Tall Fescue Canopy Density Effects on Brown Patch Disease

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ABSTRACT

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Canopy density was investigated as a factor determining the severity of brown patch disease, caused by *Rhizoctonia solani*, in the field. In two separate experiments, tall fescue (*Festuca arundinacea*) cv. Fawn was seeded at 10 to 50 g/m^2 to create canopies with different levels of blade density (i.e., numbers of leaf blades per unit area) and verdure. Brown patch lesion development was more severe at the 50-g/m^2 seeding rate than at 10 g/m^2 in both experiments. Six cultivars of tall fescue, representing combinations of susceptibility (as determined in a growth chamber) and stature (tall, medium, or dwarf), were evaluated in the field for brown patch disease severity and canopy density. Disease severity measured over 2 years was highly correlated with blade density and verdure, but was not related to cultivar susceptibility. The tall cultivars produced the least dense canopies and sustained the least amount of disease. The medium and dwarf groups, however, could not be distinguished on the basis of canopy density or response to brown patch disease. These results show that canopy density directly affects brown patch disease severity under field conditions and is, in part, related to a cultivar's stature.

Tall fescue (*Festuca arundinacea* Schreb.) is a widely grown turfgrass in the Great Plains and other temperate regions. It is commonly selected for its drought and shade tolerance and low fertilizer requirement (2). One of the most destructive diseases of tall fescue is brown patch disease or Rhizoctonia blight, caused by several anastomosis groups of *Rhizoctonia solani* Kühn (6). *R. solani* infections cause foliar necrosis and crown rot, which can result in blighted patches with diameters exceeding 1 m (4). Currently, control of brown patch is limited to fungicides and cultural methods.

Since the release of tall fescue cultivars Alta and Kentucky-31 in 1940, many diverse cultivars have been developed (1). Differences in susceptibility to brown patch disease among cultivars have been reported in evaluations conducted at many locations (3,5,12–14,17,20–22), but immunity has not been found. Cultivars also vary in growth habit or stature and are commonly placed in one of three categories: tall or forage type, intermediate or turf type, and short or dwarf. Furthermore, tall fescue cultivars produce different canopy densities, i.e., numbers of leaf blades per unit area (17). Cultivar stature appears to be related to canopy density; as canopy stature is reduced, more energy is partitioned into tiller production and higher density canopies are produced. Yuen et al. (22) found an association between canopy density and brown patch severity in the field in an evaluation of nine randomly selected tall fescue cultivars. The effects of cultivar structure and canopy density on brown patch disease have not been directly tested.

One objective of our study was to test the effects of canopy density on brown patch disease severity by altering planting density. Another objective was to investigate the relationship of cultivar stature to canopy density and brown patch lesion development. Preliminary results have been published (8,9,11,12).

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MATERIALS AND METHODS

Evaluation of seeding density effects. All field experiments were performed at the University of Nebraska John Seaton Anderson Turfgrass Research Facility near Mead, NE. In two tests (designated as 1993 and 1994 experiments), canopy density was altered in the field by planting tall fescue cv. Fawn at different seeding rates. In the 1993 experiment, 10, 30, and 50 g of seed per m^2 were planted in 3 × 4.5 m plots on 26 May 1993. In the 1994 experiment, Fawn was seeded at 10 and 50 g/m^2 on 5 May 1994. The experiments were located in adjoining sites that had been planted previously in wheat or left fallow. A randomized complete block design with four replications was used in both experiments. The blocks were separated by 1-m-wide alleys planted with tall fescue cv. Kentucky-31. *R. solani* AG-1-IA was applied to each plot as colonized oat seed (19) at 39 g/m^2 using a fertilizer drop spreader. Inoculum applied on 10 July 1993 in the 1993 experiment contained isolate R251 from tall fescue in Nebraska. On 4 August 1994, these plots were reinfested with a 1:1 mixture of isolates R251 and R212, which was obtained from Kentucky bluegrass. The 1994 experiment also was infested with the isolate mixture on the same date.

The 1993 seeding density experiment was rated for brown patch lesion development from 1 August through 2 September in 1993 and from 16 August through 2 September in 1994. The 1994 experiment was evaluated on 26 August and 2 September 1994. Lesion development was rated on a 0 to 10 scale in three 930-cm^2 areas within each plot, with the three ratings being averaged prior to statistical analysis. The ratings were based roughly on the percentage of grass blades containing brown patch lesions: 0 = no lesions, 1 = less than 5%, 2 = 5 to 10%, 3 = 10 to 20%, 4 = 20 to 30%, 5 = 30 to 40%, 6 = 40 to 50%, 7 = 50 to 60%, 8 = 60 to 70%, 9 = 70 to 80%, and 10 = over 80%. Therefore, a more dense canopy with the same number of lesions as a sparse canopy would receive a lower rating. This method was selected over visual assessments of disease severity made across entire plots because the extent of lesion development was considered to be more directly reflective of pathogen activity. Furthermore, symptom expression in entire plots can be affected by other factors such as cultivar color, environmental stress, and other diseases.

Evaluation of stature effects. Six cultivars were chosen for their stature type (tall, medium, or dwarf). Stature designations were determined by the seed producers. The cultivars were also selected for this study on the basis of reported levels of susceptibility to *R. solani* determined under controlled, uniform environmental conditions (22). There was one susceptible and one resistant cultivar for each of the three stature categories. The cultivars were Kentucky-31 (tall-resistant), Fawn (tall-susceptible), Arriba (medium-resistant), Shenandoah (medium-susceptible), Emperor (dwarf-resistant), and El Dorado (dwarf-susceptible). Reported susceptibility levels were based on experiments using only one pathogen isolate, R212. Because we also used isolate R251 in the field experiment, the six cultivars were reevaluated in this study for susceptibility to isolate R251 in a growth chamber. Methods described by Yuen et al. (22) were used, except that cultivars were first grown under artificial lighting (10 W/m^2) instead of under greenhouse conditions. There were two growth chamber experiments with five and six replications per treatment.

In the field experiment, the cultivars were planted at 30 g of seed per m^2 into 3.0 × 6.1 m plots replicated four times in a randomized complete block design. The blocks were separated by alleys (1 m wide) containing Kentucky-31. Plots were planted in 1992 and then overseeded on 13 May 1993 with 15 g of seed per m^2 to compensate for plot damage from insects. Oat seed inoculum containing R251 was applied on 3 August 1993, and subsequent brown patch lesion development was assessed weekly from 9 August through 2 September. In 1994, a mixture of isolates R251 and R212 was applied on 14 June, and plots were evaluated for disease development from 30 June through 2 September.

Plot maintenance and density measurement procedures. All plots were mowed weekly to 8-cm height, and clippings were removed with each mowing. Sprinkler irrigation was applied daily between 19:00 h and midnight for two 10-min intervals to supply 3.8 cm of water per week. This ensured high relative humidity and long periods of leaf wetness to favor disease development. All experiments were fertilized monthly from May through September with 50 kg of N per ha per month to encourage disease development.

All experimental plots were evaluated for canopy density on the basis of blade density and verdure. Canopy density measurements were made on 17 August 1993 and 17 July 1994 in the 1993 seeding density experiment, and on 12 September 1994 in the 1994 seeding density experiment. The cultivar study was evaluated for blade density on 21 July and 30 August 1993 and on 9 July 1994. Verdure also was measured on the latter two dates. Three samples of turf were collected from each plot with an 11-cm-diameter cup cutter immediately after mowing. The samples were then taken to the laboratory and kept at 16°C until sample processing. The total number of shoots and the number of blades on six shoots were counted in each sample. Blade density within a sample was calculated by multiplying shoot number by the average number of blades on six shoots. Verdure was determined as weight of all green tissue in a sample after drying for 48 h at 60°C in a convection oven.

Statistical analysis. Analysis of variance was performed on all data, with data sets from each year of an experiment being treated separately. Pooled analysis of variance for measurements over time was applied to disease severity data. The LSD test was used for mean separation in the seeding density experiments. In the cultivar study, contrast analysis was performed for average disease severity ratings of the two susceptibility classes and for disease ratings and canopy density of cultivar stature types. For all multiple contrasts, the Bonferroni correction (18) was applied to $\alpha = 0.05$ to determine statistical significance. Relationships among disease severity ratings, blade density, and verdure measurements were determined using correlation analysis. All statistical analyses were performed with Statistical Analysis Software (SAS Institute, Cary, NC).

RESULTS

Effects of seeding density on brown patch. Brown patch disease was more severe when canopy density was increased by increasing the seeding rate (Table 1). In the 1993 seeding density experiment, there was no significant seeding rate by time interaction for lesion ratings measured in 1993. The mean 1993 lesion rating for plots seeded at 10 g/m^2 (2.1) was significantly lower than in plots seeded at 50 g/m^2 (3.8). Mean lesion ratings did not differ significantly between adjacent seed rates. Lesion ratings at the height of disease activity (9 August) were 2.5, 3.6, and 4.9 in the low-, medium-, and high-seeding-density turfs, respectively. Blade density measured on 17 August 1993 differed significantly among the three seeding rates (Table 1). Verdure in the low-seeding-density turf was lower than in the other two seeding rates, but there was no significant difference in verdure between the medium and high seeding rates.

In 1994 evaluations of the same experiment, canopy densities were less differentiated among the seeding rate treatments (data not shown). Blade density in the low-seeding-rate plots remained lower than in the other two treatments, but blade densities in the medium- and high-seeding-density canopies were similar. Verdure did not differ among the seeding treatments. There were no differences among the seeding rates in disease severity averaged over three evaluation dates. When data from each date were analyzed separately, disease severity at one date in the low seeding rate was lower ($P = 0.05$) than in the other two seeding treatments (data not shown).

Similar results were obtained in the 1994 seeding rate experiment. A higher level of brown patch disease was detected in the high-seeding-density (50 g/m^2) turf than in turf seeded at 10 g/m^2 (Table 1). A significant difference in blade density was found between seeding treatments, but verdure measurements were similar.

Relationship of cultivar stature to canopy density and brown patch disease. Cultivar stature was found to affect canopy density and disease development. When the six cultivars in this study were grouped by stature type (tall, medium, or dwarf), tall cultivars were found to have a lower blade density (measured in July) in comparison to the medium and dwarf selections in both years of this study, but there was no difference in blade density between medium and dwarf types (Table 2). The same contrasts were found with blade density measured on 30 August 1993 and with verdure measurements (data not shown). In both years, cultivar effects on disease severity were significant, but cultivar by time interactions were not. When the three stature types were compared for disease severity averaged over each year, significant effects due to stature type were found (Table 2). Medium stature cultivars sustained the highest levels of disease in both years. There was no difference in disease levels between tall and dwarf type cultivars in 1993, but disease levels in the tall cultivars were lower than in the dwarf cultivars in 1994.

Brown patch severity measured in the six cultivars was independent of susceptibility levels determined in the growth chamber. When cultivars were grouped

Table 1. Canopy density and brown patch disease severity in tall fescue cultivar Fawn planted at different seeding rates in 1993 and 1994 field experiments

	1993 experiment			1994 experiment		
Seeding rate (g/m^2)	**Blade density[a]**	**Verdure (g)[b]**	**Lesion rating[c]**	**Blade density**	**Verdure (g)**	**Lesion rating**
10	162	1.2	2.1	120	1.9	2.0
30	265	1.5	3.1	---[d]	---	---
50	321	1.5	3.8	255	1.8	3.8
LSD ($P = 0.05$)	52	0.2	1.2	27	NS[e]	1.4

[a] Number of leaf blades per 95 cm^2. Values are means of four blocks. Measurements were made on 17 August 1993 and 12 September 1994.

[b] Average dry weight of green tissue in samples described above.

[c] Values for the 1993 experiment are means from five dates from 1 August through 2 September 1993. Values for the 1994 experiment are means of three dates from 16 August through 2 September 1994. On each date, three ratings were made in 930-cm^2 areas in each of four replicate plots on a 0 to 10 scale, with 0 = no disease and 10 = more than 80% of foliage exhibiting brown patch lesions.

[d] --- = not tested.

[e] NS = not significant.

Table 2. Canopy density and brown patch disease severity in six tall fescue cultivars differing in stature and brown patch susceptibility

Cultivar	Stature type[a]	Resistance class[b]	1993 evaluation Blade density[c]	1993 evaluation Lesion rating[d]	1994 evaluation Blade density[c]	1994 evaluation Lesion rating[d]
Emperor	Dwarf	Resistant	309	3.6	230	2.1
El Dorado	Dwarf	Susceptible	407	4.2	237	2.0
Arriba	Medium	Resistant	384	4.4	257	2.1
Shenandoah	Medium	Susceptible	426	4.6	265	2.3
Kentucky-31	Tall	Resistant	290	4.1	207	1.5
Fawn	Tall	Susceptible	193	3.4	137	0.9
LSD ($P = 0.05$)			53	0.6	25	0.5
$P > F$[e]						
Tall vs. medium			<0.01	<0.01	<0.01	<0.01
Medium vs. dwarf			0.07	0.01	0.06	0.13
Tall vs. dwarf			<0.01	0.41	<0.01	<0.01
Resistant vs. susceptible			0.60	0.80	0.05	0.12

[a] Designation provided by seed producer.
[b] Resistance or susceptibility determined in previously reported growth chamber evaluations (22).
[c] Number of blades per 95 cm^2 averaged over four blocks. Measurements were made on 21 July 1993 and 9 July 1994.
[d] 1993 values are means of four dates from 9 August through 2 September. 1994 values are means of six readings from 30 June through 2 September. On each date, three ratings were made in 930-cm^2 areas in each of four replicate plots on a 0 to 10 scale (0 = no disease, 10 = more than 80% of foliage exhibiting brown patch lesions).
[e] $P \leq 0.01$ required for statistical significance at the 95% confidence level for multiple contrasts according to the Bonferroni correction.

into susceptible and resistant classes as determined by Yuen et al. (22), there was no difference in mean lesion ratings in 1993 or 1994 (Table 2). Evaluation of the six cultivars in the growth chamber for susceptibility to a different isolate of *R. solani* (R251) resulted in different relative disease levels than previously reported using isolate R212 (22) (data not shown). Kentucky-31, which sustained 55% necrosis in two experiments, was significantly ($P = 0.05$) less susceptible to R251 than the other cultivars, which exhibited 75 to 90% necrosis. No correlation, however, between these growth chamber susceptibility levels and field disease levels was found on any evaluation date.

Disease levels among the six cultivars were related to canopy density. In both years, mean lesion ratings were highly correlated ($r \geq 0.85$, $P \leq 0.11$) with blade density and verdure measurements (data not shown). On every reading date, the lowest disease levels were observed in the susceptible cultivar Fawn, which also produced the lowest blade density (Fig. 1) and verdure (data not shown). Shenandoah, another susceptible cultivar, developed the highest density canopy and also sustained the highest disease levels on most dates. Positive correlations with r values exceeding 0.80 ($P \leq 0.06$) between blade density and lesion rating occurred on 2 out of 4 days in 1993, and on 5 out of 6 days in 1994. The r values tended to be higher on evaluation dates with the higher levels of disease, e.g., 18 August 1993 and 2 September 1994 (Fig. 1). The correlation between verdure and lesion ratings severity also was positive for most dates and followed a similar pattern of r values as the correlation of disease severity to blade density (data not shown).

DISCUSSION

This study provides both direct and associative evidence of the importance of canopy density as a determining factor for brown patch development in the field. The direct causative effect of canopy density on lesion development was demonstrated in the two Fawn seeding density experiments in which greater disease severity occurred in plots seeded at higher plant densities. A close relationship between canopy density and brown patch disease development was found in the cultivar experiment, which supports findings from a previous study involving a different set of tall fescue cultivars (22). In this experiment, canopy density measurements were obtained prior to all but one evaluation of disease severity. The high correlations found between canopy density measurements and disease levels that were determined subsequently strongly suggest that canopy density can influence disease severity. The mechanism by which canopy density affects disease severity has not been clearly identified. We have found differences in microenvironmental conditions between the low- and high-density canopies tested in these experiments (10), but it appears that high-density turfs are more favorable to the pathogen for more than one reason.

As we previously reported (22), the effects of canopy density in the field appear to mask physiological susceptibility measured under growth chamber conditions. This may be explained by the dissimilarity between growth chamber and field environments and their effects on host physiology. Environmental conditions, such as light intensity, and seedling age have been shown to affect susceptibility in grass species (7,23). Tall fescue seedlings grown under shaded conditions exhibited greater brown patch disease severity than unshaded plants (23). This last factor could account in part for different levels of susceptibility being determined in the growth chamber in this study, as opposed to those we previously reported (22) for the same set of cultivars. The plants used in these growth chamber evaluations were first grown under low artificial light, as compared to seedlings being grown under higher light intensities in the greenhouse in the previous study. Different isolates of *R. solani* were used between the two growth chamber studies, and therefore it is also possible that the differences in results could be related to differences in pathogen virulence, as reported by Martin and Lucas (16). No brown patch disease was observed in the noninfested borders surrounding each experiment block, and therefore it was unlikely that the disease in the field experiment was caused by resident pathogen isolates differing in virulence from those that were introduced. Regardless of the mechanism for the discrepancies in results between experiments, it is clear that susceptibility–resistance levels determined in controlled environments are not predictive of cultivar response to brown patch disease in the field.

Canopy density was dynamic within the duration of these experiments. In the 1993 Fawn seeding rate experiment, which was evaluated over a 2-year period, blade density differences between the seeding rate treatments became less pronounced in the second year because of decreased tiller development at the medium (30 g/m^2) and high (50 g/m^2) seeding rates. Blade density in the plots seeded at the low rate, 10 g of seed per m^2, was stable across the 2 years, but increased leaf development, manifested in broader leaf blades (data not presented), contributed to uniformity in verdure. This compensation has been reported for tall fescue grown for forage (15). In the cultivar experiment, in which the plots were seeded initially at 30 g/m^2, all of the cultivars exhibited a decrease in canopy density between the first and second year. While brown patch disease also may have caused some of the canopy thinning observed between years, the downward trends in canopy density suggest that recommended seeding rates (30 to 50 g of seed per m^2) may generate canopies that are abnormally high and transitory in density.

In our evaluation of cultivars, we found that cultivar stature can affect brown patch disease because canopy density in a cultivar reflects in part its stature. There was a separation between the tall cultivars and the other two stature types relative to brown patch disease levels and canopy density. Tall type cultivars are described as producing more top growth and develop-

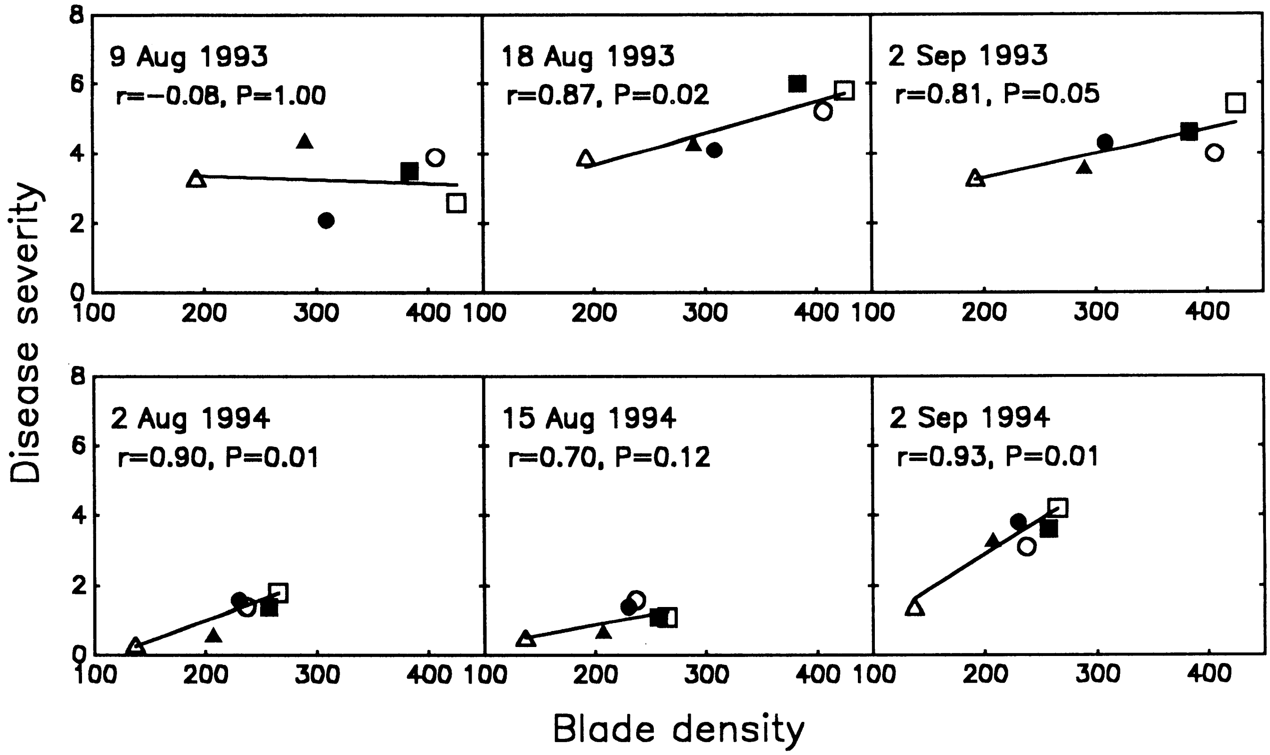

Fig. 1. Relationship of brown patch disease severity in six tall fescue cultivars, measured on representative days in 1993 and 1994, to blade density (number of leaf blades per 95 cm^2) determined on 21 July 1993 and 9 July 1994. Each cultivar represents a combination of stature type and susceptibility group: Kentucky-31 (▲) is tall-resistant; Fawn (Δ) is tall-susceptible; Arriba (■) is medium-resistant; Shenandoah (□) is medium-susceptible; Emperor (●) is dwarf-resistant; and El Dorado (○) is dwarf-susceptible. Disease severity was measured on a 0 to 10 scale (0 = no disease; 10 = more than 80% of the foliage containing lesions) within 930-cm^2 areas in each plot. Correlation analysis was conducted on mean disease severity and blade density data for each cultivar.

ing fewer tillers than dwarf or medium cultivars. This is consistent with our observations of tiller numbers made during the course of the cultivar experiment (data not shown). We also observed the tall cultivars to produce more vertical growth between mowings, compared to the medium and dwarf cultivars. As leaf elongation occurred, some of the infected tissues were pushed upward and subsequently were removed by mowing. The greater ability of the tall cultivars to "outgrow" and thereby escape disease may be related to the differential recovery of tall cultivars following brown patch epidemics reported by Burpee (3). Because only six cultivars were tested in this study, more observations are needed to make generalizations across the range of available tall fescue genotypes. Objective standards must also be developed and consistently applied for categorizing genotypes to a stature group before the relationship of stature to any other parameter can be accurately and uniformly examined.

This research provides some explanations for the differences in results among tall fescue cultivar evaluations conducted across the United States. While it can be assumed that each researcher plants cultivars at uniform seeding rates, a standard seeding level needs to be adopted to ensure consistency in stands between studies. Furthermore, we recommend that canopy density measurement be included as a regular part of cultivar evaluations. While there is not yet enough evidence to suggest that canopy density for any given cultivar will be consistent across geographic areas or environmental conditions, canopy density appears to be a contributing factor in field susceptibility to brown patch disease.

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