turf qty[z]		2007 Turf qty[y]		2007 Percent stand density[x]	
Effect	df num	df den	*F* value	*Pr* > *F*	*F* value	*Pr* > *F*	*F* value	*Pr* > *F*
Mow[w]	1	3	3.76	0.148	0.17	0.7115	0.30	0.6247
Traffic (traf)[v]	2	12	32.58	<0.0001	6.5	0.0122	2.63	0.1127
Species (spec)[u]	16	287	175.65	<0.0001	226.88	<0.0001	250.48	<0.0001
Mow*spec	16	287	1.2	0.265	0.86	0.6217	1.12	0.3375
Traf*spec	32	287	2.17	0.0004	2.2	0.0004	1.65	0.0175
Mow*traf*spec	34	287	0.8	0.775	0.57	0.9755	0.63	0.9486
CV (%)				10.59		14.97		20.69

[z]Average of eight turfgrass quality ratings in 2006 (1 to 9 scale, 9 = optimum turf quality). Ratings were taken monthly from April through October (two ratings were taken in May and averaged before analysis). Quality components included density, uniformity, color, and leaf texture.

[y]Average of six turfgrass quality ratings in 2007 (1 to 9 scale, 9 = optimum turf quality). Ratings were taken monthly from May through October. Quality components included density, uniformity, color, and leaf texture.

[x]Percent living stand density determined using grid interest method in Oct. 2007.

[w]Plots were mowed at either 1.90 or 2.54 cm.

[v]Each species was evaluated at three levels of traffic (zero, three, and six passes per week).

[u]Seventeen species were included in this evaluation.

Newell and Wood (2003) evaluated one cultivar of the species in a golf fairway traffic trial and found that it performed as well as other fine fescue species under typical fairway management conditions in Great Britain.

Sheep fescue is typically used in hard–to-mow areas and for higher-cut turf (Ruemmele et al., 2003) and therefore most research on this species has been done at mowing heights greater than 3.5 cm. Diesburg et al. (1997) evaluated 12 grass species for 3 years at seven research sites throughout the north–central United States under a low-input management regime (limited herbicide application, no irrigation after establishment, 49 kg·ha^{-1}/year N) and found that when maintained at 7.6 cm, sheep fescue and tall fescue were the most widely adapted species for use as low-input turf. The only site at which the species did not perform as well was Columbia, MO, indicating that high summer temperatures may limit the use of this species in certain regions. They also found that sheep fescue did not perform adequately at a 3.8-cm mowing height under low-input conditions; this is contrary to performance of the species in our study, which may be the result of cultivar differences (the earlier study used the common-type cultivar Covar). Dernoeden et al. (1994) compared 'Big Horn' sheep fescue, 'Aurora' hard fescue, and two cultivars of tall fescue (Silverado and Rebel II) for 3 years under low-input conditions (no irrigation or fertility after establishment) at three mowing heights (5.5 cm, 8.0 cm, and 8.0 cm after seed senescence). They found that the sheep fescue and hard fescue outperformed both tall fescue cultivars in the final 2 years of the study. The authors speculated that a limitation of these fine fescue species would be tolerance of high levels of traffic.

Newell and Wood (2003) evaluated cultivars of fine fescue species managed as a regularly maintained golf course fairway under either golf buggy (motorized golf cart) or golf trolley (motorized pull cart + simulated foot traffic) wear. They found that most Chewings fescue cultivars did well under golf trolley wear. Under golf buggy wear, the cultivars of this species ranged from fairly poor to good. In the United States, the use of motorized golf carts may be a factor that limits the use of Chewings fescue and other fine fescues on golf course fairways; however, the range of response under golf buggy wear in the aforementioned study, along with our results, suggests that Chewings fescue has the potential to be used for fairways that experience significant motorized golf cart use.

Shearman and Beard (1975) found that when maintained at 5.0 cm, wear tolerance of Chewings fescue was significantly less than that of other cool-season turfgrass species such as perennial ryegrass and kentucky bluegrass. In our study, under low-input fairway conditions, wear tolerance of Chewings fescue, as evidenced by turfgrass quality ratings, was as good as any other species in the trial. This difference in performance could be the result of cultivar differences, differences in thatch levels resulting

Table 3. Turfgrass quality and percent living stand density for species receiving either zero, three, or six passes of traffic per week averaged over both mowing heights (ranked by overall 2007 turfgrass quality under high-traffic treatment) for a low-input fairway trial in St. Paul, MN, established in Sept. 2005.

	2006 Turf qty[z]			2007 Turf qty[y]			2007 Percent living Stand density[x]		
	Level of traffic[w]								
Species	0	3	6	0	3	6	0	3	6
Sheep fescue	5.1 de[v]	4.6 ghi	4.4 d	6.7 a	6.3 a	5.8 a	86.0 a	80.4 a	76.8 ab
Chewings fescue	5.9 bcd	4.9 fghi	4.6 d	5.5 b	5.4 b	5.3 b	85.0 a	72.9 ab	73.6 bc
Hard fescue	4.4 fg	3.9 k	3.8 ef	5.5 b	5.2 b	4.6 c	79.4 ab	72.4 ab	65.3 cd
Colonial bentgrass	7.5 a	6.3 ab	6.1 b	4.1 d	4.0 cd	4.4 cd	84.4 a	80.4 a	85.1 a
Kentucky bluegrass	6.3 bcd	5.3 ef	5.3 c	4.0 d	3.6 def	3.9 de	55.0 f	51.9 c	54.4 e
Tall fescue	6.1 bcd	5.6 de	5.2 c	4.7 c	4.2 c	3.7 e	56.1 f	48.6 c	44.9 f
Velvet bentgrass	7.5 a	6.8 a	7.0 a	4.0 d	3.8 cd	3.7 e	73.3 bc	70.3 b	71.3 bc
Creeping bentgrass	6.4 bcd	6.3 ab	6.2 b	3.1 e	3.3 efgh	3.7 e	67.4 cd	66.0 b	71.3 bc
Supine bluegrass	6.0 bcd	5.9 bcd	6.0 b	2.6 ef	3.0 ghi	3.1 f	26.5 g	34.1 d	44.4 f
Timothy	4.6 efg	4.4 ij	4.2 de	3.0 e	3.2 fgh	3.1 f	60.9 def	52.8 c	58.4 de
Perennial ryegrass	5.6 cde	5.8 cde	5.7 bc	3.1e	2.9 hi	2.4 g	34.1 g	33.0 d	33.1 g
Redtop	3.7 hi	3.2 l	3.0 g	2.9 ef	2.7 ij	2.3 g	57.1 ef	53.5 c	56.5 de
Canada bluegrass	2.8 j	2.7 m	2.5 h	2.2 f	2.1 k	2.3 g	17.5 h	14.0 e	23.6 h
Tufted hairgrass	4.1 ghi	3.9 jk	3.4 fg	2.4 f	2.4 jk	2.0 g	16.8 h	9.5 e	10.5 i
Rough bluegrass	3.6 i	3.3 l	3.1 g	1.4 g	1.2 l	1.2 h	1.4 i	3.9 ef	4.5 ij
Alkaligrass	2.0 k	1.9 n	1.8 i	1.2 g	1.1 l	1.1 h	0.0 j	0.0 f	0.0 j
Annual bluegrass	3.6 i	4.5 hi	3.8 ef	1.0 g	1.1 l	1.1 h	1.6 i	4.4 ef	1.6 ij

[z]Average of eight turfgrass quality ratings in 2006 (1 to 9 scale, 9 = optimum turf quality). Ratings were taken monthly from April through October (two ratings were taken in May and averaged before analysis). Quality components included density, uniformity, color, and leaf texture.

[y]Average of six turfgrass quality ratings in 2007 (1 to 9 scale, 9 = optimum turf quality). Ratings were taken monthly from May through October. Quality components included density, uniformity, color, and leaf texture.

[x]Percent living stand density determined using grid interest method in Oct. 2007.

[w]Traffic was applied at three levels: zero, three, and six passes per week.

[v]Species mean differences determined by LSMEANS. Means followed by the same letter within a column are not significantly different.

Table 4. Turfgrass quality and percent living stand density for species maintained at 1.90 cm receiving six passes of traffic per week (ranked by overall 2007 turfgrass quality) for a low-input fairway trial in St. Paul, MN, established in Sept. 2005.

Species	2006 Turf qty[z]	2007 Turf qty[y]	2007 Percent living Stand density[x]
Sheep fescue	4.0 ef[w]	5.7 a	76.5 abc
Chewings fescue	4.6 e	5.3 a	77.0 ab
Hard fescue	3.8 fg	4.5 b	63.3 cde
Colonial bentgrass	6.1 b	4.5 b	83.8 a
Creeping bentgrass	6.3 b	4.0 c	68.8 bcde
Tall fescue	5.5 cd	4.0 c	56.5 def
Kentucky bluegrass	5.0 de	3.9 c	58.5 def
Velvet bentgrass	7.1 a	3.7 c	69.8 bcd
Supine bluegrass	6.0 bc	3.1 d	45.0 fg
Timothy	4.4 e	3.1 d	60.3 def
Perennial ryegrass	5.3 d	2.4 e	35.8 gh
Canada bluegrass	2.5 i	2.2 e	24.8 hi
Redtop	2.8 hi	2.2 e	56.0 ef
Tufted hairgrass	3.4 fgh	2.1 e	11.8 ijk
Rough bluegrass	3.2 gh	1.2 f	3.75 jk
Alkaligrass	1.8 j	1.2 f	0.0 k
Annual bluegrass	4.1 ef	1.1 f	2.0 jk

[z]Average of eight turfgrass quality ratings in 2006 (1 to 9 scale, 9 = optimum turf quality). Ratings were taken monthly from April through October (two ratings were taken in May and averaged before analysis). Quality components included density, uniformity, color, and leaf texture.

[y]Average of six turfgrass quality ratings in 2007 (1 to 9 scale, 9 = optimum turf quality). Ratings were taken monthly from May through October. Quality components included density, uniformity, color, and leaf texture.

[x]Percent living stand density determined using grid intersect method in Oct. 2007.

[w]Species mean differences determined by LSMEANS. Means followed by the same letter within a column are not significantly different.

from nitrogen inputs, or environmental conditions that may have affected growth and development. Because this species can be prone to thatch buildup (Ruemmele et al., 2003), future studies should study thatch development under low-input fairway conditions.

After the first year of the study, some bentgrass species showed great promise. Velvet and colonial bentgrass had excellent turf cover and survived well under all traffic treatments. However, all bentgrass species declined in performance throughout the 2007 growing season (Fig. 3).

Velvet bentgrass is known to be prone to thatch buildup, which is a consequence of higher-input management (Skogley, 1975). Samaranayake et al. (2008) found that velvet bentgrasses outperformed many creeping bentgrass cultivars when subjected to traffic stress under higher input fairway conditions. In Wisconsin, Koeritz and Stier (2009) found that ‘Vesper’ velvet bentgrass, the cultivar that was used in our study, had higher turf quality than the commonly used creeping bentgrass cultivars Penncross and L93 (also used in our study) when managed as a lower-input golf green turf (low to moderate N fertilization, mowing heights of 4 mm or less, and simulated foot traffic). It should be noted that their study also included another velvet bentgrass that did not perform as well as the two creeping bentgrass cultivars, which indicates that intraspecific differences should be evaluated. A reduction in thatch levels resulting from high levels of traffic, in either high- or low-input conditions, may give velvet bentgrass a competitive advantage it would not have under nontrafficked conditions. In our study, velvet bentgrass was not severely affected by traffic in the first year of the study; in Year 2, other factors such as reduced drought tolerance compared with fescue species may have prevented velvet bentgrass from performing adequately.

Velvet bentgrass has not performed well in multiple high-input golf greens cultivar evaluations at several research sites in the north–central United States. In some cases, the species does very well in the first year or two of an evaluation and then begins to decline in quality throughout the course of the study (Morris, 2003). The reasons for this decline may be related to nutrient availability, which may have played a role in our study and should be investigated further.

Colonial bentgrass has been suggested as a potential low-input grass for golf course fairways (Brilman, 2001); however, very little has been reported in the literature about its low-input characteristics. DaCosta and Huang (2005) investigated water use of bentgrass species under typical golf course fairway conditions (0.95-cm mowing height, 122 $kg \cdot ha^{-1}$/year N, fungicides as necessary) and found that acceptable quality could be maintained at 80% to 100% ETa (actual evapotranspiration) for colonial bentgrass and at 60% to 80% ETa for both creeping bentgrass and velvet bentgrass, indicating that velvet bentgrass may be a better option for low-input fairways when soil moisture is limiting. In our study, the summer of 2007 had less precipitation than 2006, which may have played a role in the severe decline in turfgrass quality in all three bentgrass species seen from 2006 to 2007.

Conclusions

This research demonstrates that alternative cool-season turfgrass species may be able to

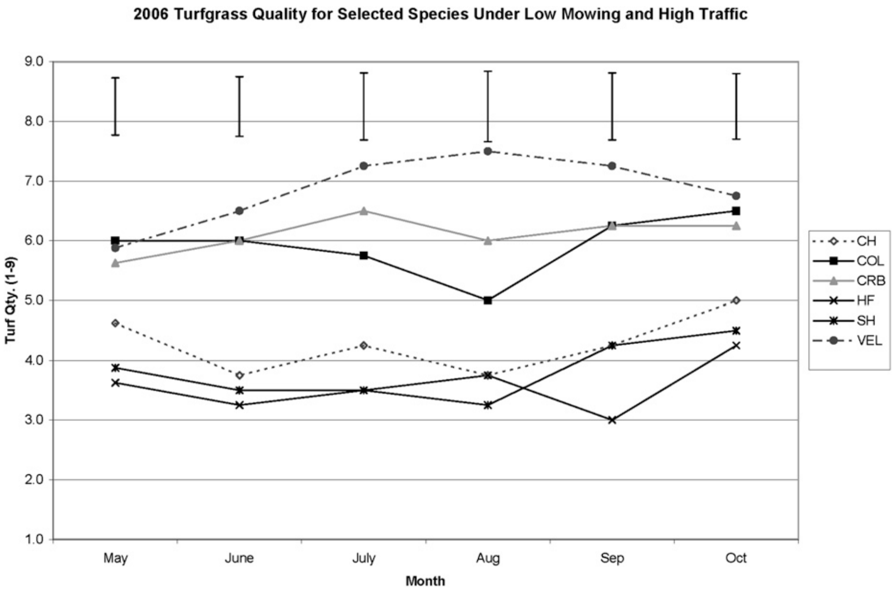

Fig. 2. Monthly turfgrass quality ratings (1.90-cm mowing height, six passes of traffic per week) during 2006 for Chewings fescue (CH), colonial bentgrass (COL), creeping bentgrass (CRB), hard fescue (HF), sheep fescue (SH), and velvet bentgrass (VEL). Rated on a 1 to 9 scale (9 = optimum turfgrass quality). Vertical bars denote least significant difference at the 0.05 level calculated using SE from the differences of least square means (Littell et al., 2002).

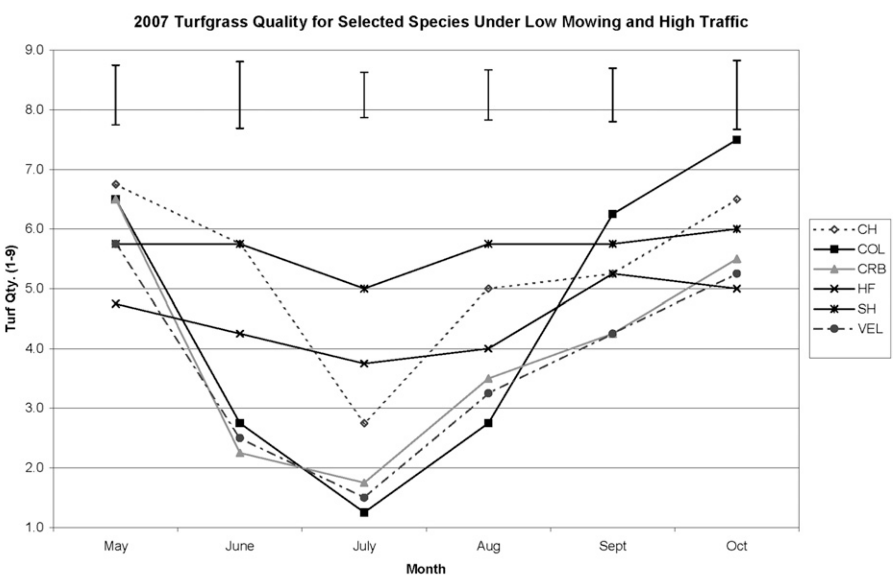

Fig. 3. Monthly turfgrass quality ratings (1.90-cm mowing height, six passes of traffic per week) during 2007 for Chewings fescue (CH), colonial bentgrass (COL), creeping bentgrass (CRB), hard fescue (HF), sheep fescue (SH), and velvet bentgrass (VEL). Rated on a 1 to 9 scale (9 = optimum turfgrass quality). Vertical bars denote least significant difference at the 0.05 level calculated using SE from the differences of least square means (Littell et al., 2002).

perform adequately on golf course fairways under low-input conditions in Minnesota and similar areas. Sheep and Chewings fescue showed the best turfgrass quality after 2 years of growth under low-input conditions, indicating their potential for low-input golf course fairways. Researchers should continue to investigate multiple cultivars of these alternative species, focusing on fine leaf grasses like fine fescue and bentgrass species, to obtain more detailed management recommendations for the low-input, high-stress conditions found on golf course fairways.

Before these species can be recommended for use on golf course fairways in Minnesota and similar regions, additional research is needed to address their longer-term sustainability. Future studies should focus on disease susceptibility, thatch development, long-term wear tolerance, tolerance to chronic drought (using rainout shelters), soil fertility and plant nutrition, and recuperative potential when grown with minimal fertility.

Altering the management of golf courses to meet future challenges will be difficult. For instance, between the years 2002 and 2007, only 9% of surveyed golf courses in the United States had reduced the acreage of irrigated turfgrass, whereas 25% increased irrigated acreage; the primary reason for the increased irrigation was golfer preference for higher-quality playing surfaces (Throssell et al., 2009). In the United Kingdom, researchers found high levels of support for increased biodiversity among golf course superintendents, but there was often a conflict between the desires of the golfers and the needs of a conservation plan that would promote diversity (Hammond and Hudson, 2007). Similarly, we expect that resistance from golfers to new grass species may limit the use of low-input species on golf course fairways.

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