HortScience 48(4):493–500. 2013.

Impact of Hybrid Bluegrass and Tall Fescue Seeding Combinations on Brown Patch Severity and Weed Encroachment

Matthew A. Cutulle[1,6] and Jeffrey F. Derr[2]
Department of Plant Pathology, Physiology, and Weed Sciences, Virginia Tech, Hampton Roads Ag. Res. & Ext. Center, Virginia Beach, VA 23455

David McCall[3]
Department of Plant Pathology, Physiology, and Weed Sciences, Virginia Tech, Glade Road Research Center, Blacksburg, VA 24061

Brandon Horvath[4]
Plant Science Department, 252 Ellington Plant Science Building, 2431 Joe Johnson Drive, Knoxville, TN 37996

Adam D. Nichols[5]
Department of Plant Pathology, Physiology, and Weed Sciences, Virginia Tech, Hampton Roads Ag. Res. & Ext. Center, Virginia Beach, VA 23455

Additional index words. turfgrass polystand, brown patch, turfgrass disease management, turf weed management

Abstract. **Tall fescue (*Festuca arundinacea*) and hybrid bluegrass (*Poa pratensis* L. × *Poa arachnifera*) can both be successfully grown in the transition zone of the United States. However, each grass has limitations. Tall fescue is susceptible to the fungal pathogen *Rhizoctonia solani*, whereas slow establishment and susceptibility to weed infestations limit hybrid bluegrass. Previous studies have shown the benefits of combining kentucky bluegrass with tall fescue in seeding mixtures. Research was conducted to evaluate the impact of two seeding combinations of hybrid bluegrass and tall fescue (one combination seeded at a 1.9:1 seed count ratio favoring tall fescue, the other combination seeded at a 1:1.8 seed count ratio favoring hybrid bluegrass) as well as monocultures of the species on turfgrass cover, weed species infestation, brown patch disease severity caused by *R. solani*, sod strength and species ecology. The seeding combinations had lower weed density during establishment and greater turf cover than the monoculture of hybrid bluegrass. The monoculture of tall fescue was subjected to more brown patch disease than the seeding combinations during and after the first year of establishment. Brown patch infestations likely reduced tall fescue cover and led to a species shift favoring hybrid bluegrass in the seeding combinations based on tiller count and weight data. Seeding combinations of tall fescue and hybrid bluegrass are beneficial from an epidemiological perspective because they reduce disease and weed infestations compared with monocultures of either species. From an agronomic perspective, the seeding combination favoring tall fescue provided the densest turf, whereas the seeding combination favoring hybrid had the greatest sod strength. Chemical name used: clopyralid (3,6 dichloropyridine-2 carboxylic acid)**

Turfgrasses make up a majority of commercial and residential landscapes in the United States. Sixteen million hectares of turfgrass is irrigated each year, which makes it the most irrigated crop when all species are taken into consideration (The Lawn Institute, 2010). Additionally, an estimated $2.8 billion U.S. of gasoline, $700 million U.S. of pesticides, and $5.2 billion U.S. of fossil fuel-derived fertilizers are used to manage lawns (The Lawn Institute, 2010). Turfgrasses provide erosion control, quicken restoration of disturbed soils, sequester CO_2, dissipate urban heat, and reduce noise and visual pollution (Beard and Green, 1994). Individual homeowners manage many small areas of turfgrass. Therefore, adaptations of proper cultural practices are important to optimize the environmental, economic, use, and aesthetic impact of turfgrasses in home lawns. The most important cultural practice might be turfgrass selection, particularly when the home lawn is managed in the transition zone of the United States, which stretches from central New Jersey to the panhandle of Texas. Two cool-season turfgrasses that have desirable agronomic qualities and can be grown in the transition zone are tall fescue and hybrid bluegrass.

Tall fescue [*Festuca arundinacea* Shreb synonym *Schedonorus phoenix* (Scop.) Holub] is the dominant cool-season perennial grass in the United States (Ju et al., 2006). Tall fescue provides great use as a lower maintenance turfgrass in the transition zone compared with other cool-season grasses. The plant's well-developed root system, modest nitrogen requirements, and aesthetically pleasing dark green color make it a popular choice for home lawns, parks, golf course roughs, and other low-traffic situations. However, the major limiting factor to tall fescue's success as a turf in the transition zone is its susceptibility to the fungal pathogen *R. solani* Kuhn (Piper and Coe, 1919), which causes the disease brown patch in the summer months. Brown patch is particularly problematic when nighttime temperatures average 21 °C, relative humidity exceeds 85%, and the leaf wetness duration period is prolonged (Couch, 1995; Fidanza et al., 1996; Gross et al., 1998). No tall fescue cultivars are immune to *R. solani*; thus, applications of fungicides are necessary to effectively reduce brown patch spread (Yuen et al., 1994). Brown patch infestations not only decrease the aesthetic appearance of tall fescue, but can thin the turf stand, which may lead to infestation of undesirable weed species (Ferrell et al., 2003). Tall fescue's bunched-type growth habit limits recovery from brown patch infection (Turgeon, 1999).

Hybrid bluegrass may be an alternative cool-season grass to grow in the transition zone. Hybrid bluegrass (*Poa pratensis* L. × *Poa arachnifera* Torr.) was created by crossing kentucky bluegrass (*Poa pratensis* L.) and texas bluegrass (*Poa arachnifera* Torr.) (Read et al., 1999). This cross results in a grass that has the agronomic qualities of kentucky bluegrass but the heat and drought characteristics of texas bluegrass. Hybrid bluegrass has a rhizomatous growth habit; thus, it exhibits better recuperative ability than a bunch-type grass like tall fescue and can fill in bare spots in a turfgrass stand. Hybrid bluegrass exhibits superior range in adaption compared with traditional cool-season grass cultivars; it can be grown in lawns as far south as Atlanta and Dallas. The rhizome system allows for turf recovery with less need for reseeding compared with tall fescue (Turgeon, 1999). Hybrid bluegrass' shade tolerance compares with tall fescue and it is resistant to brown patch. In one study, 'Thermal Blue Blaze' hybrid bluegrass exhibited greater visual quality than traditional kentucky bluegrass and tall fescue in conditions of high temperature, drought, and salinity stress (Suplick-Ploense et al., 2002). Gross photosynthesis was reduced 21% in 'Thermal Blue' hybrid bluegrass, 30% in kentucky bluegrass, and 27% in tall fescue when plants were subjected to high temperature and drought conditions (Su et al., 2007). Electrolyte leakage was significantly less in hybrid bluegrass than kentucky bluegrass or tall fescue. Hybrid bluegrass use is limited by

Received for publication 4 Dec. 2012. Accepted for publication 25 Feb. 2013.
We thank Dr. Mike Goatley, Department of Crop and Soil Science, Virginia Tech, for providing the sod stretcher.
[1]Former Graduate Research Assistant. Current address: Postdoctoral Researcher, Plant Science Department, 252 Ellington Plant Science Building, 2431 Joe Johnson Drive, Knoxville, TN 37996.
[2]Professor.
[3]Research Associate.
[4]Assistant Professor.
[5]Research Assistant.
[6]To whom reprint requests should be addressed; e-mail mcutulle@utk.edu.

its slow establishment period, higher nitrogen requirements, and susceptibility to diseases such as dollar spot (*Sclerotinia homeocarpa*) F.T. Bennett and summer patch (*Magnaporthe poae*) Landschoot and Jackson (Serensits et al., 2011). Mixing hybrid bluegrass with tall fescue may increase the quality of the turf stand when compared with individual monocultures of these species.

Seeding mixtures of different species increase the genetic variability of a turfgrass stand (Donald, 1963). Environmental stresses such as drought, nutrient availability, salinity, cold and heat tolerance, and competition from weeds have varying impacts on individual species. Proper selection of species for seeding combinations should focus on alleviating potential damage from pathogens, insects, weeds, drought, or shade. A grass species that is resistant to a specific disease should be mixed with a grass species that is resistant to a different disease. From an epidemiological perspective, polystands of different plant cultivars or species reduce the rate that a disease spreads. Mitchell et al. (2002) demonstrated that increasing species diversity in grasslands decreased pathogen load. The best defense against a ubiquitous pathogen such as *R. solani* might be to keep a polystand as close to a 1:1 sensitive grass to resistant grass species ratio. A study by Dunn (2001) documented the reduction in brown patch and improved quality seen in mixtures of kentucky bluegrass and tall fescue when compared with the monoculture of tall fescue. However, another study by Hunt and Dunn (1993) showed that mixing tall fescue with kentucky bluegrass and perennial ryegrass (*Lolium perenne* L.) did not impact disease incidence when compared with a monoculture of tall fescue. Therefore, more information is needed on different kinds of seeding combinations to fully elucidate the epidemiological impact of multiturfgrass systems.

Establishment period may be an important consideration when selecting mixtures of turfgrass species. Grasses that are slow to establish might be more susceptible to weed infestations and should then be mixed with a turfgrass species that establishes quickly. The growth habit of grasses should be considered as well. For example, tall fescue has good wear tolerance but exhibits a bunch-type growth habit, which limits its recovery from excessive traffic or thinning resulting from disease. Mixing in a rhizomatous grass such as hybrid bluegrass or kentucky bluegrass with tall fescue would ideally result in a polystand that has good wear tolerance and recuperative ability. Agronomic traits of the two grasses are important. Turfgrass species with contrasting colors would not be aesthetically pleasing in a polystand. The grasses should be able to tolerate similar mowing regimes and fertilizer application (Davis, 1958). Mixing turf-type tall fescue with hybrid bluegrass has potential to become a successful polystand. Although tall fescue is a bunched-type species, turf-type tall fescues establish quickly and could serve as a nurse crop for the slower establishing hybrid bluegrass. Therefore, it is important to evaluate how combinations of tall fescue and hybrid bluegrass compare with monocultures when evaluating disease pressure, weed infestations, and turfgrass density over multiple years. Research was conducted to evaluate the impact of seeding rate combinations of 'Greenkeeper' tall fescue and 'Thermal Blue Blaze' hybrid bluegrass on turf species dynamics, weed species encroachment, disease severity, and sod strength.

Materials and Methods

The experiments were conducted at the Virginia Tech Hampton Roads Agricultural Research and Extension Center located at 1444 Diamond Springs Road, Virginia Beach, VA 23451. The first study was established in Oct. 2006 and was repeated in an adjacent area in Oct. 2008. The soil type at the site was a Tetotum loam (fine-loamy, mixed, thermic Aquic Hapludults) that contained 3.3% organic matter and had a pH of 5.2. Plots were 4.8 m × 4.8 m and there were four seeding treatments: 1) 302 $kg{\cdot}ha^{-1}$ 'Greenkeeper' (Scotts, Marysville, OH) tall fescue; 2) 110 $kg{\cdot}ha^{-1}$ 'Thermal Blue Blaze' (Scotts) hybrid bluegrass; 3) 264 $kg{\cdot}ha^{-1}$ 'Greenkeeper' with 29 $kg{\cdot}ha^{-1}$ 'Thermal Blue Blaze'; and 4) 151 $kg{\cdot}ha^{-1}$ 'Greenkeeper' with 55 $kg{\cdot}ha^{-1}$ 'Thermal Blue Blaze'. The seed count ratio in Treatment 3 was 1.9 tall fescue (TF): 1.0 hybrid bluegrass (HB) and will be referred to as 1.9TF:1HB. The seed count ratio in Treatment 4 was 1.0 tall fescue (TF):1.8 hybrid bluegrass (HB) and will be referred to as 1TF:1.8HB. Each treatment was replicated four times in a randomized complete block design. All plots were regularly mowed at 10 cm twice per week and received 171 kg of nitrogen applied per hectare annually with the application being split between October and March. The fertilizer N–P–K ratio was 19–0–19 and contained 2.5% ammonical nitrogen, 3.6% water-insoluble, 4.2% urea nitrogen, 8.7% other water-soluble nitrogen, and 19% K_20 (Lebanon Turf, Lebanon, PA). Plots were irrigated as needed to sustain active growth. No preemergence herbicides or fungicides were applied to either trial to simulate low-input maintenance practices. The postemergence herbicide clorpyralid was applied 1.5 years after establishment for white clover (*Trifolium repens*) control at a rate of 0.2 kg a.i./ha.

Tiller counts of hybrid bluegrass and tall fescue species were taken biannually for three years in March and October using a circular cup cutter 1 dm in diameter. Three samples were taken from each plot for the tiller counts. Tiller weights were recorded 2.5 years after establishment. The tiller weights presented are the sum of all tillers in a 1-dm diameter sample. Sod strength was measured in Nov. 2010 in the first study and in Mar. 2011 for the second study. Three square pieces of sod 0.5 m × 0.5 m wide and 5 cm in depth were harvested from each plot. The pieces of sod were placed on a custom-made machine where a piece of sod is secured between stationary and mobile frames. The mobile frame is attached to a push/pull gauge scale and when engaged, the force required to tear the sod in half is recorded. Periodical estimations of weed species percent cover, turfgrass percent cover, and disease severity ratings were estimated visually as a percentage of the entire plot for four years. Smooth crabgrass (*Digitaria ischaemum* Schreb. ex Muhl) was rated in September and purple deadnettle (*Lamium purpureum* L.) was rated in November annually. Turfgrass cover was rated annually in November. Brown patch severity was rated annually in August.

Data analysis. Data were subjected to analysis of variance (ANOVA) ($\alpha = 0.05$) using mixed model methodology (Statistical Analysis software, Version 9.1, Cary NC). Fisher's protected least significant difference test was used for mean separation. Analysis of variance was conducted separately for each individual trial because of the longer analysis in the first compared with the second trial. The first study was analyzed over five years, whereas the second study was analyzed over three years. The main plot factor of seeding treatment was considered a fixed effect and replications were considered random. Data for all visual ratings were subjected to arcsin transformation before ANOVA. Interpretations were not different from non-transformed data and normality was acceptable based on the Shapiro-Wilk diagnostic; thus, non-transformed means are presented for clarity.

Results and Discussion

Turfgrass cover. In Study 1, seeding only hybrid bluegrass resulted in 40% percent cover in Nov. 2006 (Table 1). The tall fescue monoculture and the seeding combinations had significantly more turf cover during the first month of establishment than the hybrid bluegrass monoculture. One year after seeding, the monoculture of hybrid bluegrass had 58% cover, which was significantly less cover compared with the other seeding treatments (Table 1). One year after seeding, the monoculture of tall fescue and the two seeding combinations had ≈90% turf cover. Two

Table 1. Impact of monoculture and combination seeding treatments of tall fescue and hybrid bluegrass on visual percent turfgrass cover ratings taken in November of Trial 1 (seeded Oct. 2006).

	Percent cover				
Seeding treatment	2006[z]	2007	2008	2009	2010
Tall fescue	70 a	91 a	86 a	65 b	44 a
Hybrid bluegrass	40 b	58 b	72 b	68 b	43 a
Tall fescue:hybrid bluegrass 1.9:1	69 a	92 a	89 a	87 a	70 a
Tall fescue:hybrid bluegrass 1:1.8	61 a	91 a	85 a	84 a	55 a

[z]Means within a column followed by the same letter are not significantly different according to the Fisher's protected least significant difference test at the 0.05 level.

years after seeding, there was still lower cover in the monoculture of hybrid bluegrass compared with the other seeding treatments. Hybrid bluegrass is slow to establish; thus, the low initial cover rating is expected. Weed competition probably limited establishment of hybrid bluegrass during the first year of the study. However, because it grows by rhizomes, hybrid bluegrass can form a dense competitive turf after establishment. Three years after establishment, the lowest turfgrass cover was observed in plots seeded with only tall fescue. The reduction in tall fescue cover may be attributed to brown patch infestations reducing turf cover over time. Because tall fescue exhibits a bunched-type growth habit, it is unable to quickly recover when the stand has been thinned. Percent turfgrass cover in the monoculture plots was 65% in tall fescue and 68% in hybrid bluegrass. Seeding combination 1.9TF:1HB and 1TF:1.8HB had 87% and 84% cover, respectively, three years after establishment, which was significantly greater than the percent cover in the monoculture plots.

Four years after establishment, there were no significant differences among seeding treatments for percent turfgrass cover, although numerically the seeding combinations had greater turfgrass cover compared with both monocultures (Table 1). Nevertheless, the percent turfgrass cover in the seeding combinations at the end of the study was unacceptable as a result of weed encroachment. More inputs such as preemergence herbicide applications may increase the benefits of growing two different HB and TF polystands in the transition zone.

Similar results were observed in the second study. Turfgrass cover in plots seeded with the monoculture of hybrid bluegrass was lower than in the other three treatments in 2008, 2009, and 2010 (Table 2). One month after seeding, turf cover was similar in the monoculture of tall fescue and the two seeded combinations. However, at one and two years after seeding, turf cover was higher in the seeding combinations compared with the monoculture of tall fescue. The quicker recession of tall fescue turf cover in Study 2 (established 2008) compared with Study 1 (established 2006) may be attributed to the severe brown patch infestations in the summer of 2009, leading to thinning of the tall fescue stand during the first summer after establishment.

Percent brown patch. In Study 1, visual brown patch ratings ranged from 13% to 37% in the monoculture of TF; comparatively, brown patch in the seeding combinations ranged from 4% to 8% (Table 3). Brown patch was observed in plots containing the monoculture of hybrid bluegrass but the lesions were on the smooth crabgrass plants that had infested the monoculture of hybrid bluegrass.

Brown patch was more severe in 2009 than in 2008 or 2010. In Study 2, the monoculture of tall fescue had significantly more brown patch when compared with the other seeding treatments in Aug. 2009. The monoculture of tall fescue contained 29% and 19% brown patch in Aug. 2009 and 2010, respectively (Table 4). Brown patch in the seeding combinations ranged between 4% and 11% from both years, whereas less than 5% brown patch was observed in the monoculture of hybrid bluegrass in 2010. In 2009, higher brown patch incidence was observed in the more mature three-year-old stands in Study 1 compared with the first year in Study 2. Brown patch inoculum levels may have steadily increased over the three years of Trial 1, resulting in the higher disease infestation observed in this trial compared with Study 2.

Mixing cultivars or species of plants that vary in susceptibility to a pathogen may suppress diseases by four possible mechanisms (Wolfe, 1985). First, a dilution effect occurs by increasing the distance between susceptible plants, thus slowing the rate of plant-to-plant spread by pathogens. Additionally, a barrier effect will come from the presence of resistant plants in the canopy, which protects against spore dispersal and mycelium contact. The number and size of the resistant plants and the physics of pathogen dispersal have a direct impact on the strength of the barrier effect. Induced resistance occurs when host defenses are triggered after inoculation with an avirulent race or strain. Triggering these biochemical defenses may slow the future infection processes of virulent pathogens. Finally, plant polystands modify the microenvironment, which could impact disease spread. Plant attributes such as leaf thickness and canopy characteristics modify the microclimate toward less favorable conditions for pathogen growth, which can suppress certain diseases. Meaning that in addition to a barrier and dilution effect that comes from mixing hybrid bluegrass and tall fescue, certain portions of the canopy might be less dense. Therefore, the relative humidity and leaf wetness duration period could be shortened.

The epidemiological benefits of mixing hybrid bluegrass and tall fescue were noticeable in these studies. Brown patch severity was less in combinations stands when compared with the monoculture of tall fescue. Dunn (2002) observed similar brown patch epidemiological trends in their study evaluating polystands of kentucky bluegrass and tall fescue. Although we did not observe any severe outbreaks of summer patch or dollar spot in either of the trials, mixing hybrid bluegrass with tall fescue may reduce the potential damage that those diseases would cause. Reliance on disease forecasting would not be as important in the polystands as the monocultures. Therefore, the impact of human error such as missed fungicide applications is lessened because the disease progress of an epidemic would be slower in a polystand. Because of the severe brown patch infestations in Summer 2009, fall was thought to be the best time to compare Study 1 with Study 2. Despite the studies being two years apart in establishment, the patterns in turfgrass cover and species dynamics in 2009 were comparable in both studies. Turfgrass cover in the polystands was greater than in the monocultures in both studies in Fall 2009, which validates the epidemiological benefits of the polystands.

Weed cover. One month after Study 1 was established, plots seeded with only hybrid bluegrass contained 23% purple deadnettle, significantly more than the other seeding treatments (Table 5). Two years after establishment, plots seeded with only hybrid bluegrass contained greater than 30% purple deadnettle cover when compared with other seeding treatments. However, three years after establishment,

Table 2. Impact of monoculture and combination seeding treatments of tall fescue and hybrid bluegrass on visual ratings of percent turf cover taken November in Trial 1 (seeded Oct. 2008).

Seeding treatment	Percent cover		
	2008[z]	2009	2010
Tall fescue	69 a	70 b	59 b
Hybrid bluegrass	35 b	54 c	42 c
Tall fescue:hybrid bluegrass 1.9:1	65 a	81 a	72 a
Tall fescue:hybrid bluegrass 1:1.8	52 a	79 a	76 a

[z]Means within a column followed by the same letter are not significantly different according to the Fisher's protected least significant difference test at the 0.05 level.

Table 3. Impact of monoculture and combination seeding treatments of tall fescue and hybrid bluegrass on percent brown patch severity August in trial 1 (seeded Oct. 2006).

Seeding treatment	Percent brown patch severity		
	2008[z]	2009	2010
Tall fescue	13 a	37 a	24 a
Hybrid bluegrass	4 b	3 b	3 c
Tall fescue:hybrid bluegrass 1.9:1	4 b	8 b	7 b
Tall fescue:hybrid bluegrass 1:1.8	4 b	6 b	7 b

[z]Means within a column followed by the same letter are not significantly different according to the Fisher's protected least significant difference test at the 0.05 level.

Table 4. Impact of monoculture and combination seeding treatments of tall fescue and hybrid bluegrass on percent brown patch severity taken August of Trial 2 (seeded in Oct. 2008).

Seeding treatment	Percent brown patch severity	
	2009[z]	2010
Tall fescue	29 a	19 a
Hybrid bluegrass	3 c	1 c
Tall fescue:hybrid bluegrass 1.9:1	11 b	8 b
Tall fescue:hybrid bluegrass 1:1.8	8 bc	4 bc

[z]Means within a column followed by the same letter are not significantly different according to the Fisher's protected least significant difference test at the 0.05 level.

the tall fescue monoculture had the greatest purple deadnettle cover, whereas the hybrid bluegrass monoculture only had 15% purple deadnettle cover. The increase in Nov. 2009 purple deadnettle cover in tall fescue plots might be the result of the higher brown patch ratings observed in Aug. 2009 (Tables 3 and 4). Brown patch likely thinned the tall fescue canopy and allowed for increased germination and establishment of purple deadnettle. Purple deadnettle cover in the seeding combinations was less than 10% three years after establishment. Four years after establishment, both monocultures had more purple deadnettle cover than the seeding combinations.

Similar trends were observed in Study 2. The highest purple deadnettle rating in the hybrid bluegrass monoculture was 33% (Table 6). Until 2010, purple deadnettle cover was higher in the monocultures of HB compared with the other treatments. In 2010, similar purple deadnettle cover was observed in both monocultures, which was significantly more than was observed in the seeding combinations.

Smooth crabgrass cover rated one year after establishment in the monoculture of hybrid bluegrass in Study 1 was 40%, which was significantly more than any other treatment (Table 5). Plots seeded with only hybrid bluegrass had significantly more crabgrass when compared with other seeding treatments at two and three years after establishment. However, four years after establishment, the monoculture of tall fescue contained 27% crabgrass cover, which was significantly more than the 10% observed in the seeding combinations. In Study 2, smooth crabgrass cover was highest in the monoculture of hybrid bluegrass on both the evaluation dates (Table 6). Smooth crabgrass cover was numerically lower in the seeding combinations than the monoculture of tall fescue.

Tilman (1997) theorized that polystands are more stable over time because of the inverse relationship between diversity of a stand and how easily it can be invaded by undesirable pests. Dual grass systems of tall fescue and hybrid bluegrass contained less brown patch than monocultures of tall fescue, reduced the potential damage that summer patch could cause to a monoculture of hybrid bluegrass, and contained less weeds than both monocultures when analyzed over time.

Analyses of weed species cover ratings over five years indicate that the monoculture of hybrid bluegrass was never able to recover from its slow establishment, which resulted in greater weed density. Tall fescue had more winter annual weed cover and crabgrass cover after the summer of 2009 when compared with the seeding combinations. In the seeding combinations, tall fescue essentially acted as a nurse crop, reducing weed encroachment during the first year and allowing for slow establishment of hybrid bluegrass over time. Previous studies indicate that tall fescue remains competitive in seeding mixtures when mixed at a higher percentage, although minimal differences were observed in weed and disease ratings when the two seeding combinations were compared in this study (Hsiang et al., 1997). Hybrid bluegrass' ability to grow by rhizomes reduced weed encroachment in the polystands after brown patch thinned out the tall fescue during the Summer of 2009. Ecologically, polystands function to create an environment that promotes temporal, spatial, and functional niche differentiation (Wilson, 1990). Maintaining turfgrass species diversity decreases the likelihood of environmental perturbations damaging the turf landscape (Loreau, 1994; Smith et al., 2004).

Hybrid bluegrass tiller counts. Seeding treatment was significant at every rating date when hybrid bluegrass tiller counts were analyzed ($P < 0.05$). Hybrid bluegrass tiller counts in the monoculture of hybrid bluegrass ranged from 58 to 112 tillers 0.79/sq. dm and generally were lower in October and higher in March in Study 1 (Fig. 1A). Growing conditions for cool-season turfgrasses are more favorable during the spring and the fall as compared with summer; thus, more tillers grew between October and March than between March and October. Similar fluctuations were seen in the seeding combinations. Some hybrid bluegrass tillers were present in the monoculture of tall fescue in October of 2009, possibly as a result of the spread of rhizomes from adjacent plots. The greatest number of hybrid bluegrass tillers for every seeding treatment was recorded on the Mar. 2011 evaluation date. The monoculture of hybrid bluegrass contained 112 hybrid bluegrass tillers, whereas seeding combination 1TF:1.8HB had over 100 tillers per sample. Seeding combination 1.9TF:1HB contained 95 hybrid bluegrass tillers per sample. In March of 2011, substantial numbers of hybrid bluegrass plants had encroached into the plots seeded with the monoculture of tall fescue. Twenty-four hybrid bluegrass tillers were counted per sample in the monoculture of tall fescue in Mar. 2011. Similar trends were observed in the second study; however, the analytical time period was shorter. In Study 2, hybrid bluegrass tiller counts increased in every seeding treatment from Mar. 2010 until Mar. 2011 (Fig. 2A).

Tall fescue tiller counts. Seeding treatment was significant at every rating date when tall fescue tiller counts were analyzed ($P < 0.05$). In Mar. 2008 in Study 1, 68 tall fescue tillers were counted in samples from plots seeded with just tall fescue and plots seeded with combination 1.9TF:1HB (Fig. 1B). Forty-nine tillers were counted per sample in plots seeded with combination 1TF:1.8HB. Tiller counts in the monoculture of tall fescue increased from Mar. 2008 until Mar. 2009. Conversely, a decrease in the number of tall fescue tillers in the seeding combinations was observed from Oct. 2008 until Mar. 2009. The decrease of tall fescue tillers in the seeding combinations is likely the result of competition from hybrid bluegrass tillers in those plots. Between Mar. 2009 and Oct. 2009, tiller counts in all treatments containing tall fescue decreased by at least 20 tillers per sample. The decrease in tall fescue tiller counts during this time period is likely the result of the severe brown patch epidemic that occurred during the summer of 2009. Tiller counts increased from Oct. 2010 through Mar. 2011 in all treatments containing tall fescue. Throughout the study, tall fescue tiller counts were highest in the monoculture of tall fescue and lowest in seeding combination 1TF:1.8HB. Because of tall fescue's bunch-type growth habit, no tall fescue tillers were found in adjacent plots containing monocultures of hybrid bluegrass.

Similar trends were observed in Study 2, although the time period for tall fescue to establish before the severe brown patch summer was ≈700 d shorter. In Study 2, there was an initial decrease in tall fescue tiller growth between Mar. 2010 and Oct. 2010 in all seeding treatments (Fig. 2B). Interestingly, between Oct. 2010 and Mar. 2011, tiller counts increased in the monoculture of TF and seeding

Table 5. Impact of monoculture and combination seeding treatments of tall fescue and hybrid bluegrass on visual ratings of purple deadnettle cover in November and smooth crabgrass cover in September of Trial 1 (seeded Oct. 2006).

	Percent purple deadnettle cover					Percent smooth crabgrass cover			
Seeding treatment	2006[z]	2007	2008	2009	2010	2007	2008	2009	2010
Tall fescue	11 b	9 b	10 b	21 a	24 a	18 b	10 b	15 b	27 a
Hybrid bluegrass	23 a	30 a	24 a	15 b	19 a	40 a	25 a	33 a	20 ab
Tall fescue:hybrid bluegrass 1.9:1	11 b	8 b	7 b	8 c	8 b	14 b	6 b	16 b	10 b
Tall fescue:hyrbid bluegrass 1:1.8	16 b	9 b	9 b	10 c	13 b	19 b	11 b	14 b	10 b

[z]Means within a column followed by the same letter are not significantly different according to the Fisher's protected least significant difference test at the 0.05 level.

Table 6. Impact of monoculture and combination seeding treatments of tall fescue and hybrid bluegrass on percent purple deadnettle cover taken November and percent smooth crabgrass taken September in Trial 2, which was seeded in Oct. 2008.

	Percent purple deadnettle cover			Percent smooth crabgrass cover	
Seeding treatment	2008[z]	2009	2010	2009	2010
Tall fescue	11 b	21 b	24 a	19 b	25 b
Hybrid bluegrass	33 a	30 a	26 a	39 a	55 a
Tall fescue:hybrid bluegrass 1:1	11 b	14 b	8 b	12 b	14 b
Tall fescue:hybrid bluegrass 1:9	21 b	14 b	7 b	13 b	16 b

[z]Means within the same column followed by the same letter are not significantly different according to the Fisher's protected least significant difference test at the 0.05 level.

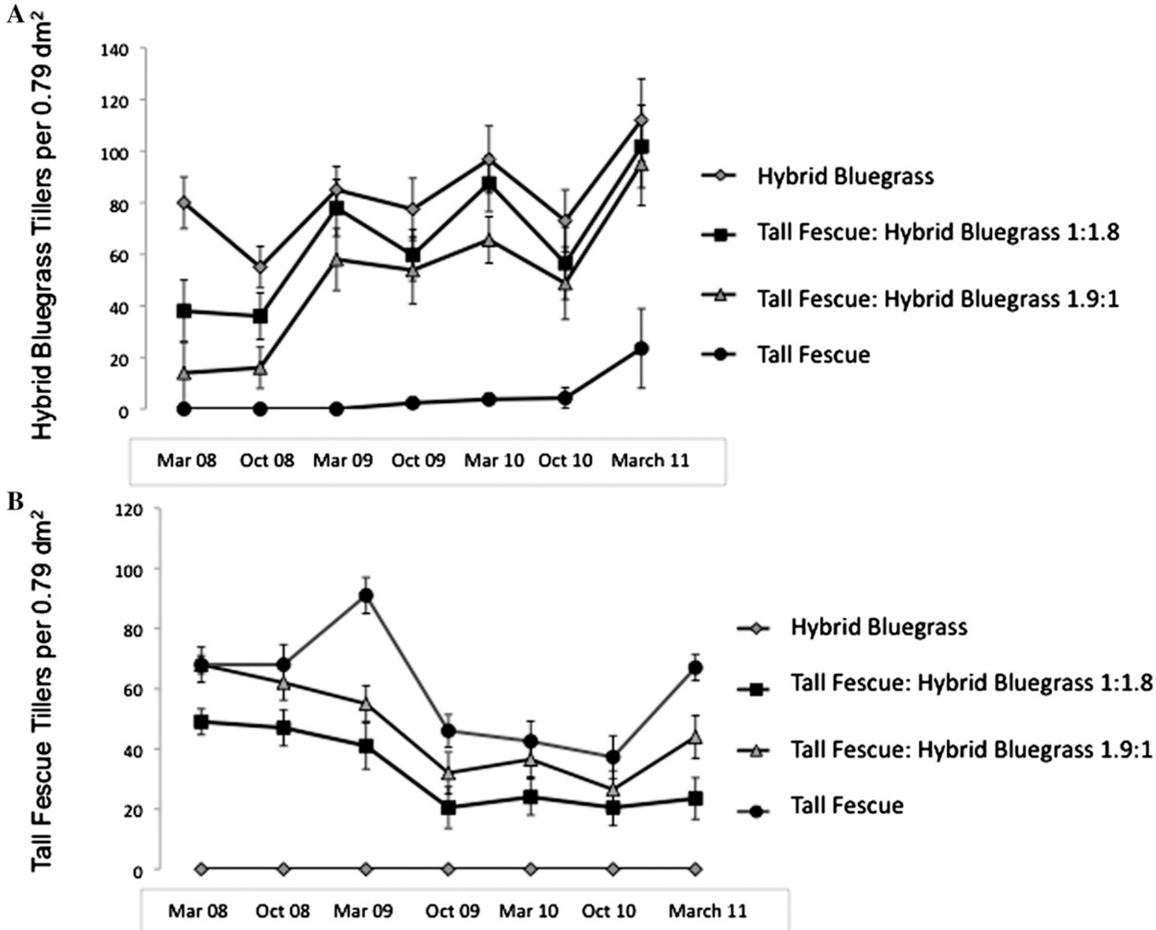

Fig. 1. (**A**) Impact of tall fescue and hybrid bluegrass seeding treatments on hybrid bluegrass tiller counts per 0.79 dm squared taken biannually from 2008 to 2011 in Study 1. Bars indicate SE. (**B**) Impact of tall fescue and hybrid bluegrass seeding treatments on tall fescue tiller counts per 0.79 dm squared taken biannually from 2008 to 2011 in Study 1. Bars indicate SE.

combination 1TF:1.8HB but not seeding combination 1.9TF:1HB. The increased hybrid bluegrass in seeding combination 1TF:1.8HB may influence the disease progress of brown patch resulting from the barrier provided by hybrid bluegrass. The incursion of hybrid bluegrass across the stand reduced the damage incurred by the susceptible tall fescue species and allowed for increased tillering during the optimal growth period between October and March. Brown patch damage may have been more severe in the 1.9TF:1HB seeding combination as a result of a higher rate of brown patch thinning, which would lead to more hybrid bluegrass tillers filling in damaged areas (Fig. 1A–B). Tall fescue in the monoculture of tall fescue was damaged by brown patch but did not have to compete with hybrid bluegrass during the spring growing season.

Tiller weights per sample size. Tall fescue tiller weight averaged 8.2 g per 1 dm diameter sample in the monoculture of tall fescue in Study 1 (Fig. 3). Total weight of hybrid bluegrass tillers in the monoculture of hybrid bluegrass was 5.3 g per sample. Trends were slightly different in Study 2. In the monoculture of tall fescue, the average weight of tall fescue tillers per sample was 6.5 g (Fig. 4). The severe brown patch that occurred in the spring/summer of 2009 likely injured the fledgling tall fescue in Study 2 substantially more than the established tall fescue in Study 1, which was seeded two years earlier. Therefore, the tall fescue tiller weights were numerically less in Study 2 than Study 1. Seeding combination 1.9TF:1HB contained 5.1 g of tall fescue, whereas seeding combination 1TF:1.8HB contained 2.9 g of tall fescue. Total tiller weights were highest in the monoculture of tall fescue and seeding combination 1.9TF:1HB and lowest in the monoculture of hybrid bluegrass.

Average tiller weight. The average tiller of hybrid bluegrass weighed ≈65 mg, 68 mg, and 70 mg when sampled from the monoculture of hybrid bluegrass, seeding combination 1.9TF:1HB, and seeding combination 1TF:1.8HB, respectively, in Study 1 (Fig. 3). The average tiller of tall fescue weighed ≈88 mg, 60 mg, and 100 mg in the monoculture of tall fescue, seeding combination 1.9TF:1HB, and seeding combinations 1TF:1.8HB, respectively. In Study 2, the average tiller of hybrid bluegrass weighed ≈75 mg, 65 mg, and 50 mg when taken from the monoculture of hybrid bluegrass, seeding combination 1.9TF:1HB, and seeding combination 1TF:1.8HB, respectively. The average tall fescue tiller weighed 65 mg, 125 mg, and 100 mg when seeded with tall fescue alone, with combination 1.9TF:1HB, and with combination 1TF:1.8HB, respectively.

Total tiller numbers and total weight of harvested core samples were generally greater in the seeding combinations when compared with the monocultures. Tall fescue and hybrid bluegrass may occupy slightly different niches in the turfgrass canopy, which would increase the density of the stand when compared with monocultures and explain why tiller weights were greater in the polystands than the monocultures three years after seeding in Study 1.

Monitoring species ecology would be an important component of a turfgrass polystand management program. Species counts in the polystands initially favored tall fescue; however, after 2009 in Study 1, a species shift favoring hybrid bluegrass began to occur. Because tall fescue grows as a bunch-type grass, whereas hybrid bluegrass spreads by rhizomes, it is expected that hybrid bluegrass might eventually dominate the stand and essentially become a monoculture. If an eventual transition to a monoculture of hybrid bluegrass is desirable, then the turf manager should increase the nitrogen applied to the turfstand. This is because bluegrass (*Poa* spp.) typically requires more nitrogen when compared with tall fescue (Beard, 1973; Teuton et al., 2007). Also, increased nitrogen fertility

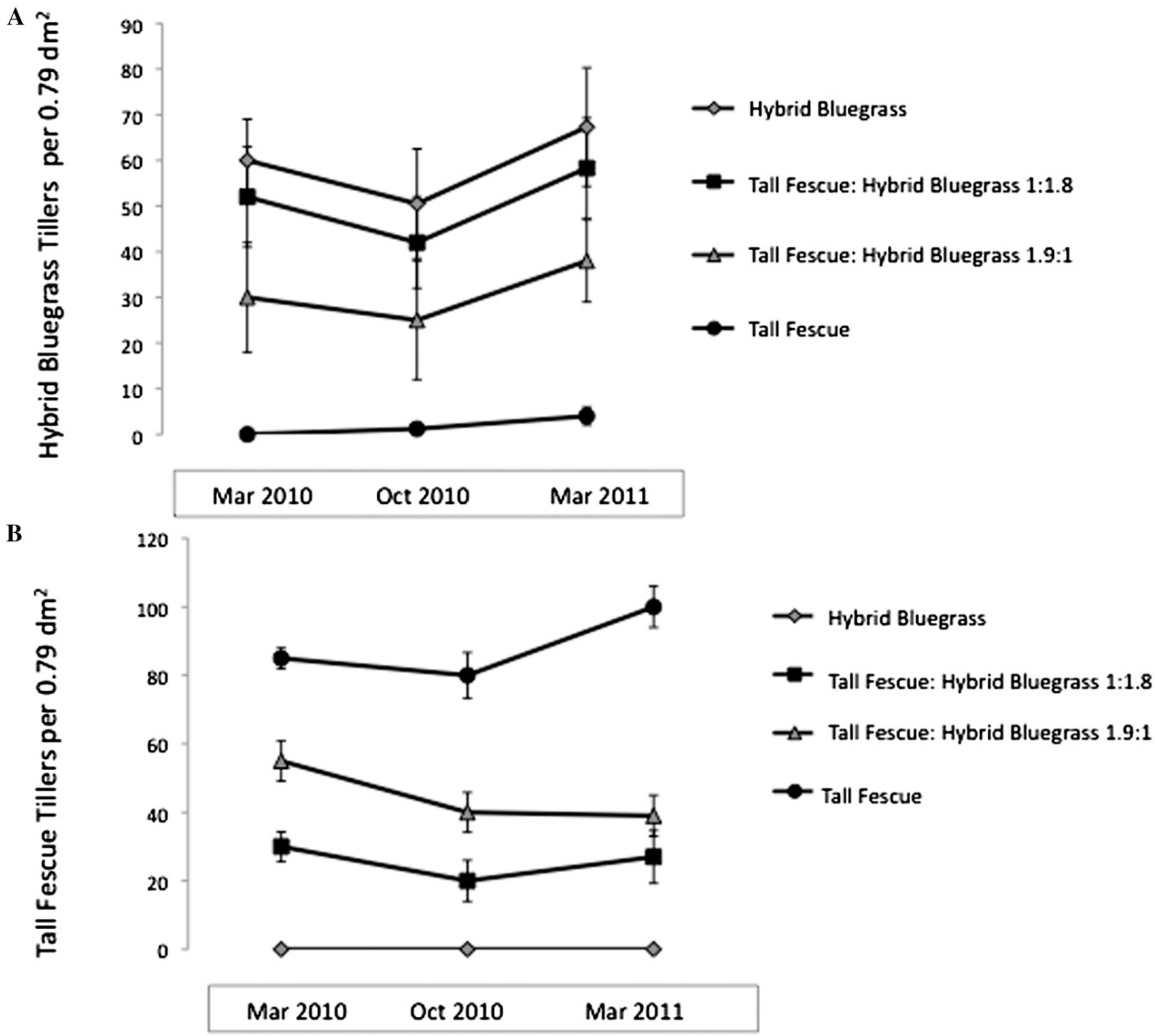

Fig. 2. (**A**) Impact of tall fescue and hybrid bluegrass seeding treatments on hybrid bluegrass tiller counts per 0.79 dm squared taken biannually from 2010 to 2011 in Study 2. Bars indicate SE. (**B**) Impact of tall fescue and hybrid bluegrass seeding treatments on tall fescue tiller counts per 0.79 dm squared taken biannually from 2010 to 2011 in Study 2. Bars indicate SE.

has been shown to increase brown patch incidence in tall fescue, which may thin out the tall fescue (Vincelli et al., 1997). However, to maintain the epidemiological benefits of polystands, tall fescue should be overseeded into the polystand every few years.

Sod strength. In Study 1, sod strength was numerically lowest in the monoculture of tall fescue and highest in the 1TF:1.8HB seeding combination (Fig. 5). In Study 2, sod strength in plots containing the monoculture of tall fescue were significantly lower when compared with the other seeding treatments (Fig. 6). A force of 31 kg was required to break sod samples from the monoculture of tall fescue as compared with a force of ≈48 kg for the treatments containing hybrid bluegrass (Fig. 6).

These data suggest that tall fescue and hybrid bluegrass polystands will benefit sod growers. These polystands should provide the same benefits as kentucky bluegrass and tall fescue seeding mixtures but with potentially increased range into the transition zone by use of the hybrid bluegrass cultivars. Not only do polystands of tall fescue and hybrid bluegrass reduce disease and weed species encroachment when compared with monocultures, they improve the strength of the sod as well compared with a monoculture of tall fescue. Sod strength values recorded from plots treated with seeding combination 1TF:1.8HB were the highest numerically on all the dates that sod strength was evaluated (Figs. 5 and 6).

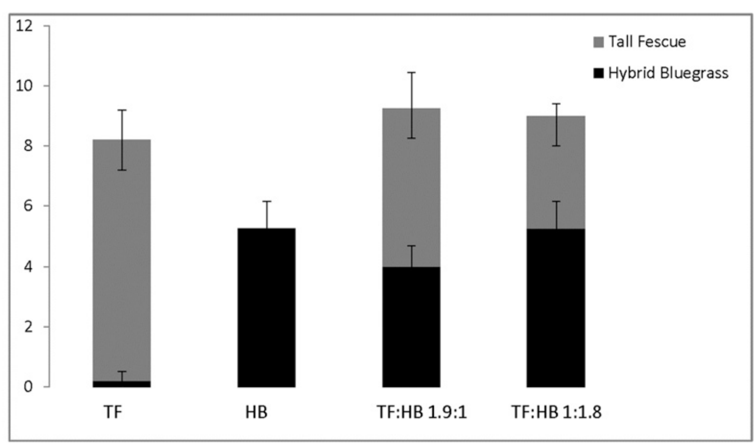

Fig. 3. Impact of tall fescue and hybrid bluegrass seeding treatments on tiller weights in grams per 0.79 dm squared recorded 2.5 years after establishment in Study 1. Bars indicate SE.

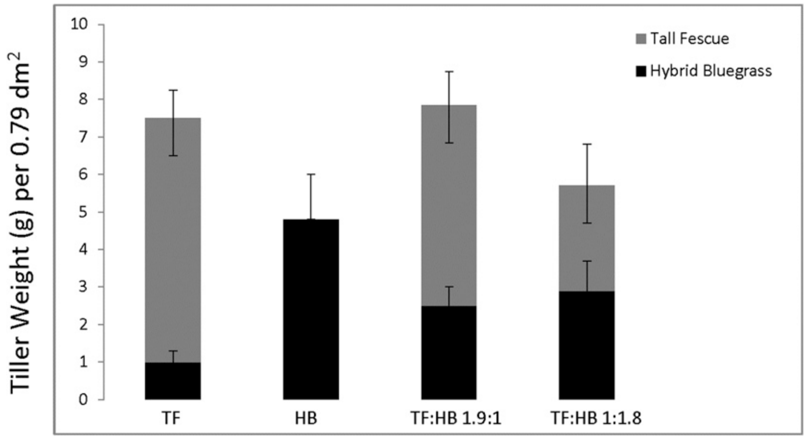

Fig. 4. Impact of tall fescue and hybrid bluegrass seeding treatments on tiller weights in grams per 0.79 dm squared recorded 2.5 years after establishment in Study 2. Bars indicate SE.

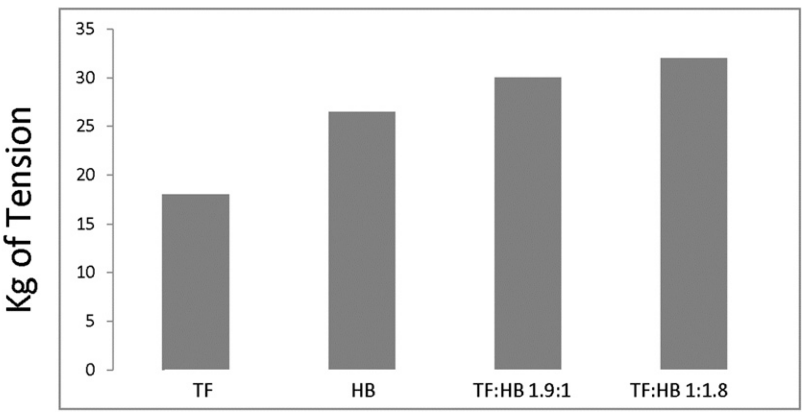

Fig. 5. Impact of tall fescue and hybrid bluegrass seeding treatments on sod strength recorded in Nov. 2010 in Study 1. Sod strength was measured by recording the kg required to tear a piece of sod 0.5 × 0.5 m in diameter. There were no significant differences among means according to Fisher's protected least significant difference at the 0.05 level.

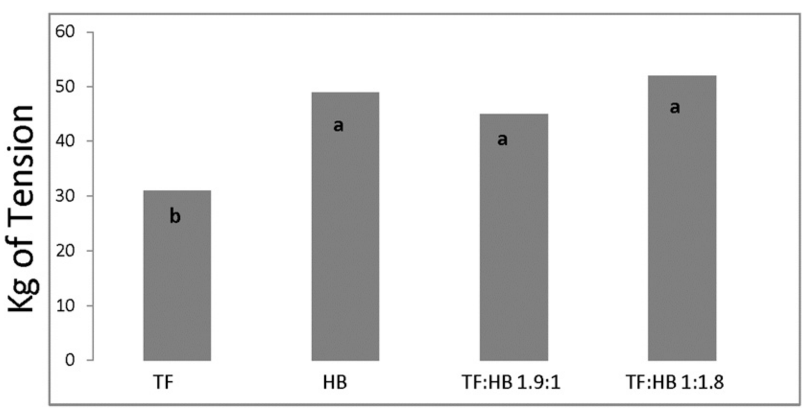

Fig. 6. Impact of tall fescue and hybrid bluegrass seeding treatments on sod strength recorded in Mar. 2011 in Study 2. Sod strength was measured by recording the kg required to tear a piece of sod 0.5 × 0.5 m in diameter. Means followed by the same letter are not significantly different according to Fisher's protected least significant difference test at the 0.05 level.

Hybrid bluegrass spreads by rhizomes; thus, the number of hybrid bluegrass plants should be positively correlated with sod strength. However, annual weeds infested the monoculture of hybrid bluegrass during establishment. The weed infestations decreased turf density and likely reduced sod strength. The hybrid bluegrass in seeding combination 1TF:1.8HB was aided by tall fescue during establishment, which reduced the amount of transient annual weed species that would negatively impact sod strength. Over time tall fescue was thinned out by brown patch and hybrid bluegrass plants began to dominate the polystands, which increased the number of rhizomes in the sod as well as the sod strength. The numerically lower sod strength in seeding combination 1.9TF:1HB vs. seeding combination 1TF:1.8HB is likely attributed to the greater number of hybrid bluegrass plants in seeding combination 1TF:1.8HB. Overall, weed species cover, disease ratings, and turfgrass cover ratings did not significantly differ in plots treated with either seeding combination; thus, either treatment could be successfully incorporated into the transition zone lawn.

General benefits of seeding combinations. It is difficult to manage cool-season turfgrasses in the transition zone, particularly when the turf is managed with minimal inputs. Mixing tall fescue with hybrid bluegrass resulted in a better overall turf stand than the monocultures when followed over a five-year period. Benefits of the seeding combinations during the establishment period include less competition from weeds and superior turf cover when compared with the monoculture of hybrid bluegrass. The seeding combinations performed almost as well regarding turfgrass coverage as the monoculture of tall fescue during the establishment period. Seeding combinations have the potential to reduce inputs compared with establishing hybrid bluegrass or tall fescue alone. No preemergence herbicides or fungicides were used in this study and less weeds were observed in the seeding combinations compared with the monocultures. Including hybrid bluegrass in a stand of tall fescue increases recuperative ability of the turf stand compared with a monoculture of tall fescue. Hybrid bluegrass' ability to grow by rhizomes allowed it to fill in areas of the turf stand that had been damaged by traffic, disease, or other factors. Growing only tall fescue will limit recovery from stresses and necessitate overseeding quicker than a polystand or monoculture of hybrid bluegrass. The slow establishment and concurrent weed infestations limit the performance of monocultures of hybrid bluegrass in low-input scenarios. To avoid uneven, clumpy stands during establishment, tall fescue should not be seeded at lower rates into polystands than the low rate used in this study (Hawes, 1995).

Polystands promote minimum use of resources and lower nutrient inputs for homeowners and managers of commercial lawns (Simmons et al., 2011). Niche differentiation of hybrid bluegrass and tall fescue in polystands allows for longer viability of the turfstand and greater resistance to climatic disturbances when compared with monocultures of tall fescue or hybrid bluegrass. Additionally, resistance to weed species and pathogens is increased, potentially allowing for management programs with reduced herbicide and fungicide inputs. Future research could focus on cost analyses associated with maintaining monocultures compared with polystands. Also of interest is estimating the time needed to overseed tall fescue in the polystands as impacted by differing mowing height and fertility programs. Based on this research, the goal of polystand management should be to maintain 1:1 tall fescue to hybrid bluegrass species ratios to optimize niche differentiations and epidemiological benefits. In conclusion, adoption of either polystand provides better turf cover and reduces both weed infestations and disease with reasonable input requirements when compared with the monocultures.

Literature Cited

Beard, J.B. 1973. Cool season turfgrasses, p. 55–131. In: Beard, J.B. (ed.). Turfgrass: Science and culture. Prentice Hall, Englewood Cliffs, NJ.

Beard, J.B. and R.L. Green. 1994. The role of turfgrasses in environmental protection and their benefits to humans. J. Environ. Qual. 23: 452–460.

Couch, H.B. 1995. Rhizoctonia blight of cool season turfgrasses, p. 59–64. In: Diseases of turfgrasses. Kreiger Publishing Co., Malabar, IL.

Davis, R.R. 1958. The effect of other species and mowing height on the persistence of lawn grasses. Agron. J. 50:671–673.

Donald, C.M. 1963. Competition among crop and pasture plants. Adv. Agron. 15:1–118.

Dunn, J.H. 2001. Mixing tall fescue with kentucky bluegrass and perennial ryegrass. Golf Course Mgt. July:70–74.

Dunn, J.H. 2002. Turf performance of mixtures and blends of tall fescue, kentucky bluegrass, and perennial ryegrass. HortScience 37:214–217.

Fidanza, M.A., P.H. Dernoeden, and A.P. Grybauskas. 1996. Development and field validation of a brown patch warning model for perennial ryegrass turf. Phytopathology 86:385–390.

Ferrell, J.A., T.R. Murphy, L.L. Burpee, and W.K. Vencill. 2003. Effect of brown patch (caused by *Rhizoctonia solani*) control on preemergence herbicide efficacy in tall fescue (*Festuca arundinacea*). Weed Technol. 17:747–750.

Gross, M.K., J.B. Santini, I. Tikhonova, and R. Latin. 1998. The influence of temperature and leaf wetness duration on infection of perennial ryegrass by *Rhizoctonia solani*. Plant Dis. 82: 1012–1016.

Hawes, K. 1995. The benefits of mixtures and blends. Golf Course Mgt. July:20–30.

Hsiang, T., K. Carey, B. He, and J.E. Eggens. 1997. Composition of mixtures of four turfgrass species four years after seeding under non wear conditions. Intl. Turfgrass Soc. Res. J. 8:671–679.

Hunt, K.L. and J.H. Dunn. 1993. Compatibility of kentucky bluegrass and perennial ryegrass with tall fescue in transition zone turfgrass mixtures. Agron. J. 85:211–215.

Ju, H.-J., N.S. Hill, T. Abbot, and K.T. Ingram. 2006. Temperature influences on endophyte growth. Crop Sci. 46:404–412.

Loreau, M. 1994. Material cycling and the stability of ecosystems. Amer. Nat. 143:508–513.

Mitchell, C.E., D. Tilman, and J.V. Groth. 2002. Effects of grassland plant species diversity, abundance, and composition on foliar fungal disease. Ecology 83:1713–1726.

Piper, C.V. and H.S. Coe. 1919. *Rhizoctonia* in lawns and pastures. Phytopathology 9:89–92.

Read, J.C., J.A. Reinert, P.F. Colbaugh, and W.E. Knopp. 1999. Registration of Reveille hybrid bluegrass. Crop Sci. 39:590.

Serensits, T., M.A. Cutulle, and J.F. Derr. 2011. Persistence of overseeded cool-season grasses in bermudagrass turf. Intl. J. Agron. doi: 10.1155/2011/496892.

Simmons, M., M. Bertelsen, S. Windhager, and H. Zafian. 2011. The performance of native and non-native turfgrass monocultures and native turfgrass polycultures: An ecological approach to sustainable lawns. J. Ecol. Eng. 37:1095–1103.

Smith, M.D., J.C. Wilcox, T. Kelly, and A.K. Knapp. 2004. Dominance not richness determines invasibility of tallgrass prairie. Oikos 106:253–262.

Su, K., D.J. Bremer, S.J. Keeley, and J.D. Fry. 2007. Effects of high temperature and drought on a hybrid bluegrasss compared with kentucky bluegrass and tall fescue. Crop Sci. 47:2152–2161.

Suplick-Ploense, Y.L. Qian, and J.C. Read. 2002. Relative NaCl tolerance of kentucky bluegrass, texas bluegrass, and their hybrids. Crop Sci. 42:2025–2030.

Teuton, T.C., J.C. Sorochan, C.L. Main, T.J. Samples, J.M. Parham, and T.C. Mueller. 2007. Hybrid bluegrass, kentucky bluegrass and tall fescue response to nitrogen fertilization in the transition zone. HortScience 42:369–372.

The Lawn Institute. 2010. July 2010. <http://www.thelawninstitute.org/education/?c=183313>.

Tilman, D. 1997. Community invisibility, recruitment limitation, and grassland biodiversity. Ecology 78:81–92.

Turgeon, A.J. 1999. Turfgrass management. Prentice Hall Pub. Co., Upper Saddle River, NJ.

Vincelli, P., D.W. Williams, and A.J. Powell. 1997. Increasing brown patch on tall fescue with increasing mowing height and spring/summer nitrogen fertility. Phytopathology 86:S100–S101.

Wilson, J.B. 1990. Mechanisms of species coexistence: Twelve explanations for Hutchinson's paradox of the plankton: Evidence from New Zealand plant communities. N. Z. J. Ecol. 13: 17–42.

Wolfe, M.S. 1985. The current status and prospects of multiline cultivars and variety mixtures for disease control. Annu. Rev. Phytopathol. 23: 251–273.

Yuen, G.Y., L.J. Giesler, and G.L. Horst. 1994. Influence of canopy structure on tall fescue cultivar susceptibility to brown patch disease. Crop Prot. 13:439–442.