Influence of Shading on the Response of Tall Fescue Cultivars to *Rhizoctonia solani* AG-1 IA

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ABSTRACT

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Isolations from turf samples with brown patch symptoms and pathogenicity tests indicated that *Rhizoctonia solani* AG-1 IA was the most important pathogen causing brown patch of tall fescue (*Festuca arundinacea*) in Arkansas in 1992. Ten tall fescue cultivars were evaluated for susceptibility to *R. solani* in sun and shade environments. Plants were grown in a greenhouse for 4 wk under either full sunlight or colored cellophane that simulated the quality and quantity of light obtained in the shade of deciduous tree canopies. Plants were then evaluated for disease reaction in growth chambers under similar sun or shade conditions. Shade-grown plants of all 10 cultivars had significantly greater disease severity than sun-grown plants ($P = 0.05$). Safari was consistently one of the most susceptible tall fescue cultivars under shade, while Hubbard 87 and Shenandoah were among the least susceptible under both light regimes. Disease severity was not altered when preconditioned plants were placed in the opposite light regime, indicating that the morphological and physiological effects of shading, and not the shade environment, had a greater influence on brown patch severity. Safari had a low level of endophyte infection, and all other cultivars showed no detectable infection.

Additional keywords: *Thanatephorus cucumeris*

An estimated 20% of managed turfgrass is grown in partial shade (3). Light intensity in the shade of a fully leafed tree ranges from 1 to 5% of full sunlight, depending upon the species and how densely the trees are planted (24). Light quality in dense deciduous shade is low in blue and red wavelengths, high in green, and very high in far red (22,27). Reduced light intensity has been reported to decrease carbohydrate reserves and the growth of roots, shoots, rhizomes, and stolons of grasses (4,30). Numerous cellular changes also result from low light intensity (6).

Burton and Deal (8) suggested that resistance to insects, diseases, and drought in shaded grasses was reduced, and they speculated that this occurred because shade-grown grass was more succulent than nonshaded grass. Shade was considered to be the primary predisposing factor to decline of tall fescue (*Festuca arundinacea* Schreb.) due to powdery mildew, caused by *Erysiphe graminis* DC. (3). Thinner cell walls and higher internal and surface moisture of the leaves under shade were associated with a subsequent increase in incidence of brown patch, caused by *Rhizoctonia solani* Kühn (11). Melting-out, caused by *Drechslera poae* (Baudys) Shoemaker, was more severe on turfgrass grown in the shade of deciduous trees than direct sunlight (26).

The fungal endophyte *Acremonium coenophialum* Morgan-Jones & W. Gams colonizes seeds and the intercellular spaces of leaf sheaths and culms but not the leaf blade or roots of tall fescue and may influence susceptibility to some diseases (2). The endophyte can be detected by ELISA (14,17) or microscopically with stains (23,28). White and Cole (29) and Siegel and Latch (25) reported that *A. coenophialum* produced antifungal compounds that inhibited growth of several pathogenic fungi in vitro. Partial resistance to *R. zeae* Voorhees has been demonstrated in endophyte-infected tall fescue (15).

Brown patch is an important foliar disease in the temperate transition zone of the United States under warm humid conditions (20) and can be caused by a number of *Rhizoctonia* spp. *R. solani* from anastomosis groups (AG) 1, 2, 4, and 5, *R. zeae*, and *R. cerealis* Van der Hoeven were isolated from diseased turfgrass species in North Carolina (19,21), whereas *R. solani* AG-2-2 was pathogenic on St. Augustinegrass (*Stenotaphrum secundatum* (Walter) Kuntze) in Texas (16). Identification of the *Rhizoctonia* spp. and AG group causing brown patch may be important for management of the disease through the use of fungicides, fertilizers, cultivars, and environmental modifications. Shade tolerance and brown patch resistance in turf-type tall fescues have been increased in many new cultivars (13). Under conducive conditions, however, all tall fescue cultivars were reported to be highly susceptible to brown patch (10). The importance of duplicating stressful conditions in a controlled environment for screening cultivars has been emphasized (5). The objectives of this study were to identify the *Rhizoctonia* spp. associated with brown patch in Arkansas and determine the response of 10 tall fescue cultivars to brown patch under simulated sun and shade environments.

MATERIALS AND METHODS

Light quality and treatments. Frames for light treatments consisted of one 8-mm-thick sheet of Lexan Thermoclear double-walled polycarbonate. Sheets of Lexan were suspended 30 cm above benches in a Lexan greenhouse. A spectrophotometer was used to measure spectral transmission through single fully developed leaves collected in July from Norway maple (*Acer platanoides* L.), sugar maple (*A. saccharum* Marsh.), pin oak (*Quercus palustris* Münchh.), and sweet gum (*Liquidamber styraciflua* L.), through Lexan and through colored cellophane. A combination of cellophane layers of blue, amber, and green (Rainbow Glow 89024, 89023, and 89021, respectively) were placed on the polycarbonate sheet for the shade treatment. An untreated polycarbonate sheet was used for the sun treatment. Radiation flux for the sun and shade treatments was measured with a LI-COR Steady-State Porometer Model LI-1600 with a Model 1905-1 Quantum Sensor (LI-COR, Inc., Lincoln, NE). For disease evaluations, plants were transferred to growth chambers (Conviron Inc., Pembina, ND 58271) having similar light regimes, with shading provided via colored cellophane.

The shade experiment setup was four growth chambers, two using cellophane for shade and two using normal light; this arrangement was used in two experimental runs. Within each growth chamber was a tray of infested cones and a tray of noninfested cones, and each tray contained three cones of each cultivar replicated three times. A split-split unit design was used; the main unit was a

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growth chamber with a main factor of light treatment, the subunit was a tray of infested or noninfested cones, and the sub-subunit was a group of three cones for each sub-subunit factor of cultivar. The sources of variation in the analyses were runs; light treatment; error "a" (the residual variation among means of chambers, light treatment, and runs); cultivar; light treatment × cultivar; and error "b" (the residual variation).

In the shade acclimatization experiments, the plants were switched after soil infestation with *R. solani*, placing the pretreated shade plants into the sun chamber and vice versa. The design setup and sources of variation were the same as in the shade experiment, but only two growth chambers were used per run.

Cultivars. The tall fescue cultivars used in these studies were Apache, Arid, Finelawn I, Guardian, Hubbard 87, Kentucky 31, Rebel, Safari, Shenandoah, Silverado, and Wrangler. These cultivars were selected from 63 cultivars evaluated in the National Tall Fescue Test–1987 based upon their sun-grown quality performance in Arkansas. Hubbard 87, Shenandoah, Safari, and Guardian had the highest scores; Wrangler, Silverado, and Arid had moderate scores; and Apache, Finelawn I, and Kentucky 31 had the lowest scores (1). Rebel was used as a standard cultivar for the pathogenicity experiments.

Leaf sheaths from 50 seedlings of each cultivar from the sun and shade treatments were stained with rose bengal (23) to detect endophyte infection. Seedlings of each cultivar also were tested with ELISA by the Auburn Fescue Toxicity Diagnostic Center, Auburn, Alabama.

Plant growth. All cultivars were grown in RL 200 Cone-Tainers (Stuewe and Sons, Inc., Corvallis, OR) containing Roxana silt loam (pH 7.7, 1.0% organic matter, 7 ppm extractable phosphorus, and 37 ppm exchangeable potassium). Ten seeds were planted in each cone, and the cones were placed under the sun or shade treatments in the greenhouse with a mean day/night temperature of 24/18 C for 4 wk. Germination was evaluated by randomly selecting 10 cones of each cultivar of both light treatments and counting the number of emerged seedlings. Germination for both light treatments over all cultivars ranged from 79 to 96% plants per cone and averaged 90%. Plants were subirrigated with a solution of 50 ppm of nitrogen as NH_4NO_3, 16.6 ppm of P_2O_5, and 16.6 ppm K_2O for 5 min once every 2 wk.

Fungal isolates, inoculum production, and disease evaluation. Five Arkansas counties—Benton, Cleveland, Logan, Pulaski, and Washington—were surveyed for brown patch, and 14 *Rhizoctonia* isolates from turf were recovered. These isolates were identified by nuclear staining using DAPI (18) and anastomosis reaction by the method of Carling et al (9). Anastomosis group was determined against known isolates of *R. solani* provided by D. E. Carling (University of Alaska Fairbanks, Palmer) or binucleate *Rhizoctonia* spp. provided by R. D. Cartwright (University of Arkansas, Fayetteville). Isolate *R. solani* AG-1 IA (Harris 1) was used for disease evaluations on the 10 tall fescue cultivars, on the basis of its high disease severity ratings in two pathogenicity tests (Table 1).

The inoculation technique of Martin and Lucas (20) was used. Ten grams of Rebel seed were placed in a 250-ml Erlenmeyer flask with 20 ml of distilled water, plugged with cotton, capped with aluminum foil, and autoclaved for 30 min at 121 C on two consecutive days. Flasks of seed were inoculated with two 2.75-cm^2 plugs from a culture grown for 36 hr on PDA at 28 C. The flasks were incubated in the dark for 7 days at 28 C and were shaken vigorously on days one and two to ensure uniform mycelial growth. The cultivars were inoculated by placing eight infested or sterilized seeds around the crowns of the plants in each cone. After infestation, the trays of cones were placed in a dew chamber at 28 C for a 12-hr dark period and then placed into a growth chamber for 12 hr of light at 28 C. This process was repeated for three consecutive days, and the plants were rated for disease severity.

Disease severity was rated on plants grown under both light regimes. Disease severity for each Cone-Tainer was rated visually on a scale where 1 = no symptoms, 2 = slight wilting and one or two small necrotic lesions, 3 = moderate wilting and three to five small necrotic lesions, 4 = extensive wilting and six to eight large necrotic lesions, and 5 = severe wilting and 10 large necrotic lesions to complete necrosis and death.

The pathogenicity experiment was a randomized complete block design. One cellophane-shaded growth chamber was used for two experimental runs. Within the growth chamber were two trays of cones, one noninfested tray and one infested tray in each run; each tray contained a group of three cones of Rebel tall fescue for each of the 14 fungal isolates. This pattern was replicated three times. The sources of variation for the pathogenicity experiment analysis were runs and isolates, with the error term being run × isolate.

Statistical analysis. All experiments were analyzed by ANOVA (SAS Institute, Cary, NC). Data for analyses from experiments were obtained by averaging ratings of the three cones, then averaging over the three replications for each isolate or cultivar. Because preliminary analyses of all experiments showed smaller scores and less variation among the noninfested controls vs. larger scores and greater variation in the infested treatments, they were analyzed separately to compare isolates and/or light treatments. The main effects could not be examined because of a light treatment × cultivar interaction, and thus the means for combinations of light treatment and cultivars were examined. Light

Table 1. Identification of *Rhizoctonia* isolates from turf with brown patch symptoms in Arkansas and pathogenicity on tall fescue cv. Rebel

Isolate	Host, county	Anastomosis group[y]	Disease rating[z]
R. solani			
Elliot	*Festuca arundinacea*, Pulaski (tall fescue)	AG-1 IA	2.6
Fields	*F. arundinacea*, Benton	AG-1 IA	2.3
Harris 1	*F. arundinacea*, Benton	AG-1 IA	4.0
Harris 2	*F. arundinacea*, Benton	AG-1 IA	3.6
West 1	*F. arundinacea*, Benton	AG-1 IA	2.4
CH171	*Cynodon dactylon*, Benton (common bermudagrass)	AG-2-2	1.0
CH172	*C. dactylon*, Benton	AG-2-2	1.1
CH72	*C. dactylon*, Benton	AG-2-2	1.0
West 2	*F. arundinacea*, Benton	AG-2-2	1.0
Hudson	*F. arundinacea*, Benton	AG-6	1.4
Binucleate *Rhizoctonia* spp.			
RHCH	*Zoysia japonica*, Benton (Japanese lawngrass)	AG-A	1.2
TFSH	*F. arundinacea*, Washington	AG-A	1.3
558	*Eremochloa ophiuroides*, Cleveland (centipedegrass)	AG-Ba	1.1
R. zeae			
CF-2	*Agrostis palustris*, Logan (creeping bentgrass)		1.1
Control			1.0
LSD among isolates (0.05)			0.8

[y] Determined against known isolates.
[z] Combined data from two experiments. Visual rating scale of 1–5, with 1 = no disease and 5 = dead.

treatment × cultivar interaction means were separated by a protected LSD at 5% probability.

RESULTS

Among the 14 isolates of *Rhizoctonia* obtained from a survey of turfgrasses with brown patch symptoms in Arkansas during 1992 (Table 1), 10 were *R. solani* (five AG-1 IA, four AG-2-2, and one AG-6). One isolate of *R. zeae* was obtained from creeping bentgrass (*Agrostis palustris* Huds.), and three binucleate *Rhizoctonia* spp. isolates were obtained (two AG-A and one AG-Ba). Only the AG-1 IA isolates demonstrated significant pathogenicity (Table 1).

Safari was the only cultivar that had any endophyte present in seedlings. Staining indicated that leaf sheaths from three of 50 Safari plants tested had endophyte (6% infection). ELISA also detected the endophyte in Safari.

Lexan allowed 80% transmission of all wavelengths between 400 and 800 nm (Fig. 1). Light transmitted through cellophane layers of a combination of blue, amber, and green gave similar spectral transmission as leaves from the four deciduous trees. These layers decreased transmission of light from 200 to 500 nm and from 600 to 700 nm. The mean radiation flux for the sun and shade treatments were 419.7 $\mu E \cdot s^{-1} \cdot m^{-2}$ and 87.3 $\mu E \cdot s^{-1} \cdot m^{-2}$, respectively.

All 10 cultivars of shade-grown tall fescue had significantly ($P = 0.05$) greater disease severity than sun-grown plants (Table 2). Disease ratings for noninfested treatments ranged from 1.0 to 1.3, with a mean of 1.2. Several cultivars differed in disease severity between sun and shade environments. Disease severity on shade-grown Safari was significantly greater than on eight other shade-grown cultivars. Sun-grown Apache, Silverado, and Wrangler had significantly more disease than five other sun-grown cultivars. Apache and Wrangler were the most susceptible in sun but among the least susceptible in shade. Hubbard 87 and Shenandoah were the least susceptible among all cultivars in both environments.

For all 10 cultivars, shade-acclimatized plants in infested cones placed in a sun environment immediately after inoculation had significantly more disease than sun-grown plants placed in a shade environment (Table 3). Noninfested disease ratings ranged from 1 to 1.1. When environments were switched, shade-acclimatized Silverado, Safari, and Guardian had significantly greater disease than the other seven cultivars (Table 3). These results were similar to the shade-treated cultivars. Sun-acclimatized Apache had significantly higher disease ratings than the other nine cultivars when the plants were placed in a shade environment (Table 3).

DISCUSSION

R. solani AG-1 IA was isolated most frequently from turf with brown patch symptoms and was the only *Rhizoctonia* spp. that was pathogenic to tall fescue. Martin and Lucas (21) also demonstrated that *R. solani* AG-1 isolates were very aggressive on tall fescue, while *R. solani* AG-2-2 isolates were found to be pathogenic on St. Augustinegrass and other warm-season grasses (16). AG-2-2 was isolated primarily from common bermudagrass displaying brown patch symptoms, but these isolates were nonpathogenic at 28 C on tall fescue. Burpee (7) isolated binucleate *R. cerealis* CAG-1 (AG-D) from symptomatic turfgrass and determined that the optimum temperature for growth was 23 C. In this study, the binucleate *Rhizoctonia* isolates in AG groups A and Ba from symptomatic turfgrass were nonpathogenic.

Shade-grown plants exhibited greater disease severity than sun-grown plants of the same cultivar and were visibly less developed than the sun-grown plants, with fewer, thinner, longer blades and a lighter green color. In addition, shade-grown plants grew slower than sun-grown plants and had fewer tillers and less top and root growth (*unpublished*). This lower physiological activity may account for the increased disease severity found in the shade-grown plants. Physiological changes associated with low light intensity that might influence disease reaction include decreased carbohydrate reserves (30) and thin cell walls with high internal cell water content and high total water potential (11). These

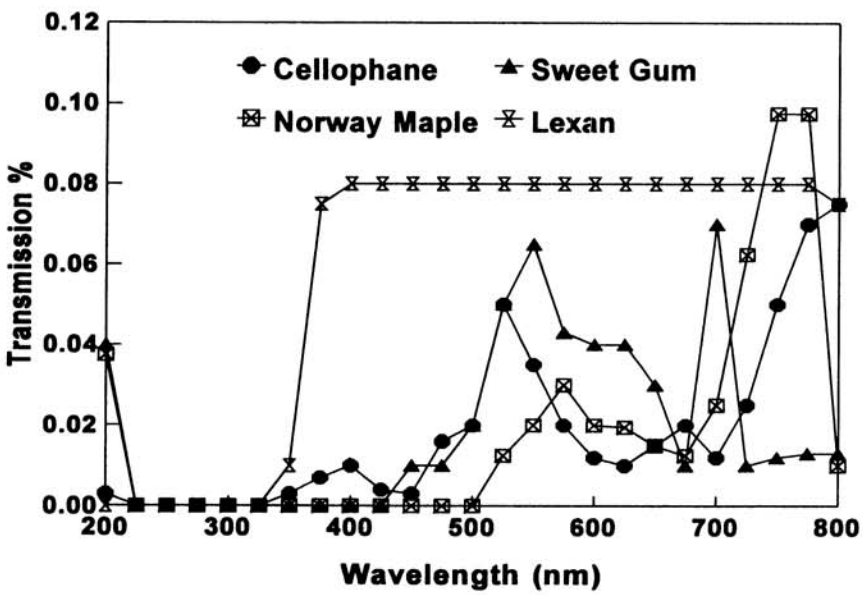

Fig. 1. Light transmission through two deciduous tree leaves, through Lexan polycarbonate ($\times 10^{-3}$), and through a combination of green-, blue-, and amber-colored cellophane ($\times 10^{-1}$).

Table 2. Susceptibility of tall fescue cultivars grown in shade or sun to *Rhizoctonia solani* AG-1 IA

Cultivar	Disease rating[y]	
	Shade	Sun
Apache	3.8 d[z]	3.1 ab
Arid	4.2 c	2.7 c
Finelawn I	4.4 bc	2.7 c
Guardian	4.6 ab	2.8 abc
Hubbard 87	4.0 cd	2.4 c
Kentucky 31	4.4 bc	2.7 bc
Safari	4.9 a	2.6 c
Shenandoah	4.1 cd	2.5 c
Silverado	4.4 bc	3.1 ab
Wrangler	4.2 cd	3.1 a
LSD between light treatments (0.05)	0.5	

[y] Visual rating scale of 1–5, with 1 = no disease and 5 = dead.
[z] Means within a column followed by same letter are not significantly different according to LSD ($P = 0.05$).

Table 3. Influence of shade acclimatization on severity of disease on tall fescue cultivars caused by *Rhizoctonia solani* AG-1 IA

Cultivar	Disease rating[y]	
	Shade-acclimatized	Sun-acclimatized
Apache	4.2 c[z]	3.8 a
Arid	4.6 b	2.1 e
Finelawn I	4.4 bc	3.3 b
Guardian	5.0 a	2.9 c
Hubbard 87	3.5 d	2.3 d
Kentucky 31	3.5 d	3.3 b
Safari	5.0 a	3.0 c
Shenandoah	4.5 b	1.8 f
Silverado	5.0 a	2.2 de
Wrangler	3.3 d	2.4 d
LSD between light treatments (0.05)	0.2	

[y] Combined data from two experiments. Visual rating scale of 1–5, with 1 = no disease and 5 = dead. Shade-acclimatized plants were pretreated in shade treatment but switched into sun treatment after soil infestation; the converse was done for sun-acclimatized plants.
[z] Means within a column followed by same letter are not significantly different according to LSD ($P = 0.05$).

experiments did not take into account any role UV light may have on brown patch severity, since Lexan blocks the transmission of UV light.

Switching the shade or sun-acclimatized plants to the sun or shade growth chambers, respectively, did not change their disease reaction (Table 3). These data indicate that the environment in the shade did not have as great an impact on disease severity as the morphological and physiological effects of low light intensity and changes in light quality. In addition, these morphological or physiological changes were not dramatically altered by changing the light regime at the time of soil infestation, as indicated by a lack of change in disease susceptibility in the acclimatization experiments. Other researchers also have suggested a role for the physiological status of plants grown under low light intensity in disease susceptibility due to the reduction in plant photosynthetic activity (11,12).

Disease susceptibility was not associated with the presence of the endophyte, since all cultivars were free of the endophyte, except for Safari, which had a very low level of infection. Some differences in cultivar reactions were found. Safari was very susceptible in the shade. Safari and Silverado are dwarf cultivars, and their shorter height would leave the foliage closer to the soil surface where the inoculum had been placed. Apache and Wrangler had greater relative susceptibility in the sun, and Hubbard 87 and Shenandoah performed well over both sun and shade environments. No differences in growth including plant weight or tillering under the two environments accounted for relative differences in disease susceptibility among the cultivars evaluated (*unpublished*).

These results show that simulated shading conditions increased brown patch severity. The data suggest that tall fescue cultivars differ in susceptibility to a shade-related disease, brown patch, caused by *R. solani* AG-1 IA. Clarke et al (10) also found differences in susceptibility of tall fescue cultivars to brown patch. Cultivars should be evaluated for disease reaction under both shade and full sunlight.

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