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RESEARCH

Response of Tall Fescue and Kentucky Bluegrass Mixtures to Wear

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ABSTRACT

Tall fescue (TF) [*Schedonorus arundinaceus* (Schreb.) Dumort.] and Kentucky bluegrass (KBG) *Poa pratensis* L.) are often seeded as mixtures in temperate and transition climates. This study assessed the performance and species composition of TF and KBG mixtures containing newer cultivars that were subjected to wear. Individual plots of TF cultivars were established in 2010 on a loam along with 16 mixtures of TF and KBG (TF 90/KBG 10; w/w). Wear was applied during autumn 2011, 2012, and 2013. Plots were evaluated for turfgrass quality, brown patch disease (caused by *Rhizoctonia solani*), and species composition. Data were analyzed using a 5 × 4 × 2 factorial of KBG (none, 'Midnight II', 'Blue Note', A05–361, A05–361), TF ('Falcon V', 'Mustang 4', 'Justice', 'Greenkeeper'), and wear (no wear and wear) arranged in a strip plot design with three replications. Wear reduced quality but had no effect on species composition. Mixing KBG with Falcon V or Mustang 4 TF had no effect on quality after wear compared with either TF alone; however, the quality of Greenkeeper TF was better when mixed with Midnight II or Blue Note KBG, whereas mixing with A05–361 and A05–344 KBG had no effect on quality. Kentucky bluegrass selection had a much greater influence on species composition compared with TF selection. Tall fescue composition was influenced by KBG cultivar and ranged from 37 to 79%. Brown patch severity was decreased in TF mixtures with KBG and was more strongly influenced by KBG cultivar than TF cultivar. Our data indicate that KBG cultivars can dramatically affect TF composition of mixes and brown patch severity, whereas autumn wear does not.

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Abbreviations: TF, tall fescue; KBG, Kentucky bluegrass.

Tall fescue (TF) [*Schedonorus arundinaceus* (Schreb.) Dumort. syn. *Festuca arundinacea* Schreb. syn. *Lolium arundinaceum* (Schreb.) Darbysh.] and Kentucky bluegrass (KBG) (*Poa pratensis* L.) are turfgrass species well adapted for use on athletic fields, golf course roughs, home lawns, and parks throughout the north, central, and transition zones of the United States (Meyer and Funk, 1989). Tall fescue is well known for its persistence during drought in warm climates. Kentucky bluegrass with its vigorous, dense rhizome and root system is useful for sod production and provides excellent recuperative ability in athletic fields (Beard, 1973). Mixtures of TF and KBG initially became popular with sod producers within the transition zone of the United States, providing a broader range of genetic diversity and tolerance to environmental stresses (Bonos and Huff, 2013).

Although turf mixtures comprised of these two species are widely used, there continues to be concern with KBG dominating the mixture, resulting in segregation of TF plants as isolated patches. Juska et al. (1969) reported that a seeded mixture of 'Kentucky 31' TF and common-type KBG produced more clumps of TF compared with TF seeded alone. Brede (1993) found that the tendency for species segregation was more likely when common-type TF was in the mix compared with improved turf types.

Hall (1980) determined that various factors can affect the composition of TF and KBG mixtures. Tall fescue content was reduced at lower mowing heights, under spring N-fertilization programs, and when established during late fall seeding timings. In contrast, Hunt and Dunn (1993) observed that N programming

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and cutting height had little effect on the botanical composition of TF and KBG mixtures. However, the authors concluded that TF cultivars can adapt to close mowing and remain competitive with KBG for several years when managed under nonirrigated conditions.

The turfgrass literature has addressed the impact of TF and KBG seed mixture ratios on species composition and performance. Davis (1958) found that a TF/KBG ratio of 75:25 (w/w) resulted in TF clumping 5 yr after seeding; the author suggested that TF should constitute 90% of the mixture to avoid clumping. Brede (1993) assessed seeding ratios and determined that TF/KBG ratios of 75:25, 90:10, and 95:5 (w/w) tended to produce higher TF shoot counts compared with a TF/KBG ratio of 50:50. Reynolds et al. (2005) examined TF/KBG ratios, including 100:0, 97.5:2.5, 95:5, and 90:10 (w/w), and concluded that these ratios in mixtures had little effect on long-term species composition; however, TF/KBG mixtures of 90:10 and 95:5 may reduce brown patch (caused by *Rhizoctonia solani*) pressure when a susceptible TF cultivar is selected for the mixture. Moreover, addition of KBG to TF improved turf quality compared with TF alone; however, the observed effect was dependent on the KBG and TF cultivar as well as mixing ratio.

Dunn et al. (2002) applied 15 passes of traffic using a Brinkman Traffic Simulator) (Cockerham and Brinkman, 1989) over 2 wk to blends and mixtures of perennial ryegrass (*Lolium perenne* L.), TF, and KBG. Some mixtures containing KBG exhibited more rapid recovery compared with TF after traffic; however, traffic had little effect on species population 1 yr after the traffic was applied. A reduction in brown patch disease occurred where susceptible TF cultivars were mixed with KBG.

Kentucky bluegrass generally produces a denser, finer-textured turf than TF and is less susceptible to brown patch disease, which causes widespread damage to TF in the transition zone (Tredway et al., 2003). Turfgrass breeding efforts continue to develop TF plants with a lower vertical growth rate, greater shoot density, finer leaf blades, and better disease resistance (Bonos and Huff, 2013), which presumably could affect the performance and composition of mixtures containing these improved cultivars. The recent literature is lacking information on the performance of mixtures comprised of newer TF and KBG cultivars. Moreover, there is a dearth of information on the species composition response of TF and KBG mixtures subjected to traffic stresses. The objectives of this study were to assess the performance and species composition of TF and KBG mixtures containing newer cultivars and subjected to autumn wear.

MATERIALS AND METHODS

The trial was conducted on a Nixon loam (fine-loamy, mixed, semi-active, mesic Typic Hapludults) in North Brunswick, NJ, from 2010 through 2014. Plots (1.1 m by 1.5 m) were seeded during September 2010. Four unique TF cultivars (Falcon V, Mustang 4, Justice, and Greenkeeper) and four genetically diverse types of KBG, including the cultivars Midnight II (Compact-Midnight type) and Blue Note (Compact-America type) and the experimental selections A05–361 (Mid-Atlantic ecotype) and A05–344 (Shamrock type), were used to seed 16 mixtures. Tall fescue cultivar selection represented a range of moderate to high turf quality performance (Saxena et al., 2010). Mixtures were seeded at a rate of 218 and 23 kg ha^{-1} of TF and KBG, respectively, which corresponded to a TF/KBG mixing ratio 90:10 (w/w). Beard (1973) indicated that this mixing ratio results in an approximately equal number of TF and KBG seeds. Additionally, each TF cultivar was seeded separately at 436 kg ha^{-1}. This combination of treatments constituted a 5 × 4 factorial of Kentucky bluegrass (including a no Kentucky bluegrass level) and tall fescue arranged within a randomized complete block design and three replications.

Wear was applied as a strip across half of each plot; the other half of each plot did not receive wear treatment. A modified version of the machine described by Bonos et al. (2001) was used to apply wear. The machine was operated at 2.4 km h^{-1} with the paddle axle set at a noncontact rotational velocity of 250 rpm. Wear was applied in autumn 2011, 2012, and 2013 to correspond with play on North American football fields. Fourteen passes with the wear machine were applied during autumn 2011 (four passes per week during 28–30 Sept. and 4–6 Oct. 2011; two passes on 11, 21, and 26 Oct. 2011). Because this wear schedule was deemed too intense, 14 passes (two passes per week) of the wear machine were applied over 7 wk (19 Sept.–1 Nov. 2012 and 18 Sept.–28 Oct. 2013). Every other pass was made in the opposite direction.

The trial was mowed twice per week at 3.8 cm and irrigated when necessary to avoid drought stress during the growing season (i.e., April through November). The trial was fertilized with N at 49 kg ha^{-1} at seeding in 2010 and 181, 114, 152, and 129 kg ha^{-1} yr^{-1} during 2011, 2012, 2013, and 2014, respectively. Soil testing (Mehlich 3 extractant) indicated sufficient soil P and K. Lime was applied in November 2011 to adjust a soil pH of 5.6.

Data Collection

Plots were visually rated by one evaluator for turf quality at the end of each wear period and in May and August of the next year to assess recovery during 2011 through 2014. Plots were rated using a 1 to 9 scale, with 9 representing the most complete, uniform turf cover; 6 was considered acceptable quality. Damage from brown patch disease was visually assessed on 15 Aug. 2012 and 5 July 2013 using a 1 to 9 scale, where 9 represented no disease damage.

Species composition of the plots was assessed by visual identification of 24 selected leaves from each plot in July 2012 and August 2013 and 2014. Plots were approximately divided into thirds, and a device equipped with eight vertically movable tines was positioned in each one-third section of the plots. The tines were then lowered until contact was made with a single turfgrass leaf, which was then identified to species. Species composition assessments were performed immediately after mowing.

Statistical Analysis

Data were analyzed using a 5 × 4 × 2 factorial arrangement of Kentucky bluegrass and tall fescue (vertical strip) and wear (no-wear and wear horizontal strips) arranged in a strip plot design. All data were subjected to ANOVA using the General Linear Model procedure (PROC GLM) in the Statistical Analysis

Table 1. Analysis of variance of turfgrass quality at the end of each autumn wear period and during recovery as affected by wear, tall fescue, and Kentucky bluegrass.

					Recovery					
		End of autumn-wear period			2012		2013		2014	
Main effect	df	2011	2012	2013	May	Aug.	May	Aug.	May	Aug.
		1 to 9 scale†								
Wear (W)										
No wear		7.1	7.6	8.7	5.5	6.3	7.7	7.8	7.9	8.7
Wear		4.2	3.7	6.1	4.6	6.6	5.4	6.9	5.8	8.0
		Mean squares								
Source										
Tall fescue (TF)	3	12***	11***	6.1***	0.9	4.2	6.8***	4.5*	5.7***	3.0***
Kentucky bluegrass (KBG)	4	7.0**	3.9***	1.4	0.8	15***	2.9*	5.1*	23***	1.8**
TF × KBG	12	0.9	0.8*	1.8**	0.8	1.3	1.1	1.5	3.0***	1.5***
REP × TF × KBG	38	1.3	0.4	0.6	0.6	2.1	0.8	1.4	0.7	0.4
W	1	252**	452**	195***	21	2.7	161**	23**	132*	16.1**
TF × W	3	4.2	3.1	0.3	0.7	2.0	1.0	1.4	0.3	0.9
KBG × W	4	7.7	2.3	0.3	0.5	0.5	8.1	0.7	0.9	0.4
TF × KBG × W	12	1.0	0.5	0.5	1.1	0.7	0.8	0.3	0.7	0.3
REP × W	2	2.3	2.1	0.03	1.8	2.3	1.6	0.2	6.8	0.2
Error	38	0.5	0.5	0.3	0.8	1.3	0.8	0.5	0.7	0.2

* Significant at the 0.05 probability level.

** Significant at the 0.01 probability level.

*** Significant at the 0.001 probability level.

† Visual rating, where 9 represents the most complete, uniform turf cover; 6 represents acceptable turfgrass quality.

System software v. 9.3 (SAS Institute). Wear treatments (no-wear and wear) were considered different based on a significant *F* statistic. All other treatment means were separated using Fisher's protected LSD ($p \leq 0.05$) using calculations described by Little and Hills (1978). The amount of sample variance for brown patch disease and species composition attributed to each treatment was determined by comparing the sum of squares for each source with the model sum of squares.

RESULTS AND DISCUSSION

Turfgrass Quality

Not surprisingly, wear reduced turfgrass quality at the end of autumn-wear periods and was the dominant factor compared with the species factors (Table 1). There were species effects on turfgrass quality, but these effects were independent of the level of wear. Thus, relative differences in species responses at the end of wear periods in all years were the same regardless of the level of wear; species responses pooled over both wear levels are discussed herein. Tall fescue and KBG influenced turfgrass quality as main effects at the end of the first autumn-wear period in October 2011 (Table 1). In subsequent years, however, these species factors interacted to influence turfgrass quality at the end of the wear periods (November 2012 and October 2013).

The main effect of TF in October 2011 indicated that mixtures containing Falcon V, Mustang 4, and Justice TF exhibited better turfgrass quality compared with mixtures with Greenkeeper TF (Table 2). The KBG main effect on turfgrass quality at the end of the wear period in 2011 indicated that mixing Midnight II, Blue Note, and A05–344 KBG with TF improved quality compared with TF alone, but mixing A05–361 KBG with TF did not (Table 3). Interactions in the second and third year of the trial (2011 and 2012) indicated that mixture performance depended on

Table 2. Turfgrass quality as affected by the main effect of tall fescue cultivar at the end of the autumn wear period in October 2011 and the recovery period in 2013.

		Recovery in 2013	
Tall fescue	Oct. 2011	May	Aug.
	1–9 scale†		
Falcon V	6.3a‡	6.4b	7.8a
Mustang 4	5.6b	6.5b	7.5ab
Justice	5.9ab	7.2a	7.2ab
Greenkeeper	4.8c	6.0b	6.9b

† Visual rating, where 9 represents the most complete, uniform turf cover; 6 represents acceptable turfgrass quality.

‡ Means followed by the same letter are not significantly different.

Table 3. Turfgrass quality as affected by the main effect of Kentucky bluegrass cultivar at the end of the autumn wear period in October 2011 and the recovery period in 2012 and 2013.

		Recovery		
Kentucky bluegrass	Oct. 2011	Aug. 2012	May 2013	Aug. 2013
	1–9 scale†			
None (tall fescue alone)	4.8b‡	6.4bc	7.0a	7.3ab
Midnight II	6.0a	7.6a	6.1c	7.9a
Blue Note	6.2a	6.6b	6.7ab	7.6a
A05–361	5.5ab	6.3bc	6.5abc	7.2ab
A05–344	5.6a	5.5c	6.2bc	6.7b

† Visual rating, where 9 represents the most complete, uniform turf cover; 6 represents acceptable turfgrass quality

‡ Means followed by the same letter are not significantly different

Table 4. Turfgrass quality at the end of the autumn wear periods in 2012 and 2013 as affected by the interaction of tall fescue and Kentucky bluegrass.

Kentucky bluegrass	Tall fescue (Nov. 2012)				Tall fescue (Oct. 2013)			
	Falcon V	Mustang 4	Justice	Greenkeeper	Falcon V	Mustang 4	Justice	Greenkeeper
	1–9 scale†							
None (tall fescue alone)	6.7aA‡	5.8abB	5.7abB	4.3bC	8.2aA	7.7aAB	7.3abB	6.2bcC
Midnight II	6.7aA	6.3aA	6.3aA	6.0aA	7.5aA	7.5aA	8.0aA	8.0aA
Blue Note	6.0aA	5.5bAB	5.2bB	5.3aAB	8.0aA	7.5aAB	7.2bB	7.5aAB
A05–361	6.0aA	5.8abA	5.5bA	4.3bB	7.8aA	7.7aAB	7.0bBC	6.7bC
A05–344	6.2aA	5.5bAB	5.3bB	4.3bC	7.8aA	7.5aA	7.5abA	5.7cB

† Visual rating, where 9 represents the most complete, uniform turf cover; 6 represents acceptable turfgrass quality.

‡ Means followed by the same letter (lowercase: columns; uppercase: rows) within a sampling date are not significantly different.

the cultivars of each species (Table 4). Mixing KBG with Falcon V or Mustang 4 TF had no effect on turfgrass quality compared with either TF alone at the end of the wear period in both years (Table 4). Similarly, turfgrass quality of Justice TF alone was similar to or better than mixes with KBG; however, the mix with Midnight II KBG had better quality than mixes with Blue Note and A05–361 KBG in 2012 and 2013 and A05–344 KBG in 2012. Conversely, the turfgrass quality of Greenkeeper TF was better when mixed with Midnight II or Blue Note KBG, whereas mixing with A05–361 and A05–344 KBG had no effect on quality. Dunn et al. (2002) observed that mixing TF and KBG often resulted in superior turf quality compared with TF alone. It is important to note, however, that our research examined the performance of individual cultivars of TF and KBG seeded as two-way mixtures; whereas Dunn et al. (2002) studied mixtures comprised of two- and three-way blends of the two species.

In the absence of KBG, Falcon V TF exhibited the best turfgrass quality in 2012 and was among TF cultivars with the best turfgrass quality in 2013, and Greenkeeper TF had the poorest turfgrass quality after wear in both years (Table 4). Turfgrass quality responses in our study indicate that mixing KBG with better performing cultivars of TF may have limited benefits to turfgrass quality. Previous research has indicated that TF cultivar affects the performance of mixtures with KBG. Reynolds et al. (2005) found that turfgrass quality response to mixing KBG with TF was better when the TF cultivar had greater brown patch susceptibility. Additionally, Brede (1993) reported that TF cultivar (Pixie [low-growing, high-density type], Arid [improved, intermediate type], and Southern Cross [open, forage type]) had a more profound effect on the turfgrass quality of mixes with KBG than the effect of KBG cultivars (NuStar [dense, improved type] and S-21 [common type]).

Turfgrass quality during the first recovery period (2012) was not significantly affected by wear, indicating that recovery was rapid and complete (Table 1). Recovery of turfgrass quality after subsequent wear periods, however, was reduced by wear, and this effect persisted into August of 2013 and 2014, indicating that recovery, although acceptable in quality, was not complete by the next wear period (Table 1). There were species effects on turfgrass quality during recovery, but, similar to quality at the end of wear periods, these effects were independent of the level of wear. Thus, relative differences in species responses during recovery in all years were the same regardless of the level of wear; species responses pooled over both wear levels will be discussed.

Similar to the wear factor, the species factors had little effect on turfgrass quality during recovery in 2012, except that mixes with Midnight II KBG had better turfgrass quality than TF alone in August (Table 3). During the second recovery period (2013), both species affected turfgrass quality (Table 1). Plots with Justice TF had better turfgrass quality than plots of the other TF cultivars in May, and the quality of plots with Falcon V TF was better than plots with Greenkeeper TF in August (Table 2). The KBG effect on quality during recovery in 2013 differed between May and August (Table 3). None of the mixes with KBG improved recovery (quality) over TF alone in May; in fact, mixes with Midnight II and A05–344 KBG were slower to recover (poorer quality) than TF alone in May. Additionally, mixes with Midnight II KBG were slower to recover than mixes with Blue Note KBG. By August, all mixes with KBG were performing similarly to TF alone, but differences among the mixes were evident: mixes with A05–344 KBG had poorer quality than mixes with Midnight II and Blue Note KBG.

Species interactions during the recovery period of the third year of the trial (2014) indicated that mixture performance had become dependent on the cultivars of each species (Table 5). Midnight II KBG mixed with the better TF cultivars (Falcon V, Mustang 4, Justice) had poorer turfgrass quality than those TF cultivars alone in May 2014 (Table 5). Similarly, Blue Note KBG mixed with Mustang 4 or Justice TF had poorer turfgrass quality than those TF cultivars alone in May 2014. Greenkeeper TF, the poorest performing TF, was the only TF not affected by mixing with KBG in May 2014. Compact-Midnight type cultivars are known to exhibit late spring green-up and improved heat tolerance (Park et al., 2005); thus, it is not surprising that mixes with Midnight II KBG exhibited poorer quality in May relative to performance in August

Table 5. Turfgrass quality during recovery in 2014 as affected by the interaction of tall fescue and Kentucky bluegrass.

Kentucky bluegrass	Tall fescue (May 2014)				Tall fescue (Aug. 2014)			
	Falcon V	Mustang 4	Justice	Greenkeeper	Falcon V	Mustang 4	Justice	Greenkeeper
	1–9 scale†							
None (tall fescue alone)	8.0aA‡	8.0aA	8.2aA	6.2aB	9.0aA	8.7aAB	8.2aBC	8.0bC
Midnight II	3.8bB	5.8cA	5.3cA	5.8aA	8.2bB	8.5abAB	8.3aAB	8.8aA
Blue Note	7.5aA	6.5bcAB	6.7bAB	6.3aB	9.0aA	8.3abB	8.7aAB	8.8aAB
A05–361	7.2aAB	7.5abAB	8.0aA	6.7aB	8.8aA	8.0bB	8.2aB	7.8bB
A05–344	7.3aAB	7.7aA	8.3aA	6.5aB	9.0aA	8.0bB	8.3aB	6.7cC

† Visual rating, where 9 represents the most complete, uniform turf cover; 6 represents acceptable turfgrass quality.

‡ Means followed by the same letter (lowercase: columns; uppercase: rows) within a sampling date are not significantly different.

2014. These data suggest that Midnight II KBG can exert a strong influence over mixture performance.

By August 2014, many plots exhibited excellent turf quality. Turf quality of Greenkeeper KBG was the only TF strongly influenced by mixing with KBG in August; mixing with Midnight II and Blue Note KBG produced better quality, whereas mixing with A05–344 KBG resulted in poorer quality than Greenkeeper TF alone. Additionally, slightly lower turf quality was observed in mixes of Midnight II KBG with Falcon V TF and A05–361 or A05–344 KBG with Mustang 4 TF compared with the respective TF alone in August. Despite these differences, plots exhibited very good turfgrass quality.

Whereas the previous studies of Brede (1993) and Reynolds et al. (2005) found that KBG cultivar was not a consistent factor affecting the turfgrass quality of mixes with TF, our data indicate that KBG and TF cultivars can influence turfgrass quality of mixes. Over the time scale of years, the species effects in our trial became more complex (species interaction), indicating that predicting the performance of TF mixed with KBG was dependent on the characteristics of the cultivars of both species in the mixture. This is likely attributable to the differences in phenotypes of KBG (cultivars and experimental selections) used in our study compared with those studied by Brede (1993) and Reynolds et al. (2005).

Table 6. Brown patch severity as affected by tall fescue, Kentucky bluegrass, and wear in 2012 and 2013.

Main effects	df	Aug. 2012	July 2013
		1–9 scale†	
Kentucky bluegrass (KBG)			
None (tall fescue alone)		6.0b	4.0c
Midnight II		7.9a	7.8a
Blue Note		7.2a	7.0a
A05–361		6.3b	5.5b
A05–344		6.1b	5.0b
Wear (W)			
No wear		7.5	5.2
Wear		5.9	6.5
		Mean squares	
Source			
TF	3	2.3	3.2
KBG	4	17***	56***
TF × KBG	12	1.9	6.1**
REP × TF × KBG	38	1.6	1.9
W	1	80**	52*
TF × W	3	0.9	1.0
KBG × W	4	1.8	10
TF × KBG × W	12	0.5	2.8
REP × W	2	0.6	0.6
Error	38	0.9	1.4

* Significant at the 0.05 probability level.

** Significant at the 0.01 probability level.

*** Significant at the 0.001 probability level.

† Visual rating, where 9 represents no observed brown patch disease.

Brown Patch Disease

Kentucky bluegrass was the dominant species factor affecting the severity of brown patch disease severity on mixes in both years (Table 6). Similar to turfgrass quality, the effect of KBG became dependent on the cultivar of TF in the mix (species interaction) as the study progressed (July 2013). Although wear influenced the disease response, species effects on brown patch disease were independent of the level of wear (no interaction). Thus, relative differences in species responses were the same regardless of the level of wear; species responses pooled over both wear levels are discussed herein. Brown patch disease response to wear during recovery periods was inconsistent; wear increased disease in 2012 but decreased disease in 2013 (Table 6). Although the reason for this inconsistency is not understood, there is an opportunity for an assessment of the potential relationship between traffic stresses and brown patch disease.

Mixes with Midnight II and Blue Note KBG had less damage caused by brown patch compared with tall fescue alone and mixes with A05–361 and A05–344 KBG in 2012 and 2013 (Table 6). Mixes with A05–344 and A05-361 KBG did not reduce the damage from disease compared with TF alone in 2012.

The interaction in 2013 also indicated that all mixes with Midnight II KBG had less damage caused by brown patch than the individual TF cultivars alone (Table 7). Blue Note KBG mixed with most TF cultivars had less damage caused by brown patch than the individual TF cultivars; Blue Note KBG did not improve brown patch tolerance when mixed with Falcon V TF. Disease effects on mixes with A05–361 and A05–344 KBG were strongly

Table 7. Brown patch severity as affected by the interaction of tall fescue and Kentucky bluegrass in July 2013.

Kentucky bluegrass	Tall fescue			
	Falcon V	Mustang 4	Justice	Greenkeeper
	1–9 scale†			
None	5.7bA‡	5.2cA	2.8cB	2.3dB
Midnight II	8.0aA	7.3aA	7.5aA	8.3aA
Blue Note	6.2bA	7.0abA	7.7aA	7.2abA
A05–361	5.8bAB	4.8cB	4.8bB	6.5bA
A05–344	5.7bA	5.5bcAB	4.8bAB	4.0cB

† Visual rating, where 9 represents no observed brown patch disease.

‡ Means followed by the same letter (lowercase: columns; uppercase: rows) within a sampling date are not significantly different.

dependent on the TF cultivar. Cultivars A05–361 or A05–344 KBG mixed with Falcon V and Mustang 4 TF did not reduce damage compared with these tall fescue cultivars alone, whereas A05–361 or A05–344 KBG mixed with Justice and Greenkeeper TF did reduce damage compared with these TF cultivars alone. Thus, Midnight II and Blue Note KBG had a strong positive influence on the brown patch tolerance of mixtures with TF compared with A05–361 and A05–344 KBG. A05–361 and A05–344 KBG only improved brown patch tolerance of TF cultivars (Justice and Greenkeeper) that were more susceptible to the disease, and the improvement in tolerance was less than that provided by Midnight II and Blue Note KBG.

As previously reported, TF susceptibility to brown patch was reduced by mixing with KBG (Dunn et al., 2002; Reynolds et al., 2005). Whereas Reynolds et al. (2005) found that mixture susceptibility to brown patch was largely governed by the TF cultivar, our research indicates that mixture susceptibility is more strongly influence by KBG cultivar. The KBG factor explained 24 and 43% of the total variation in brown patch susceptibility during 2012 and 2013, respectively (data not shown), whereas the TF factor did not significantly affect the disease response other than the within the interaction in 2013 (Table 6).

Species Composition

Wear during autumn had no effect on TF population of mixes in any of the 3 yr of this trial (Table 8). We hypothesized that wear would have shifted species composition, lowering TF population in favor of greater KBG given the rhizomatous growth and presumed greater postwear recuperative potential of KBG compared with TF. Our results are consistent with the report of Dunn et al. (2002), who reported that a 2-wk traffic event in 1 yr of a trial had little effect on species composition.

Species main effects were independent of each other and also did not interact with wear. Moreover, the KBG factor explained 86, 82, and 82% of the total variation in TF population during 2012, 2013, and 2014, respectively, whereas the TF factor explained only 1, 2, and 2% during 2012, 2013, and 2014, respectively (data not shown). Brede

Table 8. Tall fescue populations of species mixtures as affected by tall fescue, Kentucky bluegrass, and wear in 2012, 2013, and 2014.

Main effects	df	July 2012	Aug. 2013	Aug. 2014
		%†		
Tall fescue (TF)				
Falcon V		71	66a	71a
Mustang 4		70	65a	66ab
Justice		71	67a	70a
Greenkeeper		65	58b	61b
Kentucky bluegrass (KBG)				
None		100a	100a	100a
Midnight II		48c	36d	37c
Blue Note		50c	46c	44c
A05–361		72b	69b	75b
A05–344		75b	69b	79b
		Mean squares		
Source				
TF	3	193	524*	592*
KBG	4	10,730***	14,725***	16,132***
TF × KBG	12	92	176	284‡
REP × TF × KBG	38	87	134	160
W	1	177	122	293
TF × W	3	18	201	63
KBG × W	4	210	80	123
TF × KBG × W	12	23	181	132
REP × W	2	174	271	97
Error	38	67	87	66

* Significant at the 0.05 probability level.

*** Significant at the 0.001 probability level.

† Species composition of plots was assessed by visual identification of randomly selected tillers from each plot.

‡ Significant at the $p = 0.09$ probability level.

(1993) also observed that both TF and KBG cultivar affected stand composition, but the influence of the KBG factor did not appear to be as strong as observed in our trial.

Tall fescue populations were much smaller in mixes that contained Midnight II and Blue Note KBG than A05–361 and A05–344 KBG regardless of TF cultivar in all 3 yr (Table 8). By the end of the trial, TF composition was 37 and 44% in Midnight II and Blue Note KBG mixes, respectively, and mixes with A05–361 and A05–344 KBG had 75 and 79% TF, respectively. These differences were attributed to overall better turfgrass quality and competitiveness of Midnight II and Blue Note KBG compared with A05–361 and A05–344 KBG. Compact-Midnight type cultivars are capable of producing excellent turfgrass quality (Park et al., 2005). Similarly, Blue Note was among the entries with the best multiyear (2006–2010) average turfgrass quality across five locations in the northeastern United States in the 2005 National Turfgrass Evaluation Program (NTEP) Kentucky Bluegrass Test (NTEP, 2016). Brede (1993) also observed that the percentage of TF in a turfgrass stand was reduced when mixed with an improved, more aggressive KBG cultivar compared with a common-type KBG.

The main effect of TF did not influence species composition in 2012 and was small relative to the main effect of KBG in 2013 and 2014 (Table 8). Tall fescue populations were no more than 10% greater in Falcon V, Mustang 4, and Justice TF mixes compared with Greenkeeper TF mixes. Brede (1993) found that Arid TF exhibited greater competition with KBG compared with the TF cultivars Pixie and Southern Cross. More recently, Reynolds et al. (2005) determined that Wolfpack TF retained greater TF composition when mixed with KBG compared with Coronado TF mixes and was attributed to the greater brown patch susceptibility of Coronado.

Species population data suggest that TF and KBG composition of mixtures may be changing over time. Tall fescue composition averaged 48% when mixed with Midnight II KBG in 2012, whereas TF contained only 37% of mixtures with Midnight II KBG by 2014 (Table 8). Moreover, the TF × KBG interaction was significant at $p = 0.09$ in August 2014. Tall fescue and KBG interaction means indicated that Greenkeeper TF was only 24% of the mixture with Midnight II KBG, whereas Justice TF was 49% of the mixture with Midnight II KBG (data not shown). Furthermore, the interaction indicated that all TF cultivars dominated the composition (75–83%) of mixtures with the less competitive A05–344 KBG.

Turfgrass quality and brown patch data appear to support this trend. The TF × KBG interaction for turfgrass quality was not significant at the end of autumn wear in 2011 but was significant after wear in 2012 ($p \leq 0.05$) and 2013 ($p \leq 0.01$) (Table 1). Although the TF × KBG interaction was not significant for turfgrass quality during recovery in 2012 and 2013, the interaction was significant in May and August 2014. Moreover, the ANOVA of brown patch data indicated no significant TF × KBG interaction in August 2012; however, the interaction was significant in 2013 (Table 6). Mixing Midnight II KBG with Greenkeeper TF resulted in dramatically less brown patch compared with Greenkeeper TF alone, an indication of the much greater impact Midnight II KBG had on this mixture by July 2013 (Table 7).

Previous studies of management effects on species composition of TF and KBG mixtures have led to conflicting conclusions. For example, Hall (1980) found that mowing height and N fertilization affected TF population, whereas Hunt and Dunn (1993) reported that N and mowing height had little effect. Our results, along with those reported by Brede (1993) and Reynolds et al. (2005), indicate that species composition of TF mixtures with KBG is affected consistently by cultivars of TF and KBG. Thus, turfgrass sod producers and managers should recognize that the cultivars of both species can strongly influence the performance and species composition of TF and KBG mixtures. Our data indicate that KBG cultivars capable of producing very high quality turf can reduce TF composition of mixes well below 50% and can reduce stand susceptibly to brown patch when mixed with TF. Additionally, traffic during autumn did not influence species composition.

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