# Turfgrass Species Composition, Resistance Mechanisms, and Management Strategy Impacts on Brown Patch Incidence and Weed Encroachment

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# Turfgrass species composition, resistance mechanisms, and management strategy impacts on brown patch incidence and weed encroachment

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## Abstract

Tall fescue (*Festuca arundinacea* Schreb.) has great utility as a low maintenance turfgrass in the northern and transition zone regions of the United States. However, it is difficult to successfully maintain tall fescue of high quality over consecutive summers because of its susceptibility to the fungal pathogen *Rhizoctonia solani*, which causes the disease brown patch. Not only is brown patch aesthetically unpleasing in a stand of tall fescue but it can also thin out the turf and allow for the encroachment of undesirable weedy species. Cultivar selection, cultural practices, mixing turf species and timing of pesticide applications all can impact the epidemiology of brown patch in tall fescue. Research was conducted in tall fescue to quantify chitinase activity in different cultivars, elucidate the impact of mowing height and nitrogen fertility on brown patch and bermudagrass (*Cynodon dactylon* L.) encroachment, to evaluate seeding mixtures of tall fescue with hybrid bluegrass (*Poa pratensis* x *Poa arachnifera*) on diseases and weeds as well as measuring the impact of the herbicide bispyribac-sodium on brown patch. Chitinase activity was greater in the tall fescue cultivar that was less susceptible to brown patch. In the mowing-fertility studies, cutting tall fescue at 10 cm generally reduced brown patch and bermudagrass encroachment compared to 6 cm. Mixing hybrid bluegrass with tall fescue reduced disease and weed species infestations compared to tall fescue alone. Applying bispyribac-sodium earlier in April resulted in less brown patch and better weed control compared to application in May. Based on this research brown patch severity and subsequent weed species infestations can be reduced by selecting a tall fescue cultivar with a high basal level of chitinase, mowing it at 10 cm and mixing it with a hybrid bluegrass cultivar.

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## Introduction

*Rhizoctonia solani* Kuhn (Piper and Coe, 1919), the causative agent of brown patch or Rhizoctonia blight, is one of the most serious and widespread diseases affecting turfgrass stands (Vargas 2005). *R. solani* infects annual bluegrass (*Poa annual* L.), bermudagrass (*Cynodon dactylon* L. Pers. (Bogdan)), tall fescue [*Festuca arundinacea* (Schreb) synonym *Schedonorus phoenix* (Scop.) Holub], creeping bentgrass (*Agrostis stolonifera* L., syn. *Agrostis palustris*), centipedegrass [*Eremochloa ophiuroides* (Munro) Hack], zoysiagrass (*Zoysia japonica* Steud), and other turfgrass species. Additionally, fungi in the genus *Rhizoctonia* cause diseases in crops ranging from cereals, potatoes, cotton, sugar beets, multiple vegetables, trees, and ornamentals (Pumphrey et al., 1987; Huber et al., 1992). *R. solani* was first identified as a turfgrass pathogen in creeping bentgrass in 1914 (Piper and Coe, 1919). The disease was termed brown patch by F.W. Taylor due to the circular brown patch left by the withering infected leaves.

### Identifying Characteristics/ Taxonomy

The *Rhizoctonia* genus can be categorized and taxa within the genus identified utilizing the asexual stage (anamorph) and the sexual stage (telemorph). Telemorphs occur naturally in *Rhizoctonia* and are labeled as Basidomycota, or imperfect fungi. Discriminating characteristics of this genus include: a sclerotia that is undifferentiated into rind and medulla and an absence of rhizomorphs, conidia, and clamp connections. Taxa within the genus may be identified by number of nuclei (either 2 nucleate per cell or multiple nucleate per cell). *R. solani* is a multinucleate, pathogenic necrotrophic species. *R. solani* isolated on Agar media forms brown colonies with a telomorph of *T. cucumeris* (Burpee and Martin, 1991). Typically, hyphae of *R.solani* isolates are greater than 5 um in diameter. Additionally, *R. solani* may be distinguished from other *Rhizoctonia* species by pectin enzymes analysis. Identification of *Rhizoctonia* species can be achieved both through electrophoretic analyses of pectinase proteins and in conformation of antibodies produced in response to the pectinase. Finally, anastomosis grouping has been utilized as an effective way to scrutinize biotypes within the *Rhizoctonia solani* species.

**Pathogenicity and Symptomology**

The steps of infection consist of a period of inoculum build up, growth of R. *solani* toward the plant, growth of hyphae around the plant upon contact, attachment of the hyphae to the plant, infection structure formation, penetration, and tissue colonization (Dodman et al. 1968). *R. solani* can be present in the environment as basidospores, mycelium or sclerotium. Due to their survival capability, sclerotia (thick-walled undifferentiated melanized cells) are typically the source of inoculums. Favorable moisture and temperature conditions allow for the sclerotia to germinate and form mycelial threads. The hyphae of the mycelium then grow towards the plant (Kerr, 1956). Rate of pathogen growth may be correlated with quantity of amino acid, carbohydrates, and other nutrients exuded by the plant (Nour El Dein and Sharkas 1964; Martinson 1965; Reddy 1980).

Upon contact with the plant, rounded *R. solani* hyphae grow over the plant surface. Actual infection begins when the hyphae flatten out and press into the epidermal cells of the plant (Armentrout and Downer 1987; Christou; 1962). Hyphal internodes shorten and form side branches at right angles, which are a distinguishing characteristic of *R. solani*. Additionally, branching of hyphae can form tightly-packed, dome-shaped infection cushions that adhere tightly to the surface of the plant.

The process of penetration of *R. solani* begins through the formation of thin infection pegs. These infection pegs are formed from closely-adhered, swollen hyphal tips (Fukutomi and

Takada, 1979). It is believed that the hyphal tips function to find weak sites of the plant in which to initiate penetration (Matsuura, 1986). Subsequent penetration occurs when the thin infection peg exerts enough pressure on the outside of the plant. In addition to mechanized pressure, enzymatic activity aides in penetration of the host plant. Cutinase and pectin-degrading enzymes are produced by *R. solani* to destroy the cuticle and other host plant tissue.

Tissue colonization is the last step of the infection cycle and involves the degradation of cell walls and inter-cellular damage through the secretion of hydrolytic enzymes prior to advancement of hyphae. Hyphae extend to all tissues in the host plant, reaching to the vascular tissue. Infected cells have collapsed cytoplasm, destroyed organelles, and have undergone plasmolysis (Lai and Weinhold, 1968). As the infection becomes more severe, mitochondria become disorganized and the nuclear envelope begins to disintegrate in the cell.

In turfgrass infected with *R. solani*, leaves initially appear dark and water saturated; subsequently, the infected leaves dry out, wither, and turn a dark brown. Sclerotia of brown and black color may be found beneath the leaf or on roots. Brown-beige lesions are formed on the leaves. Under conditions of high humidity, a ring of mycelium may form on the outer regions of the diseased area and is termed a smoke ring. Under low levels of infection, only a few plants are killed. However, if the disease goes unchecked and no attempt is made to control it, many plants will be damaged. The loss of plants and spread of disease is most profound on low cut turfs such as golf course greens and fairways. The turf infected by brown patch is aesthetically unpleasing and will drastically affect the playability of a golf course green. Additionally, in warm weather, algae can encroach on the diseased, weakened turf, making recovery of the green very difficult. Overall, symptoms of brown patch differ according to turfgrass species, mowing height, irrigation practices, and degree of fertilization (Burpee and Martin 1991).

## Conditions Favoring *R. solani*

*R. solani* survives as sclerotia in adverse conditions in the soil. When temperatures in the soil reach more than 15 C, sclerotia start to germinate, initiating fungal growth. Parasitization of the grass foliage is not initiated until the temperature is about 30 C. Additionally, high humidity and nighttime temperatures of no lower than 21 C are required for the fungus to parasitize foliage (Rowell 1951). Typically, *R. solani* is a weak pathogen that does not seriously damage host grass plants. However, when the plant suffers heat stress, *R. solani* opportunistically infects the host grass. Additionally, applications of nitrogen in hot, humid conditions provide a favorable environment for an outbreak of *R. solani* (Bloom and Couch, 1960).

## Control

*R. solani* can be controlled culturally by limiting nitrogen application in hot, humid conditions, limiting irrigation or not irrigating at all in the afternoon and removing leaf guttation in the morning (Bloom and Couch, 1960). Phosphorus and potassium levels should be maintained normally in contrast to the reduced nitrogen levels. Chemical control has included the use of aromatic hydrocarbon, carboxamide, benzimidazole, dicarboximide, triazole, imidazole, pyrimidine, and phenylpyrrole fungicides, which have all been shown to have varying degrees of effectiveness (Cotterill et al. 1989). Regardless of the fungicide mode of action, a preventative approach to *R.solani* control is better than a curative approach regarding fungicide application. The effectiveness of the fungicide in the soil will vary with soil type. Fungicides are most effective in light-textured sandy loam soils; alternatively, more fungicide is needed to adequately control *R. solani* in heavy-textured clay or clay loam soils. Other soil traits influencing fungicide effectiveness include pH, temperature, moisture, microbial activity, salinity, and nutrient abundance.

Despite the short term effectiveness of traditional fungicide applications, fungicide use is undesirable over a prolonged period of time. Fungicides have to be sprayed more frequently and in greater quantities than herbicides or insecticides, thus application is not always economical. Additionally, on a macro scale, chemical applications would not be acceptable if they cause adverse effects to the environment or if they cause rapid development of resistance.

### Tall Fescue- Introduction and Identifying Characteristics

Tall fescue is a cool-season perennial turfgrass originally from Europe and now can be found in low, damp pastures and meadowlands throughout Europe, North Africa, and North America (Beard 1973). Tall fescue grows vigorously in the spring and fall due to its extensive root system, which also helps withstand drought. The plant has a bunched-type growth habit, spreading by erect tillers that terminate to an inflorescence. Individual tillers can reach as high as one meter and are characterized by dark green, broad leaves with serrated margins. The inflorescence consists of a compact panicle 10 cm long with lanceolate spikelets. The seeds can be identified by their size (4-7 mm long) and their elliptic shape.

### Utility and Nutrition of Tall Fescue

Tall fescue has great utility as a turfgrass in the transition zone climate. It can be used in multiple situations such as home lawns, athletic fields, golf course roughs and other low maintenance turfgrass areas (Watkins and Meyer 2004). Tall fescue exhibits adequate shade tolerance, is adapted to a wide range of soils, and can be cut at 3.8 cm or higher making it a reliable choice for the aforementioned situations. Characteristics that favor its use among homeowners include its drought tolerance, insect resistance, high turf density, and relatively low fertilizer requirements (Watkins and Meyer 2004). To optimize the aesthetic qualities of tall fescue, at least 171 kg ha$^{-1}$ of nitrogen per year should be applied (Bremer et al. 2006).

## Susceptibility of Tall Fescue to Rhizoctonia solani

Tall fescue is resistant to most diseases; however, the pathogen *Rhizoctonia solani* can inflict significant damage to this turfgrass species. There is no known cultivar that exhibits 100% resistance to brown patch, the disease caused by *R. solani*. Nevertheless, tall fescue genotype does influence the degree of tolerance. Tall fescue cultivars with ideal agronomic traits such as narrow blades and dense canopies have been associated with increased susceptibility to brown patch. The increased canopy density creates elevated levels of humidity, which extend the period of time the leaf is wet, favoring events for initiation of the disease cycle (Giesler et al. 1994). Management strategies can contribute to the disease infestation of a cultivar. Various resistant tall fescue cultivars responded differently to shorter mowing practices when they were inoculated with *R. solani*. The cultivars that did not increase in susceptibility to disease at lower mowing heights may have a mechanism which allows for quick recovery after initial necrosis rather than a defense against the initial infection. Elucidation of the molecular pathways involved in response to *R. solani* infection could be the next step for turfgrass pathologists.

## Heat-Tolerant Hybrid Bluegrass - Introduction and Identifying Characteristics

Recently, heat-tolerant hybrid bluegrass (*Poa pratensis* L. x *Poa arachnifera* (Torr).) cultivars have been developed (Read et al., 1999). Hybrid bluegrass has the desirable qualities of Kentucky bluegrass i.e., color, brown patch resistance, and utility but was bred to have increased heat and drought tolerance. Hybrid bluegrass has the same distinguishable boat-shaped tip as Kentucky bluegrass; additionally, hybrid bluegrass grows 45 to 61 cm un-mowed, and spreads through rhizomes and tillers for a quality dense turf (Abraham et al. 2004). Several cultivars of hybrid bluegrass have been introduced, including ‘Thermal Blue’, ‘Thermal Blue Blaze’,’ Dura Blue’, and ‘Solar Green’(http://www.scottsproseed.com/news/bluegrass.cfm).

## Utility and Nutrition of Hybrid Bluegrass

Hybrid bluegrass exhibits a superior range of adaptation compared to traditional cool-season grass cultivars; it can be grown in lawns as far south as Atlanta and Dallas. The rhizome system allows for good wear tolerance and recovery with reduced need for reseeding as compared to tall fescue. Additionally, hybrid bluegrass exhibits greater shade tolerance and resistance to brown patch when compared to tall fescue. 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 NaCl 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 (Su et al., 2007). Electrolyte leakage was significantly less in Thermal Blue hybrid bluegrass than Kentucky bluegrass and tall fescue under conditions of high temperature and drought. Finally, Thermal Blue hybrid bluegrass exhibited greater above-ground biomass than Kentucky bluegrass and tall fescue under moderate and high temperatures (Su et al. 2007). Hybrid bluegrass is one option when choosing a cool-season grass to grow in the transition zone to protect a lawn from high temperature damage. Though hybrid bluegrass has many advantages over tall fescue under warmer conditions, it does require more nitrogen for establishment and maintenance and it establishes slower. One of our research objectives focused on seeding mixes of tall fescue and hybrid bluegrass to look at initial establishment of the two species, as well as comparing their relative abundance in mixtures 1, 2, and 3 years after seeding.

## Crabgrass

Large, smooth, and southern crabgrass [*Digitaria sanguinalis (L.) Scop., D. ischaemum Schreb. Ex Muhl, D. ciliarsis (Retz.) Koel.*] are opportunistic and very problematic weeds in turf situations. These summer annuals may be found in lawns under a range of management conditions, including where the turf has been thinned out by disease or cut too short. Identifying characteristics of crabgrass species include the mat-like appearance due to rooting at the nodes, a membranous ligule, and purple stems, which grow up to 38 cm long (Fermanian and Michalski, 1989). The leaves are a dull green with slightly rough margins. Leaves can reach a length of 10 cm and a width of 1.8 cm. The flowers, which are produced in August and September, consist of purple spikes about 10 cm long. These crabgrass species reproduce via seed.

Establishment and maintenance of a strong competitive turf, not irrigating excessively, limiting summer fertilization, and if possible avoiding short mowing will help reduce the incidence of crabgrass and should be considered before herbicide application (Busey, 2003). However, chemical control is often utilized to prevent or eradicate crabgrass infestations. Applications of preemergence herbicides are the primary option for control. Common preemergence herbicides include the mitotic inhibiting herbicides prodiamine, pendimethalin, trifluralin, and dithiopyr (Vaughn and Lehnen 1991), the PPO-inhibiting herbicide oxadiazon, and ethofumesate. Postemergence herbicides such as MSMA, quinclorac, and fenoxaprop-p-ethyl may also be utilized to control crabgrass species.

### Annual Bluegrass

Annual bluegrass (*Poa annua* L.) is a common and troublesome weed throughout the world in turfgrass environments (Hall and Carery, 1992). Ecotypes of annual bluegrass are adaptive to diverse areas from golf course putting greens to sod production areas. (McElroy et al., 2002). The light green color and abundant seedhead yield of annual bluegrass results is unsightly and uneven turfgrass appearance. Annual bluegrass is especially problematic in overseeded tall fescue where there are very limited herbicide options for control of annual bluegrass.

A potential postemergence herbicide that could control annual bluegrass is bispyribac-sodium (sodium 2-6-bis[(4,6-dimethoxy-2-pyrimidinyl)oxy]benzoate)**,** a herbicide that inhibits the acetolactase synthatase (ALS) enzyme in susceptible plants. ALS catalyzes the condensation of two pyruvate molecules to yield acetolacate and in a parallel reaction drives the condensation of pyruvate and 2-ketobutyrate to form acetoydroxyacid (Sing and Shaner, 1995). Valine, leucine and isolecine are branched chain amino acid that are synthesized downstream of the ALS catalyzed reactions. Symptoms of ALS inhibiting herbicides include a cessation of mitosis, reduction in photosynthate transport and, eventual starvation of the plant due to a lack of branched chain amino acids.

### Effect of Brown Patch on Tall Fescue and Crabgrass Encroachment

Preemergence herbicides have been shown to have decreased efficiency for crabgrass control in tall fescue inoculated with brown patch (Ferrel et al. 2003). The decreased efficiency may be due to turf thinning by disease, resulting in an ideal environment for crabgrass germination. Studies showed that fungicide applications increased the efficiency of preemergence herbicides in tall fescue plots inoculated with brown patch, but did not have a synergistic effect on crabgrass control on plots that were not inoculated (Ferrel et al. 2003). Additionally Ferrel et al. found that oxadiazon and prodiamine were more effective at controlling smooth crabgrass in inoculated plots that incorporated fungicides rather than pendimethalin. The difference in control was attributed to the shorter half-life of pendimethalin relative to the other herbicides. Future research should focus on different environmental conditions with more combinations of fungicides and herbicides in order to determine their effect on crabgrass control in turfgrass plots infested with brown patch.

## Gene Expression in Response to *Rhizoctonia solani*

There is little known about the specificity of enzyme expression patterns related to the pathogenicity of *Rhizoctonia solani*, thus the details of enzyme expression involved in plant defense have not been completely elucidated. It is believed that the mechanisms influencing resistance is a quantitative trait controlled by multiple genes (Sha and Zhu 1989). Transcriptome analysis performed on rice revealed differential gene expression between plants inoculated with *Rhizoctonia solani* and plants that were not inoculated. Additionally, expression of proteins that act as transcription factors differed between the control and inoculated plant. Transcription factors are proteins involved in recruiting the enzyme RNA polymerase to a region of DNA, which will be transcribed to RNA. In the inoculated plants, 340 different transcription factors were identified. Proteins that were uniquely expressed in inoculated plants include endo-chitinase, non-specific lipid transfer proteins, phenylalanine ammonia lyase, metallothionein protein, serine/threonine kinase, ubiquitin–conjugating enzyme, Ras related protein and Zinc finger domains (Venu et al. 2007). Overall, there was more expression of genes related to metabolism of cofactors, lipid metabolism, signal transduction, and nucleotide metabolism in inoculated compared to control plants. There was less expression of genes relating to energy metabolism, cell growth, cell death, amino acid metabolism, replication, and repair in the inoculated plants than the control (Venu et al. 2007).

### Chitinase and Glucanase: Role in Pathogen Defense

Typically characteristics that aid in pathogen resistance are controlled by multiple genes; nevertheless, increased expression of certain proteins such as chitinase and glucanase have been correlated with resistance to *R.* solani (Shrestha et al. 2008). β-1,3-glucanase is an enzyme that is able to degrade β-1, 3-glucan, a major component of fungal cell walls (Keen and Yoshikawa, 1983). The direct degradation of the β-1, 3-glucans in the fungal cell wall results in cell lysis. The subsequent release of bioactive cell wall fragments may then induce other plant defense reactions. Overexpression of β-1, 3-glucanase genes have been shown to increase resistance to fungal pathogens in transgenic plants (Dong et al., 2007). Chitinases may be found in acidic and alkaline forms. Chitinase degrades free chitin, which will become an integral component of the fungal cell wall. Additionally, chitinase binds to chitin on the fungal cell wall, which inhibits fungal growth. Hydrolysis of the chitin in the cell wall leads to the accumulation of chitin oligosaccharides. These oligosaccharides act as elicitors for the synthesis of plant proteins involved in pathogen defense.

Chitinase activity has been correlated with resistance to *R. solani* in several plants (Metraux et al. 1991). Rice cultivars that were moderately resistant to *R. solani* constitutively expressed chitinase levels more than the susceptible control before infection (Shrestha et al., 2008). Chitinase levels increased at least 24 hours after inoculation in the resistant cultivars and 36 hours in the sensitive cultivar. Additionally, more chitinase was expressed after infection in the resistant cultivars than the susceptible control.

## Research Objectives

### Objective 1- Analysis of Tall Fescue and Hybrid Bluegrass Seeding Combinations for Prevention of Disease and Weed Encroachment.

Methods: Research was conducted to find optimum seeding rate combinations for 'Greenkeeper' tall fescue and 'Thermal Blue Blaze' hybrid bluegrass. Plots 4.8 m x 4.8 m were seeded with 4 treatment rates: 302.4 kg ha$^{-1}$ Greenkeeper alone, 109 kg ha$^{-1}$ Thermal Blue Blaze alone, 263 kg ha$^{-1}$ Greenkeeper with 29 kg ha$^{-1}$ Thermal Blue Blaze, and 151 kg ha$^{-1}$ Greenkeeper with 55 kg ha$^{-1}$ Thermal Blue Blaze. Each seeding treatment was replicated 4 times in a Randomized Complete Block Design (RCBD). Tiller counts, sod strength, weed cover and disease ratings were taken.

### Objective 2- Quantification of Chitinase Activity in Tall Fescue and Hybrid Bluegrass

Methods: Multiple tall fescue varieties and Thermal Blue Blaze hybrid bluegrass were maintained in a greenhouse. Half of the plants of each grass species were inoculated with *R. solani*. The experimental design was a completely randomized (CRD) with sampling, grass type, and inoculation being fixed effects and replication being random. A crude protein extraction was performed on leaf tissue of healthy and inoculated plants from all grasses. Protein concentrations were determined using the Bicinchonic Acid (BCA) method (Smith et al. 1985). Subsequently, a standard colorimetric method was utilized to determine chitinase activity (Wirth and Wolf 1990).

### Objective 3- Analysis of Tall Fescue Mowing Height on Bermudagrass Encroachment and Disease Severity.

Methods: Research plots containing tall fescue were subjected to a factorial split-plot treatment of 2 mowing heights (6 and 10 cm) and 3 levels of fertility (49, 171, or 220 kg N ha$^{-1}$

annually). Dependent variables were bermudagrass, disease severity, crabgrass and turf cover. The experiments were performed summers of 2008, 2009, and 2010.

### Objective 4- Determination of Physiological Mechanisms Causing Increased Susceptibility to *R. solani* in Tall Fescue Treated with Bispyribac-Sodium. Optimizing Bispyribac-Sodium Application Timing for Maximum Annual Bluegrass Control and Reduced Brown Patch Severity.

Methods: Tall fescue research plots 2.1 m x 3.0 m were subjected to a factorial treatment of bispyribac-sodium applied at 37 or 74 grams per hectare on April 22nd or May 22nd with a repeat application two weeks later. Visual assessments of annual bluegrass populations and percent brown patch severity were taken. In greenhouse studies chitinase activity and growth variables were taken from tall fescue treated with bispyribac-sodium.

# Literature Cited

Armentrout, V.N. and A.J. Downer. 1987. Infection cushion development by *Rhizoctonia solani* on cotton. Phytopathology. 77:619-623.

Beard, J.B. 1973. Turfgrass Science and Culture. Englewood Cliffs, NJ: Prentice Hall. P. 58.

Bloom, J.R., and H.B. Couch. 1960. Influence of environment on diseases of turfgrass. I. effect of nutrition, pH, and soil moisture on *Rhizoctonia* brown patch. Phytopathology. 50: 532-534.

Bremer, D.J., K. Su, S.J. Keeley, and J.D. Fry. 2006. Performance in the transition zone of two hybrid bluegrasses compared with Kentucky bluegrass and tall fescue. Available at www.plantmanagementnetwork.org/ats/. Appl. Turfgrass Sci. DOI 10.1094/ATS-2006-0808-02-RS.

Burpee, L. and B. Martin. 1991. Biology of *Rhizoctonia* species associated with brown patch symptoms. Plant Disease. 76:112-117.

Busey, P. 2003. Cultural management of weeds in turfgrass: A review. Crop Sci. 43:1899-1911.

Cotterill, P.J., D.J. Ballinger, and J.F. Kollmorgen. 1989. Use of three screening techniques for the evaluation of fungicides to control Rhizoctonia root rot of wheat. Ann. Appl Biol. 115: 22-235.

Christou , T. 1962. Penetration and host-plant relationships of *Rhizoctonia solani* in the bean plant. Phytopathology. 52:291.

Dodman, R.L., K.R. Baker, and J.C. Walker. 1968. A detailed study of the different modes of penetration by *Rhizoctonia solani*. Phytopathology 58: 1271-1276.

Dong, S., L.P., Treadway, H.D. Shew, G.L. Wang, E. Sivamani, and R. Qu. 2007. Resistance of tall fescue to two major fungal diseases. Plant Science. 173: 501-509.

Fermanian, T.W., and R.S. Michalski. 1989. Weeder: An advisory system for the identification of grasses in turf. Agron. J. 81: 312-316.

Ferrel, 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.

Fukutomi, M., and H. Takada. 1979. Ultrastructure of infection process of *Rhizoctonia solani* Kuhn in cucumber hypocotyls. Ann. Phytopath. Soc. Jpn 45:453-462.

Giesler, L.J., G.Y. Yuen, and G.L. Hoarst. 1996. Tall fescue canopy density effects on Brown Patch Disease. Plant Dis. 80: 384-388.

Hall, J.C., and C.K. Carey. 1992. Control of annual bluegrass (*Poa annua*) in Kentucky Bluegrass (*Poa pratensis*) turf with linuron. Weed Technol. 6:852-857.

Huber, D.M., E.P. Christmas, L.J. Herr, T.S. McCay-Buis and R. Baird. 1992. *Rhizoctonia* Crown Rot of canola in Indiana. Plant Dis. 76:1251-1253

Keen, N., and M. Yoshikawa. 1983. β-1,3-Endoglucanase from soybean releases elicitor active carbohydrates from fungal cell walls. Plant Physiol. 71:460–5.

Kerr, A. 1956. Some interactions between plant roots and pathogenic soil fungi. Aust. J. Biol. Sci. 9:45-52.

Lai, M-T. and A.R. Weinhold. 1968. Permeability changes in *Phaleolus aureus* associated with infection by *Rhizoctonia solani*. Phytopathology. 58:40-245.

Martinson, C.A. 1965. Formation of infection cushions by *Rhizoctonia solani* on synthetic films in soils. Phytopathology 55:129 (abst).

Matsuura, K. 1986. Scanning electron microscopy of the infection process of *Rhizoctonia solani* in leaf sheats of rice plants. Phytopathology 76:811-814.

McElroy, J.S., R.H. Walker, and E.V.Santen. 2002. Patterns of variation in Poa annua as revealed by canonical discriminant analysis of life history traits. Crop Sci. 32: 513-517.

Metraux J.P., P.A. Goy, T. Staub, J. Speich , A. Steinmann, J. Ryals, E. Ward. 1991. Induced systemic resistance in cucumber in response to 2,6-dichloro-isonicotinic acid and pathogens. *In*:Hennecke H, Verma DPS, eds. Advances in Molecular Genetics of Plant-Microbe Interactions Vol. 1.Dordrecht: Kluwer Academic Publishers, p. 432-439.

Nour El Dein, M.S., M.S. Sharkas. 1964. The pathogenicity of *Rhizoctonia solani* in relation to different tomato root exudates. Phytopathol. 51:285-290.

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

Pumphrey, F.V., D.E Wilkins, D.C. Hane, and R.W. Smiley. 1987. Influence of tillage and nitrogen fertilizer of Rhizoctonia root rot (bare patch) of winter wheat. Plant Dis. 71: 125-127.

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

Reddy, M.N. 1980. Studies on groundnut hypocotyl exudates and the behavior of *Rhizoctonia solani* in influencing the disease. Plant Soil 55: 445-454.

Rowell, J.B. 1951. Observation on the pathogenicity of *Rhizoctonia solani* on bentgrass. Plant Dis. Reptr. 35:240-242.

Sha, X.Y. and L.H. Zhu. 1989. Resistance of some rice varieties to sheathblight (ShB). Int Rice Res. Newslett. 15:7–8.

Shrestha, C.L., I. Ona, S. Muthukrishnan, and T.W. Mew. 2008. Chitinase levels in rice cultivars correlate with resistance to the sheath blight pathogen *Rhizoctonia solani*.

Eur. J. Plant. Pathol. 20:69–77.

Sing, B.K., and D.L. Shaner. 1995. Biosynthesis of branched chain amino acids: From test tube to field. Plant Cell. 7: 935-944.

Smith, P. K, R. L Krohn, G. T. Hermanson, A. R. Mallia, & F. H. Gartina. 1985. Measurement of protein using bicinchoninic acid. Analytical Biochemistry. 150: 76–85.

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 .

Vaughn, K.C. and L.P. Lehen. 1991. Mitotic disrupting herbicides. Weed Sci. 39: 450-457

Venu, R.C., Y. Jia, M. Gowda, M.H. Jia, C. Jantasuriyarat, E. Stahlberg, H. Li, A. Rhineheart, P. Boddhireddy, P. Singh, N. Rutger, D. Kudrna, R. Wing, J.C. Nelson, and G.L. Wang. 2007. RL-SAGE and microarray analysis of the rice transcriptome after *Rhizoctonia solani* infection. Mol. Genet. Genomics. 278: 421–431.

Watkins, E. and W.A. Meyer. 2004. Morphological characterization of turf type tall fescue genotypes. HortScience. 39: 615-619.

Wirth, S.J. and G.A. Wolf. 1990. Dye labeled substrates for the assay and detection of chitinase and lysozyme activity. J. of Microbiol Methods. 12: 197-205.

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

## Abstract

Tall fescue (*Festuca arundinacea*) and hybrid bluegrass (*Poa pratensis* L. x *Poa arachnifera*) can both be successfully grown in the transition zone. However, each grass has limitations. Tall fescue is susceptible to the fungal pathogen *Rhizoctonia solani* (brown patch) while 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, sod strength and species ecology. The seeding combinations had less weed infestation 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 eventually reduced tall fescue stand and led to a species shift favoring hybrid bluegrass in the seeding combinations. Seeding combinations of tall fescue and hybrid bluegrass are beneficial from an epidemiological stand point because they reduce disease and weed infestations compared to monocultures of the species. From an agronomic standpoint the seeding combination favoring tall fescue provided the densest turf, while the seeding combination favoring hybrid had the greatest sod strength.

## Introduction

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 3 billion liters of gasoline, $700 million of pesticides and $5.2 billion of fossil fuel-derived fertilizers are used to manage lawns. Individual homeowners manage small areas of turfgrass. Therefore, adaptations of proper cultural practices are important to optimize the environmental, economic, utility 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. The transition zone stretches from central New Jersey to the pan-handle of Texas. Two turf grasses that have desirable agronomic qualities and can be grown in the transition zone are tall fescue [*Festuca arundinacea* Shreb synonym *Schedonorus phoenix* (Scop.) Holub] and hybrid bluegrass (*Poa pratensis* L. x *Poa arachnifera* Torr.).

Tall fescue provides great utility as a lower maintenance turfgrass in the transition zone compared to other cool-season grasses. The plant's well-developed root zone, 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 *Rhizoctonia solani* Kuhn (Piper and Coe, 1919), which causes the disease brown patch in the summer months. No tall fescue cultivars are immune to *Rhizoctonia solani*; thus, applications of fungicides are necessary to effectively reduce brown patch spread (Yuen et al., 1994). Brown patch not only decreases 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.

Hybrid bluegrass may be an alternative cool season grass to grow in the transition zone. Hybrid bluegrass 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 to traditional cool-season grass cultivars; it can be grown in lawns as far south as Atlanta and Dallas. The rhizome system allows for good wear tolerance and recovery with reduced need for reseeding compared to tall fescue. Hybrid bluegrass' shade tolerance and resistance to brown patch compares favorably to tall fescue. 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 NaCl 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 and tall fescue. Hybrid bluegrass use is limited by its slow establish rate, higher nitrogen requirements, and susceptibility to diseases such as dollar spot (*Sclerotinia homoeocarpa* Bennet) and summer patch (*Magnaporthe poae*). Mixing hybrid bluegrass with tall fescue may increase the quality of the turf stand when compared to monocultures of these species.

Seeding mixtures of different species increases the genetic variability of a turfgrass stand. Environmental stresses such as drought, nutrient availability, salinity, cold, heat, 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. The best defense against an ubiquitous pathogen such as *Rhizoctonia 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 to the monoculture of tall fescue. Establishment period may be an important consideration when selecting turfgrass species to mix. 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 due to 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 as well. Turfgrass species with contrasting colors would not be aesthetically pleasing in a polystand. The grasses should be able to tolerate similar ranges of mowing and fertilizer.  Mixing turf type tall fescue with hybrid bluegrass has potential to become a successful polystand. Though 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.

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

Research was conducted at the Virginia Tech Hampton Roads Agricultural Research and Extension Center located in Virginia Beach, Virginia. The study was established in October of 2006 and was repeated in an adjacent area in October of 2008. Plots were 4.8 m x 4.8 m and there were 4 seeding treatments 1) 302 kg $ha^{-1}$ ‘Greenkeeper’ tall fescue, 2) 110 kg $ha^{-1}$ ‘Thermal Blue Blaze’ hybrid bluegrass, 3) 264 kg $ha^{-1}$ Greenkeeper with 29 kg $ha^{-1}$ Thermal Blue Blaze, and 4) 151 kg $ha_{-}^{1}$ Greenkeeper with 55 kg $ha_{-}^{1}$ Thermal Blue Blaze. The seed count ratio in treatment 3 was 1.9 tall fescue: 1.0 hybrid and will be referred to as 1.9TF:1HB. The seed count ratio in treatment 4 was 1.0 tall fescue: 1.8 hybrid bluegrass and will be referred to as 1TF: 1.8HB. Each treatment was replicated 4 times in a randomized complete block design (RCBD). All plots were regularly mowed at 10 cm twice per week and received 171 kg of N applied per hectare annually in October and March. Plots were irrigated as needed to sustain active growth. No preemergence herbicides or fungicides were applied. Clopyralid was applied 1.5 years after establishment for broadleaf weed control. Tiller counts of hybrid bluegrass and tall fescue species were taken biannually for 3 years in March and October using a cup cutter 10 cm 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 weight of all tillers in a 10 cm diameter sample. Sod strength was measured in November of 2010 in the first study and in March of 2011 for the second study. Three square pieces of sod 0.5 m x 0.5 m wide and 0.05 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 visual estimations of weed species percent cover, turfgrass percent cover and disease severity ratings were estimated visually as a percentage of the entire plot periodically for four years. Smooth crabgrass was rated in September; purple deadnettle was rated in November, while henbit and Persian speedwell were rated in March annually. Turfgrass cover was rated annually in November. Brown patch severity was rated annually in August.

### Data Analysis

Data were subjected to ANOVA ($\alpha$= 0.05) using mixed model methodology (Statistical Analysis software v. 9.1, Cary NC). Analysis of variance was conducted separately for each individual trial because of the longer analysis in the first compared to the second trial. The first study was analyzed over 5 years while the second study was analyzed over 3 years. The main plot factor of seeding treatment was considered a fixed effect and replications were considered random.

## RESULTS AND DISCUSSION

### Turfgrass Cover

In study 1, seeding with only HB resulted in 40% percent cover in November of 2006 (Table 1). Tall fescue and TF:HB seeding combinations had significantly more turf cover during the first month of establishment. One year after seeding the monoculture of hybrid bluegrass had 58% cover, which was significantly less cover compared to the other seeding treatments (Table 1). One year after seeding, the monoculture of tall fescue and the two seeding combinations had approximately 90% turf cover. Two years after seeding there was still lower cover in the monoculture of HB compared to the other seeding treatments; however, differences among treatments for percent turfgrass cover were not as large as previous rating dates. 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 disease reducing turf cover over time. Because tall fescue exhibits a bunched-type growth habit it is unable to recover when the stand becomes thinned out. Percent turfgrass cover in the monocultures 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 monocultures.

Additions of a rhizomatous grass such as hybrid bluegrass or Kentucky bluegrass to tall fescue results in a polystand that has good wear tolerance and recuperative ability. Tall fescue essentially acts as a nurse crop and reduces weed competition. Hybrid bluegrass provides recuperative ability after the establishment period, allowing for increased turf coverage. Four years after establishment, there was no significant differences among seeding treatments for percent turfgrass cover, although numerically the seeding combinations had greater turfgrass cover compared to both monocultures. Nevertheless, the percent turfgrass cover in the seeding combinations at the end of the study is unacceptable for most lawns. More inputs such as preemergence herbicides may increase the benefits of growing 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 HB 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 seeding combinations. However, at one and two years after seeding, turf cover was higher in the seeding combinations compared to the monoculture of tall fescue. The quicker recession of tall fescue turf cover in study 2 (established 2008) compared to study 1 (established 2006) may be attributed to severe brown patch disease in the summer of 2009, which may have thinned out tall fescue 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 HB but the lesions were on the crabgrass plants that had infested the monoculture of hybrid bluegrass.

Brown patch was more severe in 2009 than in 2008 or 2010. In study two, the monoculture of TF had significantly more brown patch when compared to the other seeding treatments in August of 2009. The monoculture of TF contained 29% and 19% brown patch in August of 2009 and 2010, respectively (Table 4). Brown patch in the seeding combinations ranged between 4% and 11% from both years while minimal brown patch was observed in the monoculture of HB in 2010.

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 micro-environment, which could impact disease spread as well. Plant attributes such as leaf thickness and canopy characteristics modify the microclimate towards less favorable conditions for pathogen growth, which can suppress certain diseases.

The epidemiological benefits of mixing hybrid bluegrass and tall fescue were noticeable in these studies. Brown patch severity was less throughout the summers in combinations stands when compared to the monoculture of tall fescue. Though 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. Brown patch severity during the summer of 2009 was the highest of all years in the study.

**Weed Cover**

One month after study 1 was established, plots seeded with only HB contained 23% purple deadnettle, significantly more than the other seeding treatments (Table 5). One year and two years after establishment, plots seeded with only hybrid bluegrass contained greater purple deadnettle cover when compared to other seeding treatments (Table 5). However, three years after establishment, the tall fescue monoculture had the greatest purple deadnettle cover while the hybrid bluegrass monoculture only had 15% purple deadnettle cover. In plots containing TF, brown patch in August of 2009 was positively correlated with purple deadnettle cover (R value of 0.79) and negatively correlated with turfgrass cover in November of 2009 (R value of -0.81).

Purple deadnettle cover in the seeding combinations ranged between 8% and 10% three years after establishment. Four years after establishment the monocultures had more purple deadnettle cover than the seeding combinations

Similar trends were observed in study 2. The highest purple deadnettle rating observed in the HB-alone plots was 33% (Table 6). Until 2010 purple deadnettle cover was higher in the monocultures of HB compared to 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 study 1 was 40%, which was significantly more than any other treatment (Table 5). Plots seeded with only HB had significantly more crabgrass when compared to other seeding treatments at two and three years after establishment. However, four years after establishment the monoculture of TF had 27% crabgrass cover, which was significantly more crabgrass cover than the 10% observed in the seeding combinations. In study 2, smooth crabgrass cover was highest in the monoculture of HB (Table 6). Smooth crabgrass cover was numerically lower in the seeding combinations than the monocultures of TF.

Percent henbit cover did not significantly differ among treatments on the March rating date for 2007. The range of percent henbit cover in 2007 was 5% to 8% (Table 7). In 2008, plots seeded with the monoculture of HB were covered in 35% henbit, which was significantly greater than the percent cover observed in the monoculture of tall fescue and seeding combinations. In March of 2009 there was less henbit observed in the monoculture of HB than in 2008. However, the 19% henbit cover observed in plots seeded with the monoculture of HB was still significantly greater than the henbit cover in plots seeded with the other treatments. In 2010, the monocultures of HB and tall fescue tended to have more henbit than the seeding combination treatments. In 2011, numerically higher amounts of henbit were observed in the tall fescue monoculture than in the other three treatments.

In March 2007 of study 1, percent Persian speedwell cover did not significantly differ among seeding treatments (Table 7). Plots seeded with only HB contained 12% Persian speedwell cover in March of 2008, which was significantly greater than any other seeding treatment. Similar ratings were recorded in March of 2009 as March of 2008. In March of 2010 the monocultures of HB and TF each contained 13% Persian speedwell, which was significantly greater than the 6% and 7% Persian speedwell covering seeding combinations 1.9TF:1HB and 1TF:1.8HB, respectively. In March of 2011, Persian speedwell cover was higher in the monoculture of TF compared to the other seeding treatments. In study 2 percent Persian speedwell cover did not significantly differ among the treatments in March of 2009 or 2011 (Table 8). In March of 2010, the plots that were seeded with the monoculture of hybrid bluegrass contained the most Persian speedwell.

Tillman (1997) theorized that polystands are more stable over time because of the inverse relationship between diversity of a stand and how easily in can be invaded by undesirable pests. These dual grass systems of tall fescue and hybrid bluegrass had less brown patch than a monoculture of tall fescue, should reduce 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 5 years indicate that the monoculture of hybrid bluegrass was never able to recover from its slow establishment. Tall fescue had more winter annual weed cover and crabgrass cover after the summer of 2009 when compared to 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 a slow establishment of hybrid bluegrass over time. Hybrid bluegrass's 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

Hybrid bluegrass tiller counts in the monoculture of hybrid bluegrass ranged from 58 to 112 and generally were lower in October and higher in March (Figure 1A). Hybrid bluegrass and tall fescue growing conditions are favorable during the spring and the fall as compared to summer, thus more tillers grew between October and March than between March and October. Similar fluctuations were seen in the seeding combinations. Surprisingly, some hybrid bluegrass tillers were present in the monoculture of tall fescue in October of 2009, possibly due to spread of rhizomes from adjacent plots. The greatest number of hybrid bluegrass tillers for every seeding treatment was recorded on the March 2011 evaluation date. The monoculture of HB contained 112 hybrid bluegrass tillers while 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 TF. Twenty-four hybrid bluegrass tillers were counted per sample in the monoculture of TF in March of 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 March of 2010 until March 2011 (Figure 2A).

## Tall Fescue Tiller Counts

In March of 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 (Figure 1B). Forty-nine tillers were counted per sample in plots seeded with combination 1TF:1.8HB. Tiller counts in the monoculture of TF increased from March of 2008 until March of 2009. Conversely, a decrease in the number of tall fescue tillers in the seeding combinations was observed from October of 2008 until March 2009. The decrease of tall fescue tillers in the seeding combinations is likely due to the increase of hybrid bluegrass tillers in those plots. Between March of 2009 and October of 2009, tiller counts in all treatments containing tall fescue decreased by at least 20 per sample. The decrease in tall fescue tiller counts during this time period is likely due to the severe brown patch epidemic that occurred during the summer of 2009. Tiller counts increased from October 2010 through March 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, though the time period was shorter. In study two, there was an initial decrease in tall fescue tiller growth between March 2010 and October 2010 in all seeding treatments (Figure 2B). Interestingly, between October 2010 and March 2011 tiller count increased in the monoculture of TF and seeding combination 1TF:1.8HB but not seeding combination 1.9TF:1HB. The increased hybrid bluegrass in seeding combination 1TF:1.8HB may be due to the epidemiological efficiency of the barrier effect provided by hybrid bluegrass, reducing the damage incurred by the susceptible tall fescue species and allowing 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, due to a higher rate of brown patch thinning and hybrid bluegrass filling in damaged areas (Figure 1B and 1A). 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.

### Combined Tiller Counts in Seeding Combinations

In study 1, eighty seven total tillers were counted per sample on March of 2008 in plots seeded with seeding combination 1TF:1.8HB, which consisted of 43% hybrid bluegrass tillers. By March of 2011, there were 125 total tillers in seeding combination 1 of which 81% were hybrid bluegrass. In seeding combination 1.9TF:1HB there was initially 82 total tillers in March of 2008, which consisted of 17% hybrid bluegrass. On the last evaluation date, March 2011, there was 140 total tillers in seeding combination 1.9TF:1HB, which was the greatest number of tillers counted among any evaluation date. Also, 68% of the tillers counted on March 2011 were hybrid bluegrass. Similar trends were seen in trial 2. Though hybrid bluegrass versus tall fescue tillers was not statistically compared, there was generally an overall numeric increase in the percentage of hybrid bluegrass tillers as well as overall tiller counts. The increase in overall tiller counts in the seeding combinations may help explain increased biomass observed in the seeding combinations per sample size.

### Tiller Weights per Sample Size

Tall fescue tiller weight averaged 8.2 g per 10 cm diameter sample in the monoculture of TF in study 1 (Figure 3). The total weight per sample of hybrid bluegrass tillers encroaching into the monoculture of TF was 0.24 g. Total weight of hybrid bluegrass tillers in the monoculture of HB was 5.3 g per sample. Trends were slightly different in study 2. In the monoculture of TF, the average weight of tall fescue tillers per sample was 6.5 g (Figure 4). Seeding combination 1.9TF:1HB contained 5.1 g of tall fescue, while seeding combination 1TF:1.8HB contained 2.9 g of tall fescue. Total tiller weights were highest in the monoculture of TF and seeding combination 1.9TF:1HB and lowest in the monoculture of hybrid bluegrass.

### Average Tiller Weight

The average tiller of hybrid bluegrass weighed approximately 65 mg, 68 mg, and 70 mg when sampled from the monoculture of HB, seeding combination 1.9TF:1HB, and seeding combination 1TF:1.8HB respectively in study 1. The average tiller of tall fescue weighed approximately 88 mg, 60 mg, and 100 mg in the monoculture of TF, seeding combination 1.9TF:1HB and seeding combinations 1TF:1.8HB. In study 2, the average tiller of hybrid bluegrass weighed approximately 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 TF alone, with combination 1.9TF:1HB, and with combination 1TF:1.8HB, respectively.

Total tiller numbers and total weight of harvested core samples was generally greater in the seeding combinations when compared to 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 to 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 while 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. 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 TF and highest in the 1TF:1.8HB seeding combination (Figure 5). In study two, sod strength in plots containing the monoculture of TF were significantly lower when compared to the other seeding treatments (Figure 6). A force of 31 kg was required to break sod samples from the monoculture of TF as compared to a force of approximately 48 kg for the treatments containing hybrid bluegrass (Figure 6).

These data suggest that tall fescue and hybrid bluegrass polystands will benefit sod farmers. These polystands should provide the same benefits as Kentucky bluegrass and tall fescue seeding mixtures, but with 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 to monocultures, they improve the strength of the sod as well compared to a monoculture of tall fescue. Sod strength values recorded from plots treated with seeding combination 1TF:1.8HB were the highest on all the dates that sod strength was evaluated (Figures 5 and 6). 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 strength. The numerically lowered sod strength in seeding combination 1.9TF:1HB versus 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 to 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 to 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 to the monocultures. Including hybrid bluegrass in a stand of tall fescue increases recuperative ability of the turfstand compared to a monoculture of tall fescue. Hybrid bluegrass's 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. Their slow establishment and concurrent weed infestations limit monocultures of hybrid bluegrass, which was observed in both studies.

Polystands promote the efficient use of resources and lower nutrient inputs for home owners 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 due to increased genetic variability of the polystands when compared to 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 to 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. This research suggests the goal of polystand management should be to maintain 1:1 tall fescue to hybrid bluegrass species ratios in order to optimize niche differentiations and epidemiological benefits. In conclusion, adoption of either polystand provides better turf cover, reduced weed infestations and pathogens with reasonable input requirements when compared to the monocultures. However, the difficulties of growing cool-season grasses in the transition zone may it difficult to maintain desirable turf-cover even in the polystands without increased inputs.

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## References

Dun, J.H. 2001. Mixing tall fescue with Kentucky bluegrass and perennial ryegrass. Golf Course Mgt. July: 70-74.

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.

Lawn Institute, 2010. http://www.thelawninstitute.org/education/?c=183313,accessed July 2010.

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

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.

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., Wilcox, J.C., Kelly, T., Knapp, A.K., 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 .

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

Wilson, J.B. 1990. Mechanisms of species coexistence: twelve explanations for Hutchinson's paradox of the plankton: evidence from New Zealand plant communities. New Zealand 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.

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 October of 2006).

| Seeding Treatment | Percent Turfgrass Cover | | | | |
|---|---|---|---|---|---|
| | 2006[†] | 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 |

[†] 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 (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 2, ( Seeded October of 2008).

| Seeding Treatment | Percent Turfgrass Cover | | |
|---|---|---|---|
| | 2008[†] | 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 |

[†]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 October of 2006).

| Seeding Treatment | Percent Brown Patch | | |
|---|---|---|---|
| | 2008[†] | 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 |

[†]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 October 2008).

| Seeding Treatment | Percent Brown Patch | |
|---|---|---|
| | 2009[†] | 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 |

[†]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 (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 October of 2006).

| Seeding Treatment | Purple deadnettle cover | | | | | Smooth crabgrass cover | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2006† | 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 |

† 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 in November and percent smooth crabgrass taken September in Trial 2 (seeded in October of 2008).

| Seeding Treatment | Purple deadnettle cover | | | Smooth crabgrass cover | |
|---|---|---|---|---|---|
| | 2008† | 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 |

†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.

Table (7). Impact of monoculture and combination seeding treatments of tall fescue and hybrid bluegrass on visual percent henbit and Persian speedwell cover taken in March of trial 1 (seeded October, 2006).

| Seeding Treatment | Henbit Cover | | | | | Persian Speedwell Cover | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2007 † | 2008 | 2009 | 2010 | 2011 | 2007 | 2008 | 2009 | 2010 | 2011 |
| Tall Fescue | 5 a | 8 b | 9 b | 21 a | 20 a | 7 a | 6 b | 7 a | 13 a | 15 a |
| Hybrid Bluegrass | 8 a | 35 a | 19 a | 15 a | 4 a | 8 a | 12 a | 11 a | 13 a | 6 b |
| Tall Fescue: Hybrid Bluegrass 1.9:1 | 4 a | 12 b | 7 b | 8 a | 3 a | 8 a | 7 b | 8 a | 6 b | 8 b |
| Tall Fescue: Hybrid Bluegrass 1:1.8 | 6 a | 11 b | 8 b | 10 a | 4 a | 6 a | 7 b | 7 a | 5 b | 8 b |

†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.

Table (8). Impact of monoculture and combination seeding treatments of tall fescue and hybrid bluegrass on visual ratings of percent henbit and Persian speedwell cover taken in March of Trial 2 (seeded October, 2008).

| Seeding Treatment | Henbit Cover | | | Persian Speedwell Cover | | |
|---|---|---|---|---|---|---|
| | 2009[†] | 2010 | 2011 | 2009 | 2010 | 2011 |
| Tall Fescue | 7 b | 10 b | 9 a | 10 a | 9 b | 9 a |
| Hybrid Bluegrass | 23 a | 17 a | 6 a | 18 a | 16 a | 6 a |
| Tall Fescue: Hybrid Bluegrass 1.9:1 | 8 b | 7 c | 3 a | 9 a | 4 c | 3 a |
| Tall Fescue: Hybrid Bluegrass 1:1.8 | 8 b | 11 b | 5 a | 14 a | 6 bc | 6 a |

[†] 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.

Figure 1A. Impact of seeding treatments on hybrid bluegrass tiller counts taken biannually from March, 2008 until March, 2011 in trial 1 (bars indicate standard error).

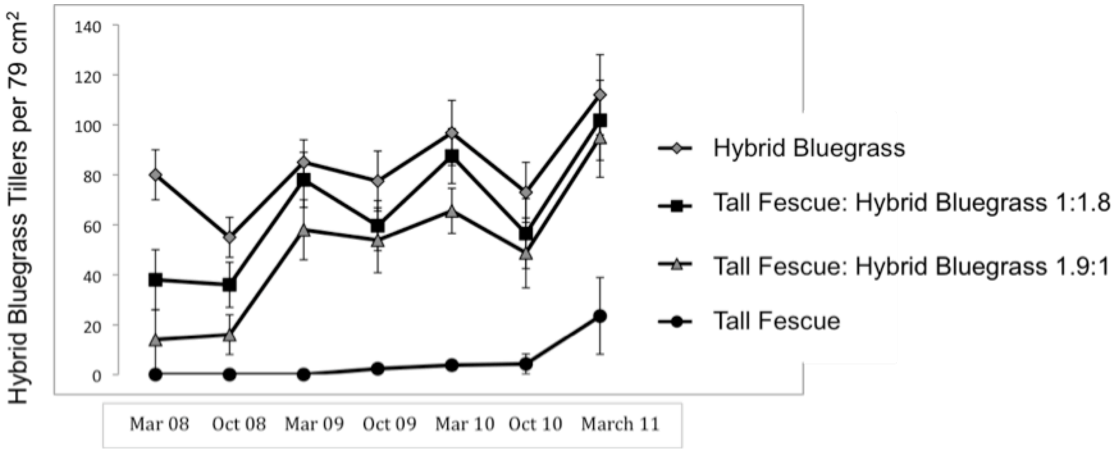


Figure 1B. Impact of seeding treatments on tall fescue tiller counts taken biannually from March, 2008 until March, 2011 in trial 1 (bars indicate standard error).

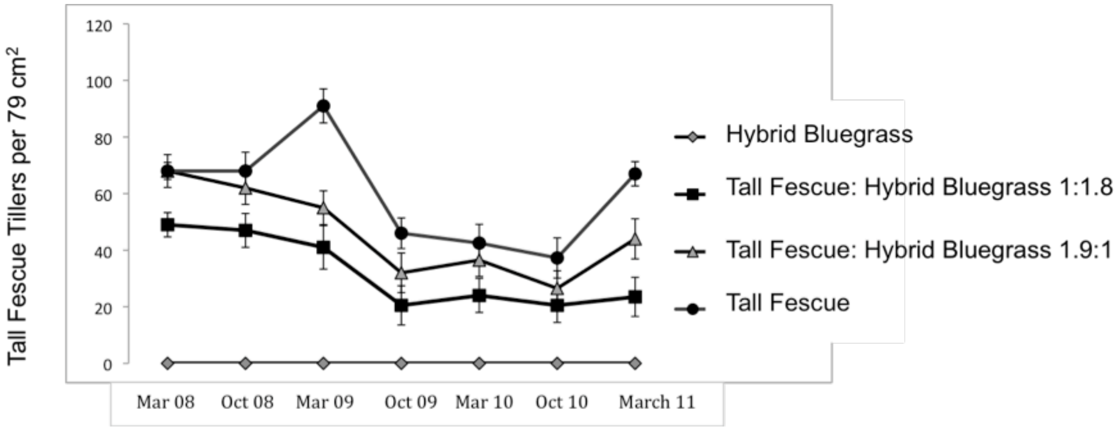


Figure 2A. Impact of seeding treatments on hybrid bluegrass tiller counts taken biannually from March, 2010 until March, 2011 in trial 2 (bars indicate standard error).

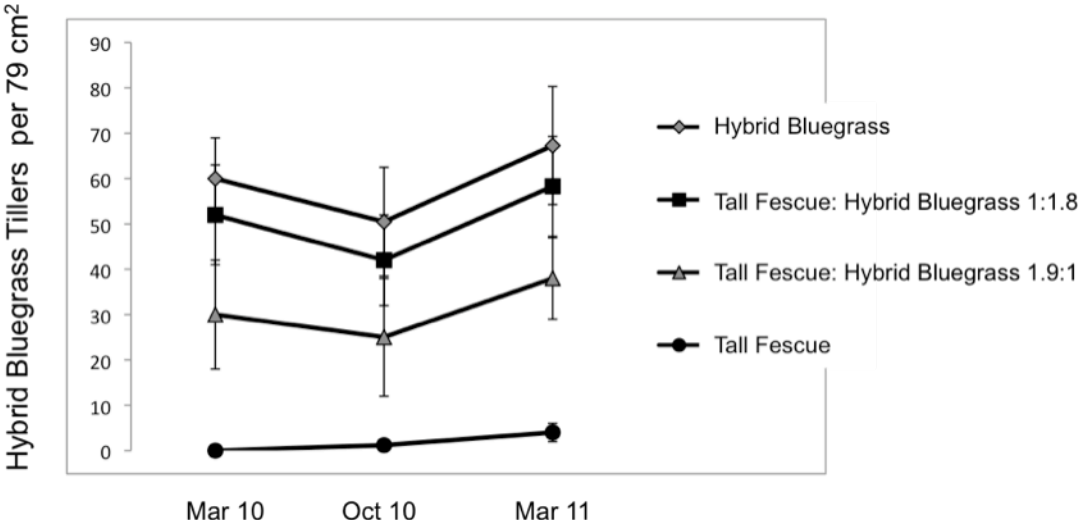


Figure 2B. Impact of seeding treatments on tall fescue tiller counts taken biannually from March, 2010 until March, 2011 in trial 2 (bars indicate standard error).

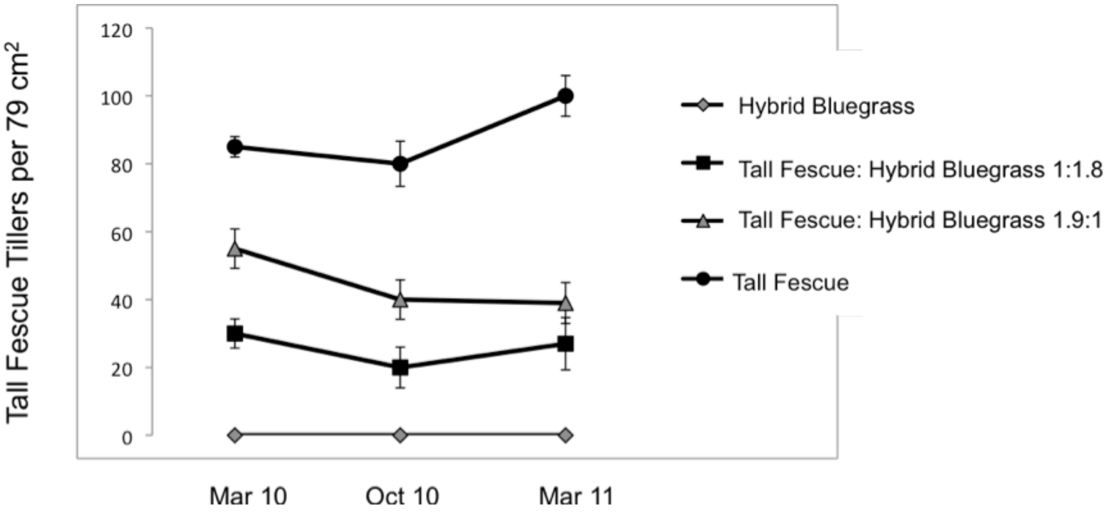


Figure (3) Impact of seeding treatments on tall fescue and hybrid bluegrass tiller weights three years after establishment in trial 1 (bars indicate standard error).

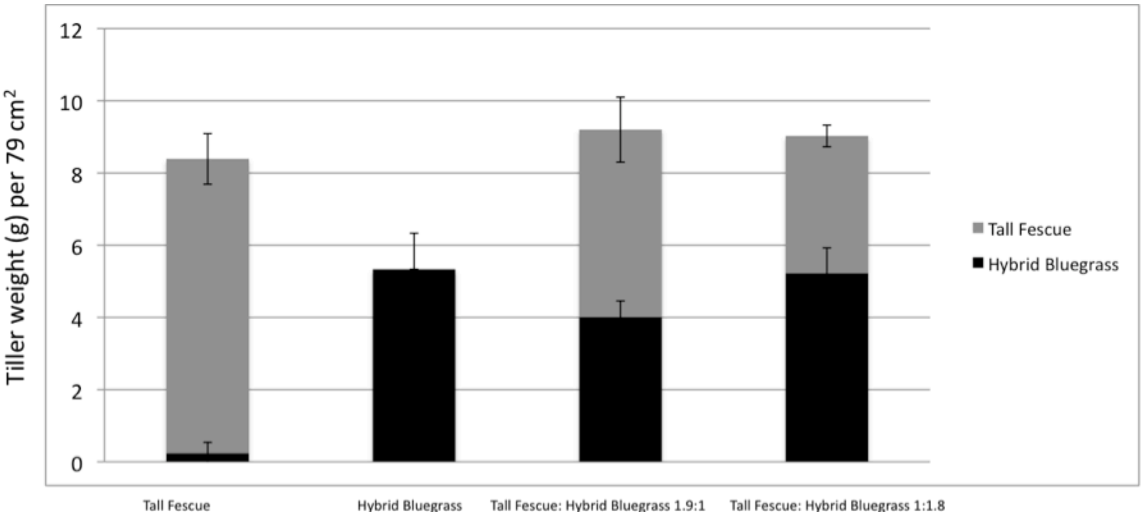


Figure (4) Impact of seeding treatments of hybrid bluegrass and tall fescue on tall fescue and hybrid bluegrass seeding weights one year after establishment in trial 2 (bars indicate standard error).

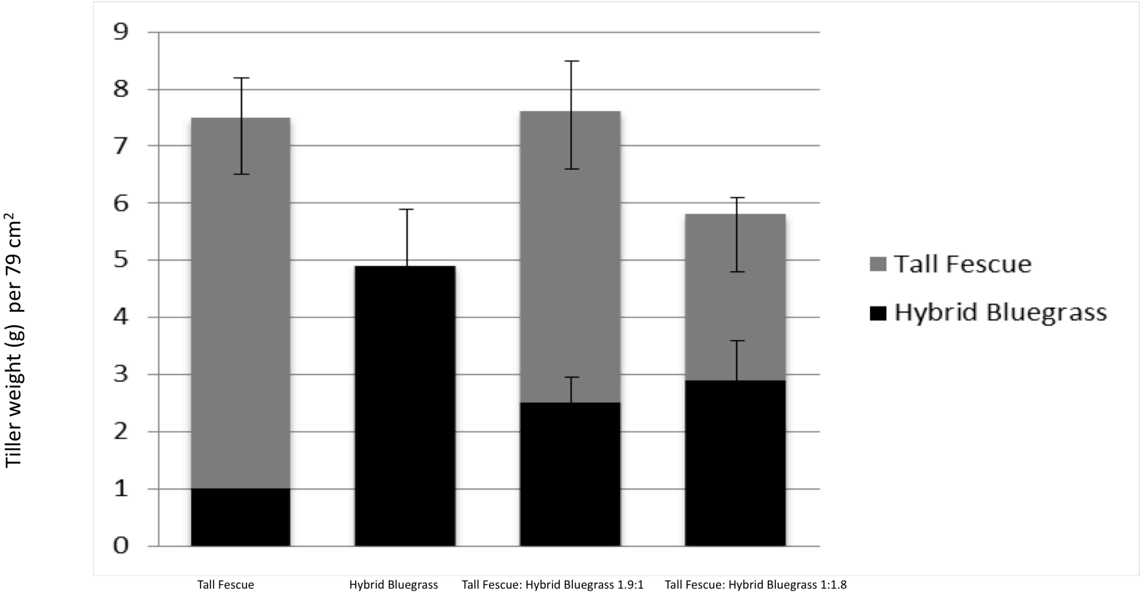
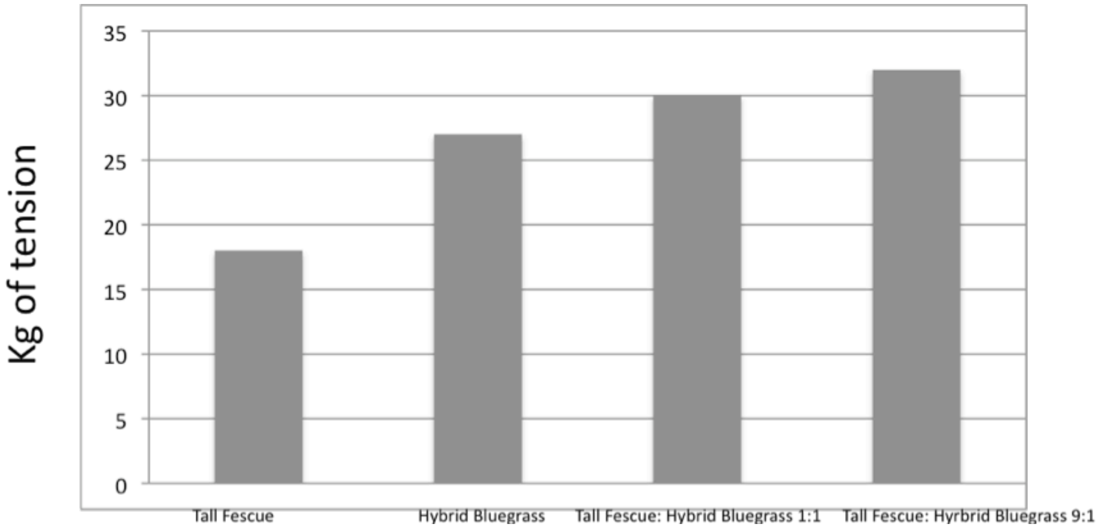
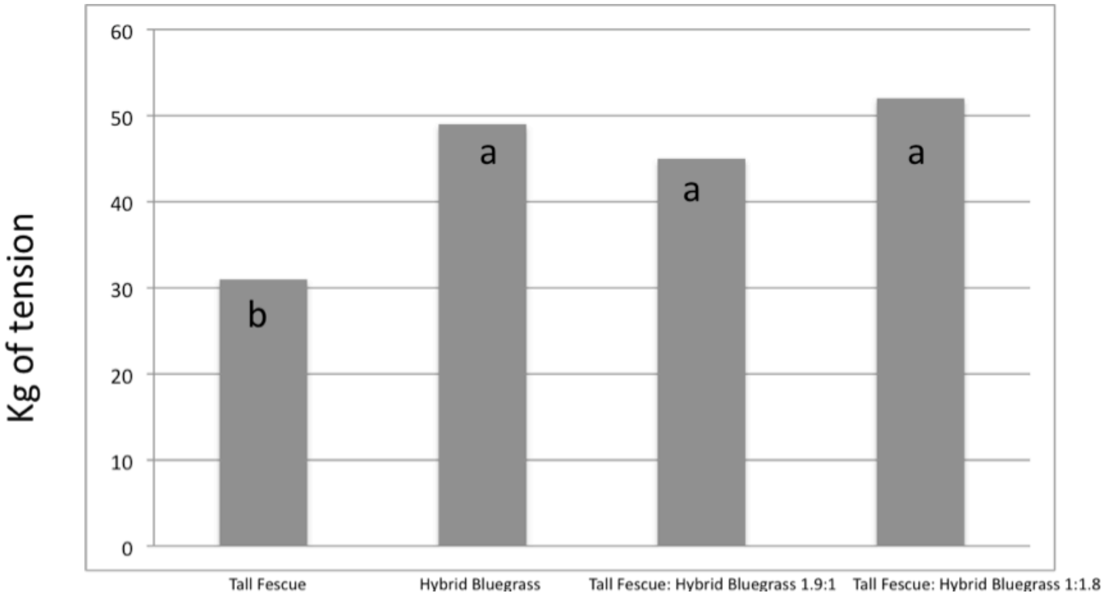


Figure (5) Impact of seeding treatments of tall fescue and hybrid bluegrass on sod strength (Kg required to tear sod) taken in November, 2010 for trial 1[†].



[†] Means were not significantly different according to Fishers protected LSD at the 0.05 level.

Figure (6) Impact of seeding treatments on sod strength (Kg required to tear sod) taken April of 2011 for trial 2[a]



[†] All means followed by the same letter group are not significantly different according to Fisher protected LSD at the 0.05 level.

## Impact of Mowing Height and Fertility on Bermudagrass Encroachment and Brown Patch Severity in Tall Fescue.

### Abstract

Tall fescue (*Festuca arundinacea*) is a commonly-utilized turfgrass in the temperate and transition zone areas of the United States. It establishes quickly, requires moderate amounts of nitrogen, and is resistant to most diseases. However, during hot, humid summers, tall fescue is under stress and is susceptible to *Rhizoctonia solani* infection. The resulting disease, referred to as brown patch, causes turf thinning, leading to encroachment from weeds such as bermudagrass (*Cynodon dactylon*). Cultural practices such as fertility and mowing height may impact bermudagrass encroachment and brown patch disease in tall fescue. Two mowing heights (6 and 10 cm), and three levels of fertility (49, 171, and 220 kg of nitrogen annually per hectare) were evaluated in an established stand of tall fescue at four locations. Mowing height had a significant effect on bermudagrass stolon length in year one and year two in Virginia Beach. A 10 cm mowing height resulted in less bermudagrass encroachment compared to a 6 cm mowing height. Increasing nitrogen levels generally led to more bermudagrass encroachment at the 6 cm mow height but not the 10 cm mow height. Typically, plots receiving 220 kg ha$^{-1}$ of nitrogen annually at the 6 cm mowing height had the most brown patch. Turfgrass cover was highest in plots mowed at 10 cm receiving 220 kg ha$^{-1}$ of nitrogen fertility annually. Blacksburg had less bermudagrass encroachment and less disease than the other locations, which was probably due to the lower nighttime temperatures in Blacksburg, VA when compared to Knoxville, TN or Virginia Beach, VA. Bermudagrass encroachment in tall fescue can be reduced by mowing at a higher mowing height and fertilizing in early spring and late summer.

## Introduction

Tall fescue [*Festuca arundinacea* Schreb synonym Schedonorus phoenix (Scop.) Holub] is a cool-season perennial turfgrass originally from Europe and now grown throughout Europe, North Africa, and North America (Beard, 1973). Tall fescue grows aggressively in the spring and fall and has a deep root system, which helps withstand drought. Tall fescue has great utility as a turfgrass in the transition zone climate. It can be used in multiple situations such as home lawns, community parks, lower maintenance athletic fields, golf course roughs and other low maintenance turfgrass areas (Watkins and Meyer 2004). Tall fescue exhibits adequate shade tolerance, is adapted to different types of soils, and can be mowed at 4 cm or more, making it a reliable choice for the aforementioned situations. Tall fescue has adequate drought tolerance for a cool-season grass, insect resistance, high turf density, and relatively low fertilizer requirements (Watkins and Meyer 2004).

Tall fescue is resistant to most diseases; however, the fungal pathogen *Rhizoctonia solani* Kuhn (Piper and Coe, 1919) can inflict significant damage to this turfgrass species. There is no known cultivar that is highly resistant to brown patch, the disease caused by *R. solani* (Yuen et al., 1994). Nevertheless, tall fescue genotype does influence the degree of tolerance. Tall fescue cultivars with ideal agronomic traits such as narrow blades and dense canopies have been associated with increased susceptibility to brown patch. Other pests that are problematic in tall fescue either by themselves or as the result of brown patch thinning the turf are warm-season grasses. Large, smooth, and southern crabgrass [*Digitaria* sanguinalis (L.) Scop.]*, D. ischaemum Schreb.* Ex Muhl*, D. ciliarsis* (Retz.) Koel.) and bermudagrass [ *Cynodon dactylon* (C.)  Pers.] are opportunistic and very problematic weeds in tall fescue turf. These C4 grasses may be found in lawns under a range of management conditions, especially where the turf has been thinned. Management strategies can contribute to both disease and weed infestation of a tall fescue stand.

Cultural management strategies are an important component of a pest control program. Mowing, fertilization, cultivation, irrigation, planting and turfgrass selection are all practices that can impact the quality of a turfgrass stand. Additionally, optimization of these practices can reduce the need for chemical input. In lower maintenance turfgrass, such as tall fescue used in home lawns and parks, the most important cultural practice may be mowing (Busey, 2003).

Mowing occurs frequently and can greatly impact weed species density in tall fescue. In all studies where mowing height had a significant effect on weed species, the lower mowing height always had greater weed density (Busey, 2003). Previous mowing height studies in tall fescue showed that lowering mowing heights resulted in increased crabgrass cover (Dernoden, 1998). Additionally, mowing tall fescue at 6 cm resulted in less broadleaf weed cover than mowing at 4 cm in one study (Gray and Call, 1993). Mowing height seems to have a variable impact even within studies on brown patch incidence (Burpee, 1995). Though mowing is the most frequent cultural practice performed, the integrity of low maintenance tall fescue can be influenced by other management techniques; specifically nitrogen application can impact weed density, turfgrass cover, and disease incidence.

Multiple studies have shown that in general increasing nitrogen levels reduces crabgrass and broadleaf weeds in multiple cool-season grass species (Voigt et al., 2001; Haley et al., 1985; Dunn et al., 1981; Murray et al., 1983). However, nitrogen application timing does have an effect on weed control. In one tall fescue study, fall fertilization resulted in less crabgrass cover than spring fertilization (Hall, 1980). Various studies have shown that applications of nitrogen to tall fescue in the spring and summer increase brown patch (Fry and Huang, 2004). Typically, the ratio of shoot growth to root growth for cool-season grasses is greater during the spring than the fall. Applying a quick- release nitrogen source to tall fescue in the spring will promote succulent shoot growth that a pathogenic fungus such as *Rhizoctonia solani* will parasitize in warm, humid conditions. Any increase in disease may increase weed density in a turf stand.

Currently, little information is available on the impact of mowing and nitrogen fertility on bermudagrass encroachment in tall fescue. Additionally, it is important to elucidate the impact of these cultural practices on brown patch in tall fescue grown in the transition zone. Of particular interest is the interaction among brown patch, bermudagrass encroachment and tall fescue health. Research was conducted to evaluate the impact of mowing height and nitrogen application on bermudagrass encroachment and brown patch severity in tall fescue grown in Virginia Beach, VA, Blacksburg VA, and Knoxville, TN.

## Materials and Methods

The study was conducted four times: (1) Hampton Roads Agricultural Research and Extension Center in Virginia Beach, VA, in 2009 and 2010 (2) Glade Road Turfgrass Research Center in Blacksburg, VA in 2010 and (3) University of Tennessee Plant Science Farm in Knoxville, Tennessee in 2010. Plots were 3.7 m x 1.52 m in dimension. The experiment was arranged as a split block with mowing heights as the main plot and fertilizer randomized in the mowing strip replicated 4 times. Treatments were conducted within factorial design with plots being mowed at either 6 or 10 cm and receiving treatments of 49 (low), 171 (medium), and 220 (high) kg ha$^{-1}$rates of nitrogen annually per hectare. The low nitrogen treatment consisted of one treatment of 49 kg ha$^{-1}$ of nitrogen in November. Plots in the medium fertility program received 49 kg ha$^{-1}$ of nitrogen in October, 49 kg ha$^{-1}$ of nitrogen in November, 49 kg ha$^{-1}$ of nitrogen in December and 24 kg ha$^{-1}$ in May. The high nitrogen fertility program consisted of 49 kg ha$^{-1}$ of nitrogen in October, 49 kg $ha^{-1}$ of nitrogen in November, 49 kg $ha^{-1}$ of nitrogen in December, 24 kg $ha^{-1}$ in May, 24 kg $ha^{-1}$ in June and 24 kg $ha^{-1}$ in August. A 19-0-19 NPK fertilizer was used with the nitrogen source being methylene urea. All nitrogen applications were made on the 1st of the assigned month with the exception of the August application, which was made on the 15th of that month. Oxadiazon was applied in March at 336 kg ai $ha^{-1}$ to reduce crabgrass infestations. Three common bermudagrass plugs 10 cm in diameter were harvested and planted in each plot on the 1st of May. Bermudagrass stolon length and brown patch severity was measured throughout the summer. Stolon lengths were determined by finding the two longest bermudagass stolons in each plug and taking the average. Bermudagrass stolons were measured on the first day of each month from May through September. Initial stolon lengths of bermudagrass plugs were 10 cm. Brown patch was rated visually as a percentage of the whole plot. Turfgrass cover was estimated as a percentage of the entire plot one year after the trial was initiated. In the Virginia Beach studies the tall fescue variety used was ‘RTF’, which is a tall fescue cultivar that produces rhizomes. ‘Falcon 4’ tall fescue was used in the Blacksburg and Knoxville studies.

### Data Analysis

Data were subjected to ANOVA ($\alpha$= 0.05) using mixed model methodology (Statistical Analysis software v. 9.1, Cary NC). Mowing height and nitrogen application treatments were considered fixed effects and replications were considered random. Study, mowing height, nitrogen application and all interactions among these fixed variables had a significant effect on bermudagrass stolon length in September. Location, mowing height, location by mowing height interaction and location by nitrogen treatment interaction all had a significant effect on brown patch severity in September. Therefore, means for brown patch severity and stolon length are presented by location and treatment.

## Results and Discussion

### Bermudagrass Encroachment

Bermudagrass stolon length was greater in plots mowed at 6 cm compared to plots mowed at 10 cm on all evaluation dates in the 2009 Virginia Beach trial (Figure 1). Bermudagrass stolon length increased approximately 3.5 cm from May to June in tall fescue plots mowed at 10 cm while  those in plots mowed at 6 cm increased approximately 10 cm from May to June. Little bermudagrass growth was observed between June and July. The longest stolon length recorded on July 1st was 23 cm, which occurred in plots mowed at 6 cm that received the highest level of nitrogen. A large increase in stolon length was observed between July and August of the 2009 study. Stolons between July and August in plots mowed at 10 cm grew 10, 8, and 5 cm when treated with low, medium and high rates of nitrogen. Much larger increases were observed in plots mowed at 6 cm. Stolon lengths in plots mowed at 6 cm increased from 21 cm to 40 cm, 19 cm to 42 cm, and 23 cm to 52 cm when treated with low, medium and high levels of nitrogen respectively. In September, plots mowed at 6 cm had stolons measurements of 51, 53 and 60 cm when treated with low, medium and high rates of nitrogen, respectively. Plots mowed at 10 cm had stolon lengths of approximately 23 cm. At the 10 cm height of cut, no differences were seen among the three fertility programs for bermudagrass stolon length. In plots mowed at 6 cm, bermudagrass stolon length was greater in the high nitrogen program compared to the lower fertility rates.

In the second Virginia Beach study, similar trends were observed, though less overall bermudagrass growth occurred and the difference between bermudagrass growth in plots mowed at 6 cm and 10 cm was not as profound. Plots mowed at 6 cm again resulted in greater bermudagrass encroachment than plots mowed at 10 cm on some of the evaluation dates (Figure 2). Additionally, implementing the high nitrogen program increased bermudagrass encroachment in plots mowed at 6 cm but not 10 cm. Stolon lengths of the bermudagrass plugs in the 2010 study did not differ much from the 2009 study for the first two months. Between May and June the maximum increase in stolon length was 3 cm, which occurred in plots mowed at 6 cm treated with the high level of nitrogen (Figure 2). The range of bermudagrass stolon length increase between June and July for plots mowed at 6 cm was approximately 2 to 4 cm. Bermudagrass stolons did not grow as much between July and August in the 2010 study as the 2009 study. In September, bermudagrass stolon length was greater when plots were mowed at 6 cm compared to 10 cm. At the 6 cm height of cut, bermudagrass stolon length was greater under higher nitrogen treatments compared to the lowest nitrogen fertility treatment. No differences were seen among fertility treatments at the 10 cm height of cut. In September, bermudagrass stolon length recorded in plots mowed at 6 cm with high nitrogen was 20 cm, which was the greatest stolon length recorded among treatment combinations in the 2010 study. However, bermudagrass stolon length recorded for the same treatment combination in the 2009 study was three times greater. More rainfall fell during July in 2010 compared to 2009, which may have helped relieve stress in the tall fescue and reduced bermudagrass encroachment in 2010.

Similar trends were observed in the Knoxville study compared to the Virginia Beach study in September (Table 1, Figures 1 and 2). Plots mowed at 6 cm had greater bermudagrass stolon lengths than plots mowed at 10 cm in the Knoxville study when treated with medium or high levels of nitrogen. Stolon lengths of bermudagrass plugs in plots mowed at 6 cm in the Knoxville study were approximately 19 cm when treated with low, medium or high rates of nitrogen, while bermudagrass stolons in plots mowed at 10 cm under the medium level of fertility were 13 cm long. The comparative differences for bermudagrass diameter in September between mowing height treatments was greater for the Virginia Beach 2009 study than the Knoxville study.

Trends observed in the Blacksburg study were different than the Virginia Beach or Knoxville studies. Little bermudagrass growth occurred during the summer in Blacksburg and there were no significant differences among mowing height and fertility treatments (Table 1).

Mowing tall fescue at a higher mowing height during the summer reduced bermudagrass encroachment in most of the trials, which complements the studies documented by Busey, (2003) who showed that raising the height of cool-season grasses during the summer reduced crabgrass and broadleaf weed cover. There was an interaction between mowing height and nitrogen application on bermudagrass encroachment ($p=0.003$) taken in September in the 2009 Virginia Beach study. Increasing nitrogen rates appeared to decrease bermudagrass encroachment slightly in plots mowed at 10 cm. However, increasing nitrogen at the lower mowing height led to more bermudagrass encroachment in both Virginia Beach trials and the Knoxville trial. Gray and Call (1993) also observed an interaction between mowing height and nitrogen level in tall fescue. In their study, mowing at a higher mowing height with increased fertility resulted in less broadleaf weed cover. In the same study, increasing nitrogen did not decrease broadleaf weed cover in plots mowed at low mowing heights. Tall fescue mowed at 10 cm during the summer appeared darker green than tall fescue mowed at 6 cm in most of the studies (quality ratings not shown). Perhaps tall fescue mowed at 10 cm was able to take advantage of increased nitrogen application, thus making it more competitive with bermudagrass, while increasing nitrogen application in plots mowed at 6 cm was more advantageous to the bermudagrass than the tall fescue.

### Impact of Mowing Height and Nitrogen Application on Percent Brown Patch Severity

At the beginning of the summer in 2009, brown patch severity was greater in plots cut at 10 cm in the 2009 Virginia Beach trial (Figure 3). In May, percent brown patch in plots mowed at 10 cm was 41%, averaged across fertility programs. Comparatively, mowing at 6 cm resulted in brown patch ratings of approximately 32% when averaged across fertility programs. Percent brown patch severity changed little from May to June. The range of percent brown patch severity in plots mowed at 10 cm was between 38% and 40%. Percent brown patch severity in plots mowed at 6 cm was between 31% and 36%. In July, percent brown patch began to decrease in plots mowed at 10 cm but not in plots mowed at 6 cm. In July plots mowed at 6 cm treated with high nitrogen had 37% brown patch, which was the most among all the treatment combinations. Plots mowed at 10 cm receiving the medium nitrogen treatment had 30% brown patch severity, which was numerically the least among all treatment combinations in July. In August, percent brown patch in plots mowed at 10 cm was approximately 25% among all nitrogen levels. Decreasing the mowing height to 6 cm resulted in percent brown patch severity ratings of 30%, 32%, and 37% when the plots were treated with low, medium and high rates of nitrogen, respectively, in August. In September, the range of percent brown patch in plots mowed at 6 cm was 27% to 35% but only15% to 19% at the 10 cm mowing height. Within each mowing height, in the first Virginia Beach study, an increase in nitrogen leads to more brown patch in September. Tall fescue plots mowed at 10 cm were able to recover from high percent brown patch levels in May while a large numerical decrease in brown patch between May and September was not observed in plots mowed at 6 cm.

There was less brown patch observed overall in 2010 when compared to 2009 in the 2010 Virginia Beach trial. In May of 2010 no more than 5% brown patch severity was recorded among any of the treatment combinations (Figure 4). In June of 2010 mowing at 6 cm resulted in approximately 13% brown patch severity but only 6% brown patch at the higher mowing height. In July of 2010, mowing at 6 cm with the high nitrogen treatment resulted in 20% brown patch severity, which was the greatest among all treatment combinations on that rating date. Mowing at 10 cm with low nitrogen resulted in 7% brown patch in July of 2010. In August, the range of brown patch severity for plots mowed at 6 cm was 19% to 25%. Mowing at 10 cm resulted in brown patch severity between 9% and 16%. A numerical increase in brown patch was observed in August in plots treated with higher nitrogen rates in both mowing heights. Mowing at 6 cm resulted in September brown patch ratings ranging from 21%, to 27% severity. Brown patch ratings in the plots mowed at 10 cm ranged from 11% to 16%.

Brown patch severity was high in the Knoxville study. Plots receiving the 6 cm mowing treatments had brown patch ratings of 29% to 35% depending on fertility program and 21% to 28% at the high mowing height in September (Table 2). No significant differences in brown patch were seen among fertility programs within the same mowing height.

Patterns in brown patch severity in the Blacksburg study were different than the other locations. No differences among mowing and fertility treatments were observed. Percent brown patch ranged from 2% to 8% when treated with low, medium or high rates of (Table 2). Plots mowed at 10 cm had 11%, 8% and 7 % brown patch severity when treated with low, medium and high rates of nitrogen respectively.

In most of the trials, a lower mowing height resulted in more severe brown patch in September. Burpee (1995) observed more brown patch at lower mowing heights in a study in Georgia. Tall fescue canopy height is believed to have a direct impact on disease incidence (Giesler et al., 1996). A denser turfgrass canopy and longer leaf wetness duration period results from lower mowing heights, which may be the reason more brown patch was observed in plots at the 6 cm height of cut compared to the plots cut at 10 cm in most of the trials. Tall fescue plots that received more nitrogen typically had more brown patch in most of the studies. Vincelli and Powell (1997) noted similar trends in their studies. The *Rhizoctonia solani* fungus is believed to be more effective at penetrating succulent leaves that contain thin cell walls, a condition that is a result of increased nitrogen application as well as lower mowing heights.

Bermudagrass growth tracked over the summer in the Virginia Beach trials varied significantly when comparing the 2009 study to the 2010 study. Specifically, growth of the bermudagrass plants between July and August was much greater in 2009 compared to 2010 at the 6 cm mowing height. The increased bermudagrass encroachment may be due to two conditions: severe brown patch in May of 2009 and less rainfall during July in 2009. Brown patch severity in May 2009 was greater than 30% in all plots; comparatively, less than 5% brown patch was observed in plots in May of the 2010 trial. Brown patch severity in plots mowed at 6 cm in May was positively correlated with September bermudagrass diameters in the 2009 trial (Pearsons r value= 0.71, P-value <0.01). Correlations were not significant (P-value >0.05) in plots mowed at 10 cm, indicating that tall fescue mowed at the higher mowing height recovered from early season brown patch and was not thinned by the disease. Rainfall during July of 2009 was 6.3 cm compared to 15.1 cm 2010, which was the month where the most bermudagrass growth was observed in the 2009 trial. Bermudagrass is more tolerant to low rainfall than tall fescue, especially during the summer months. Tall fescue that is mowed lower will have less extensive roots and thus be even less tolerant to drought. Early season brown patch compounded with mid-summer drought conditions in 2009 lead to a thinning of the tall fescue canopy mowed at 6 cm. Subsequently, bermudagrass opportunistically encroached into the turfgrass stand more so than at the other locations.

### Impact of Mowing Height and Fertility on Turfgrass Cover One Year After Establishment.

In the Virginia Beach 2009 trial, turfgrass cover was reduced when the mowing height was lowered to 6 cm. Plots mowed at 6 cm had 22 to 38% turfgrass cover compared to 55% to 70% at the 10 cm mowing height (Table 3). Applying the highest rate of nitrogen to plots mowed at 6 cm resulted in 22% turfgrass cover, which was the lowest of all the treatment combinations. These plots also had the most severe brown patch the previous summer and the most bermudagrass encroachment.

In the Virginia Beach 2010 study, mowing at 6 cm again resulted in less turf cover than at a 10 cm mowing height. Mowing at 6 cm resulted in approximately 25% turf cover for each fertility program (Table 3). Plots mowed at 10 cm were covered in approximately 40% tall fescue at the three fertility regimes.

In the Blacksburg trial, higher percent turfgrass cover was recorded compared to the Virginia Beach trials. Within a mowing height, plots receiving the lowest nitrogen rate had lower turf cover than at the higher nitrogen rates. Fertility did have a significant impact on percent turfgrass cover in the Blacksburg while mowing height did not (Table 3). Turf cover was numerically lower in plots receiving 49 kg N $ha^{-1}$ and mowed at 6 cm. No differences were observed between 171 kg N $ha^{-1}$ and 220 kg N $ha^{-1}$. Percent turfgrass cover ratings in Knoxville were similar to Blacksburg. Mowing at 6 and 10 cm resulted in percent turfgrass cover ratings of approximately 94% regardless of fertility treatment (Table 3). Mowing height or nitrogen rate did not have a significant impact on percent turfgrass cover in Knoxville.

The impact of brown patch severity and bermudgrass encroachment in tall fescue stands is influenced by environmental conditions. Mowing at a lower mowing height did not result in greater bermduagrass encroachment or brown patch in the Blacksburg trial. The difference in disease and weed encroachment among locations is likely affected by temperature. An epidemiological model used to predict brown patch with 85% accuracy in perennial ryegrass contained parameters such as consecutive days with minimum temperatures above 16 C and consecutive hours with greater than 95% relative humidity (Fidanza et al., 1995). Blacksburg had lower minimum temperatures than Knoxville or Virginia Beach, which could reduce brown patch spread in the turf stand (Figure 5). Additionally, the cooler summer in Blacksburg is better for tall fescue health, which may lessen the stress associated with lower mowing heights during the summer. Mowing tall fescue at 6 cm during the summer may be an acceptable choice in a climate like Blacksburg; however, disease forecast models should be monitored in late spring and early summer. Of all the locations, Knoxville had the most severe brown patch in September. Interestingly, in the Knoxville study, more brown patch was present in the plots treated with the lower level of nitrogen at the 10 cm mowing height, which was a trend not seen in the Virginia Beach studies. The higher nitrogen fertility levels may have helped the tall fescue recover from the disease in September at the Knoxville location.

Percent turfgrass cover in the Virginia Beach studies was noticeably lower when compared to the other locations. The differences in percent turfgrass cover between Virginia Beach and the other locations may be due to tall fescue stand maturity, disease infestation, cultivar selection, and environmental conditions. The tall fescue stand in Virginia Beach was 4 years old when the 2009 trial was established while the stands in Knoxville and Blacksburg were less than two years old. Older stands may be less vigorous and thus less able to recover from drought or disease. The 'RTF' cultivar may be less competitive than the 'Falcon 4' tall fescue cultivar used in the Knoxville and Blacksburg studies, which could also explain the increased bermudagrass stolon length in Virginia Beach during the summer of 2009. Virginia Beach's climate is probably the least ideal for growing cool-season grasses. In the 2010 trials, Virginia Beach had higher minimum temperatures than Knoxville or Blacksburg (Figure 5). However, mowing tall fescue plots at 10 cm with the high level of nitrogen fertility resulted in the highest percent turfgrass cover in the Virginia Beach studies as well as the other locations.

Managing tall fescue in the transition zone is difficult. Summer cultural practices in tall fescues stands should be optimized to maintain turfgrass integrity and reduce pests. Based on this study, mowing tall fescue at 10 cm, during the summer should reduce bermudagrass encroachment. Due to the limited availability of mowing equipment that can be adjusted to a 10 cm height of cut, homeowners may have difficulty implementing the 10 cm mowing-height strategy. Commercial landscape companies should have equipment that can be adjusted to 10 cm , this height of cut should be adapted for tall fescue grown in stressful summer conditions. Additionally, applying small amounts of slow-release nitrogen to the turf in mid-late summer should give tall fescue some recuperative ability and increase its competitiveness in early fall. If the turf has to be mowed shorter, then applying nitrogen in the summer may be more beneficial to bermudagrass than tall fescue. Also, applying high rates of nitrogen increased brown patch in some of the studies but not others at both mowing heights. Understanding the interaction between mowing height, nitrogen application and environmental conditions regarding weed and disease infestations is important for successfully managing tall fescue in the transition zone. Prioritizing goals before initiating a mowing-fertility program is important. Future research considering mowing trials should include more inputs such as fungicides and postemergence herbicides in order to improve integrated pest management strategies in more intensely-managed tall fescue.

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## Literature Cited

Beard, J.B. 1973. Turfgrass Science and Culture. Englewood Cliffs, NJ: Prentice Hall p. 58.

Burpee, L. 1995. Interactions among mowing height, nitrogen fertility, and cultivar affect the severity of Rhizoctonia blight of tall fescue. Plant Disease. 79: 721-726.

Busey, P. 2003. Cultural management of weeds in turfgrass: A review. Crop Sci. 43:1899-1911.

Dernoeden, P.H., M.A. Fidanza, and J.M. Krouse. 1998. Low maintenance performance of five *Festuca* species in monostands and mixtures Crop Sci. 38:434–439.

Dunn, J.H., C.J. Nelson, and R.D. Winfrey. 1981. Effects of mowing and fertilization on quality of ten Kentucky bluegrass cultivars. p.293–301. *In* R.W. Sheard (ed.) Proc. 4th Int. Turfgrass Res. Conf.,Guelph, ON, Canada. 19–23 July 1981. Ontario Agric. College, Univ. Guelph and Int. Turfgrass Soc., Guelph, ON, Canada.

Fidanza, M.A., P.H. Dernoden, and A.P. Grybauskas. 1996. Development and field validation of a brown patch warning model for perennial ryegrass turf. Ecology and Epidemiology 86:385-390.

Fry, J and B, Huang. 2004. Applied Turfgrass and Physiology. P. 236.

Giesler, L.J., G.Y. Yuen, and G.L. Horst. 1996. Tall fescue canopy density effects on brown patch disease. Plant Dis. 80:384-88.

Gray, E., and N.M. Call. 1993. Fertilization and mowing on persistence of Indian mockstrawberry (*Duchesnea indica*) and common blue violet (*Viola papilionacea*) in a tall fescue (*Festuca arundinacea*) lawn. Weed Sci. 41:548–550.

Haley, J.E., D.J. Wehner, T.W. Fermanian, and A.J. Turgeon. 1985. Comparison of conventional and mulching mowers for Kentucky bluegrass maintenance. HortScience 20:105–107.

Hall, J.R., III. 1980. Effect of cultural factors on tall fescue-Kentucky bluegrass sod quality and botanical composition. p. 367–377 *In* J.B.Beard (ed.) Proc. 3rd Int. Turfgrass Res. Conf., Munich, West Germany. 11–13 July 1977. ASA, CSSA, SSSA, and Int. TurfgrassSoc., Madison, WI.

Murray, J.J., D.L. Klingman, R.G. Nash, and E.A. Woolson. 1983. Eight years herbicide and nitrogen fertilizer treatments on Kentucky bluegrass (*Poa pratensis*) turf. Weed Sci. 31:825–831.

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

Vincelli, P., and A.J. Powell. 1996. Impact of mowing height and nitrogen fertility on brown patch of tall fescue. Biol. and Cultural Tests 11:34.

Voigt, T.B., T.W. Fermanian, and J.E. Haley. 2001. Influence of mowing and nitrogen fertility on tall fescue turf. Int. Turfgrass Soc.Res. J. 9:953–956.

Watkins, E. and W.A. Meyer. 2004. Morphological characterization of turf type tall fescue genotypes. HortScience. 39: 615-619.

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.

Table 1. Impact of mowing height and fertility on bermudagrass stolon length in September at the Knoxville and Blacksburg locations.

| Mowing height (cm) | N kg $ha^{-1}$ $yr^{-1}$ | Stolon length (cm) | |
|---|---|---|---|
| | | Knoxville[a] | Blacksburg |
| 10 | 49 | 18.5ab | 12.1 a |
| 10 | 171 | 12.5 b | 12.1 a |
| 10 | 220 | 14.5 b | 12.9 a |
| 6 | 49 | 19.3 a | 11.9 a |
| 6 | 171 | 18.5ab | 10.9 a |
| 6 | 220 | 20.5 a | 11.1 a |

[a] 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 2. Impact of mowing height and fertility on visual brown patch severity taken in September in the Knoxville and Blacksburg locations.

| Mowing height (cm) | N kg $ha^{-1}yr^{-1}$ | Percent brown patch | |
|---|---|---|---|
| | | Knoxville[a] | Blacksburg |
| 10 | 49 | 28 ab | 11 a |
| 10 | 171 | 21 b | 8 a |
| 10 | 220 | 24 b | 7 a |
| 6 | 49 | 32 a | 8 a |
| 6 | 171 | 36 a | 6 a |
| 6 | 220 | 30 ab | 2 a |

[a] 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 mowing height and nitrogen fertility on visual turfgrass cover taken one year after establishment in Virginia Beach 2009, 2010, Knoxville and Blacksburg locations.

| Mowing height (cm) | kg N $ha^{-1}yr^{-1}$ | Percent turf cover | | | |
|---|---|---|---|---|---|
| | | Virginia Beach 2009[a] | Virginia Beach 2010 | Knoxville | Blacksburg |
| 10 | 49 | 55 ab | 38 a | 95 a | 90 b |
| 10 | 171 | 58 ab | 40 a | 95 a | 98 a |
| 10 | 220 | 70 a | 45 a | 95 a | 95 a |
| 6 | 49 | 38 b | 24 b | 92 a | 78 b |
| 6 | 171 | 35 b | 25 b | 93 a | 94 a |
| 6 | 220 | 22 b | 25 b | 94 a | 93 a |

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

Figure 1. Impact of mowing height and nitrogen application on monthly bermudagrass stolon length during summer of the 2009 Virginia Beach trial (bars indicate standard error).

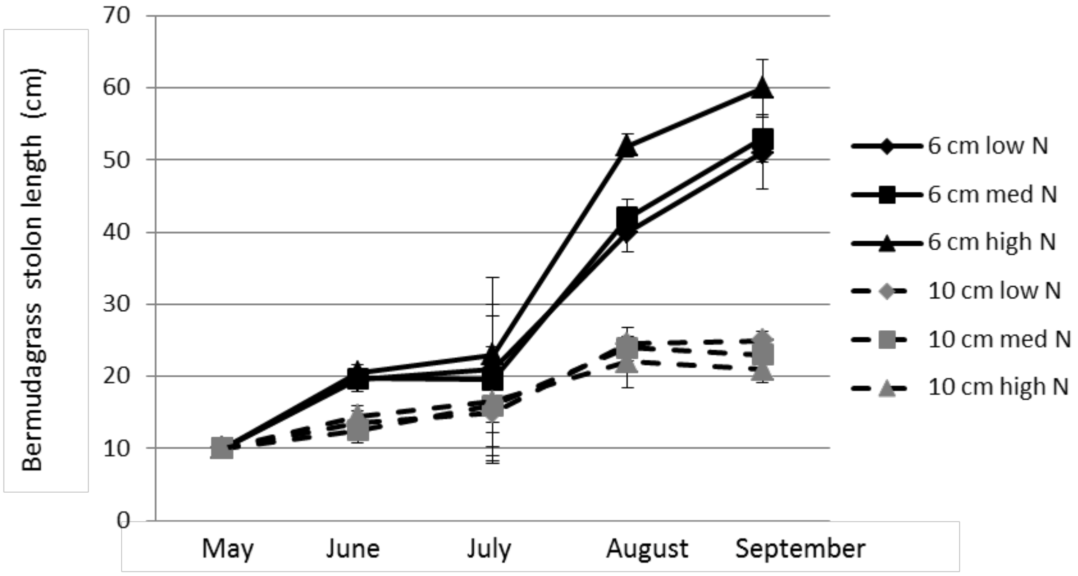


Figure 2. Impact of mowing height and nitrogen application on monthly bermudagrass stolon length during summer of the 2010 Virginia Beach trial (bars indicate standard error).

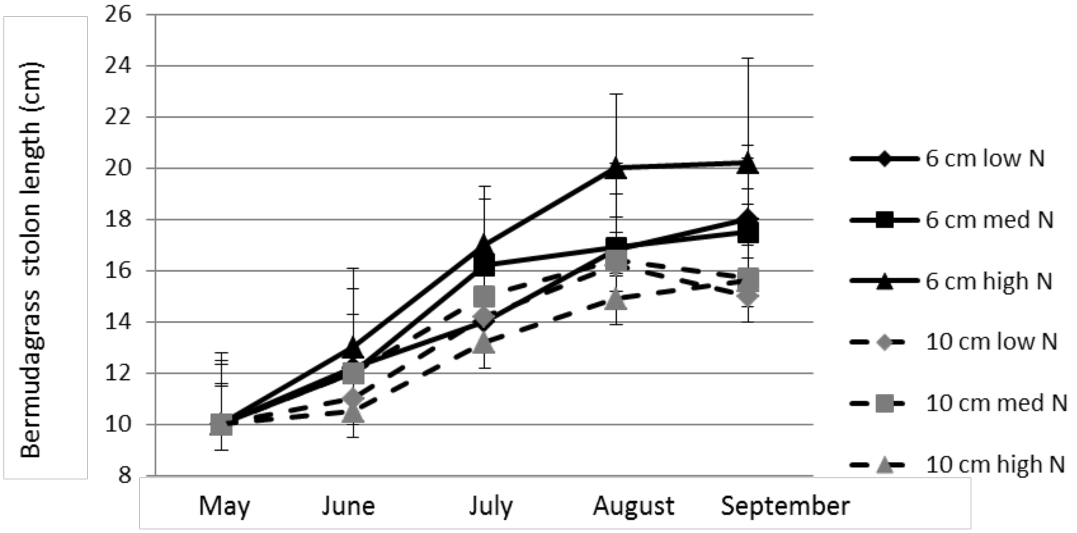


Figure 3. Impact of mowing height and nitrogen application on monthly percent brown patch severity taken monthly during summer of the 2009 Virginia Beach trial (bars indicate standard error).

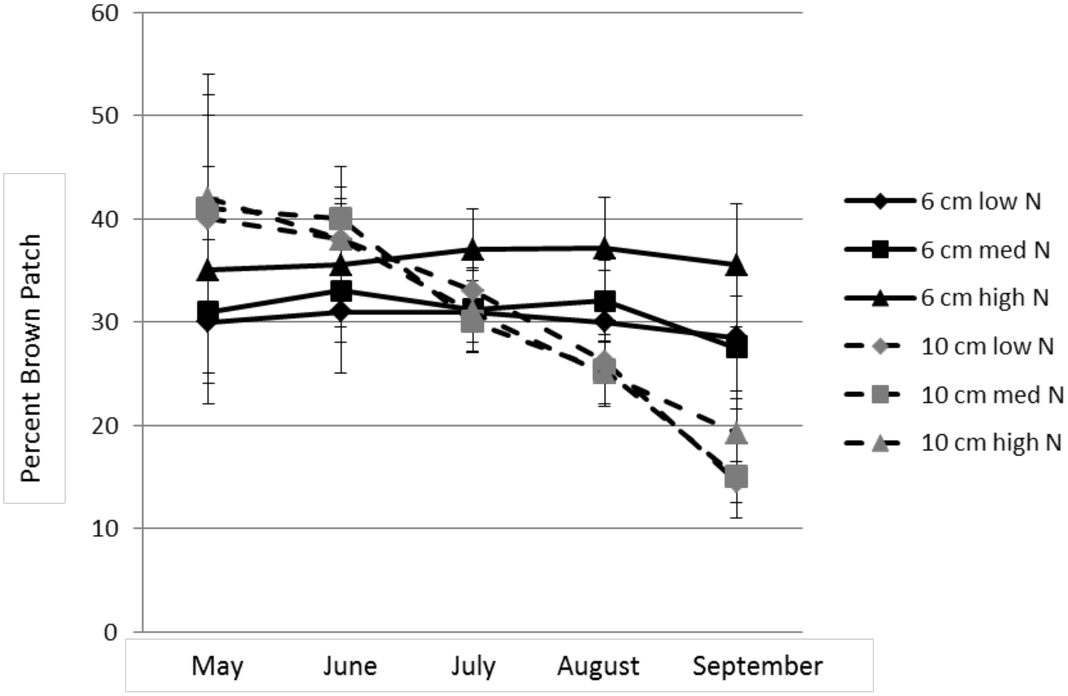


Figure 4. Impact of mowing height and nitrogen application on monthly percent brown patch severity during summer of the 2010 Virginia Beach trial (bars indicate standard error).

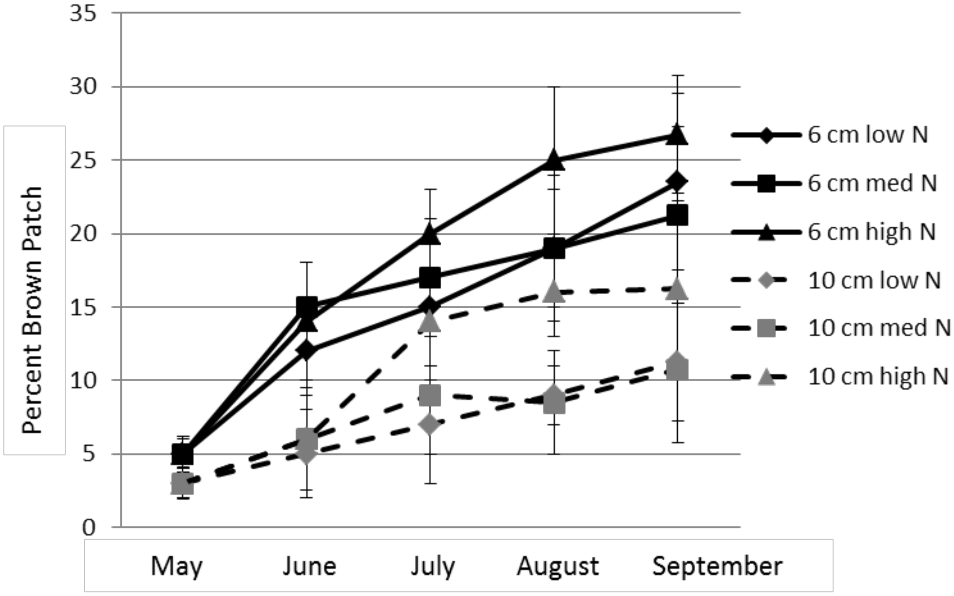
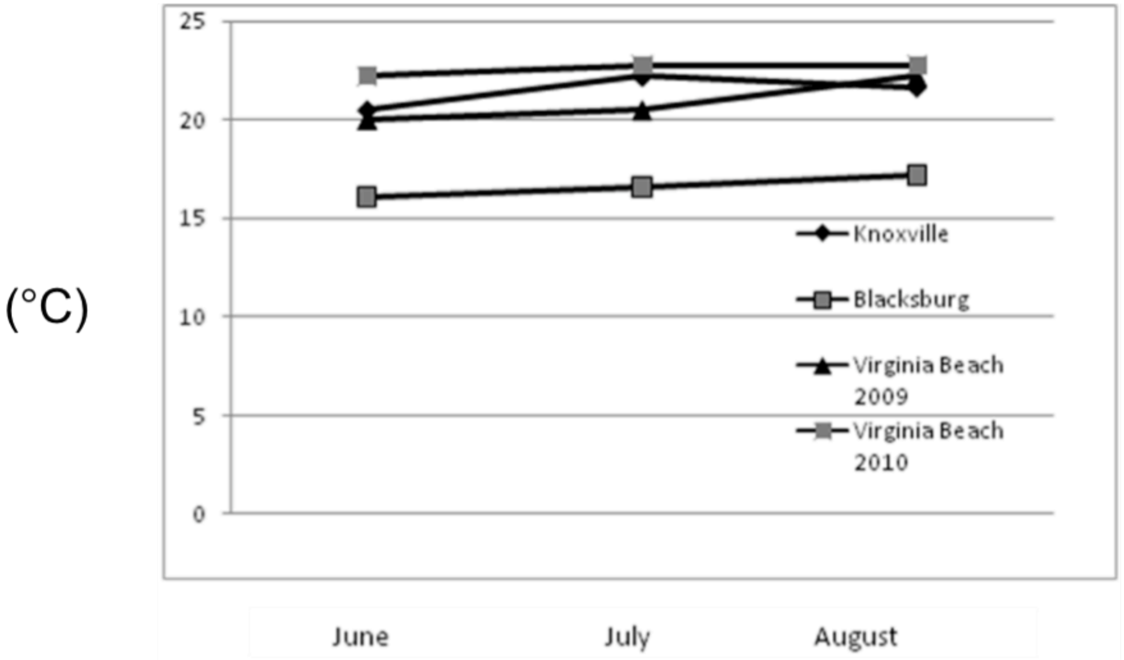


Figure (5). Mean monthly minimum temperatures (°C) taken over the summer in the 4 trials.



# Quantification of Chitinase in Tall Fescue Cultivars of Varying Susceptibility to *Rhizoctonia solani.*

## Abstract

Tall fescue has great utility as a low maintenance turfgrass in the northern and transition zone regions of the United States. A limiting factor for growing tall fescue is its susceptibility to the disease brown patch (*Rhizoctonia solani*). Experiments were conducted to determine if a similar response occurred in tall fescue. A chitinase assay was developed for use in tall fescue. Three cultivars of tall fescue with varying agronomic qualities and susceptibility to brown patch as well as a hybrid bluegrass cultivar were inoculated with *R. solani* in a greenhouse. Chitinase activity assayed from the inoculated plants revealed a negative correlation between chitinase activity 48 hours after inoculation and percent brown patch severity 10 days after inoculation. 'Jaguar' was the most resistant tall fescue cultivar to brown patch and exhibited the most chitinase activity before and after inoculation. Only small increases in chitinase activity were observed in tall fescue following *Rhizoctonia* inoculation. Identifying tall fescue cultivars expressing high amounts of chitinase activity might be important for reducing damage incurred by brown patch in tall fescue turf stands.

## Introduction

Tall fescue [*Festuca arundinacea* Schreb synonym *Schedonorus phoenix* (Scop.) Holub] is one of the most commonly-used turfgrasses for home lawns and common areas in North America, Europe, Asia and North Africa; additionally it serves as a feed for livestock and is used for soil stabilization (2). This economically-important grass species is aesthetically-pleasing, quick to establish, and requires less inputs when compared to other cool-season grass species.

The major problem with growing tall fescue is its susceptibility to fungal pathogens such as *Rhizoctonia solani*, which causes the disease brown patch (6).

Brown patch is the most severe and frequently occurring disease in turf-type tall fescue. The causative agent *Rhizoctonia solani* Kuhn (13) is a basidiomycete, soilborne fungus, consisting of multiple anastamosis groupings or strains that infect many monocots, including rice where the disease is termed sheath blight. Typically, tall fescue lawns in the summer are subject to concomitant infection by *Rhizoctonia solani* and decreases in photosynthetic efficiency, which can lead to a thinning of the turf stand. Parasitization of the grass foliage is not initiated until the air temperature reaches about 30 C (5). Additionally, high humidity and nighttime temperatures of no lower than 16 C are required for the fungus to parasitize foliage (14). Upon contact with the plant, rounded R. solani hyphae grow over the plant surface. Actual infection begins when the hyphae flatten out and press into the epidermal cells of the plant (1, 3). Hyphal internodes shorten and form side branches. Additionally, branching of hyphae can form tightly-packed, dome-shaped infection cushions that adhere tightly to the surface of the plant. *R. solani* initiates penetration through the formation of thin infection pegs. These infection pegs are formed from closely-adhered swollen hyphal tips (7). It is believed that the hyphal tips function to find weak sites of the plant in which to initiate penetration (10). Throughout penetration, carbohydrates from the fungal cell wall are introduced into the plant, which can induce defense responses. Typically, *R. solani* is a weak pathogen that does not seriously damage grass plants. However, when the plant suffers heat stress, *R. solani* opportunistically infects the host grass. Applications of fungicides are not economical in lower maintenance tall fescue, thus elucidation of tall fescue defense mechanisms against *Rhizoctonia solani* will be important for selecting appropriate tall fescue cultivars.

Chitinases are important in plant defense for their ability to catalyze the degradation of chitin. Chitin is a polymer of N-acetylglucosamine $(C_8H_{13}O_5N)_n$ and a major component of the fungal cell wall. Not only do chitinases initiate lysis of the fungal cell wall but they reduce fungal growth by binding physically to the chitin in the fungal cell wall. Furthermore the chitin oligomers formed after fungal cell wall lysis can act as elicitors by inducing a change in a receptor protein, which then can lead to a kinase cascade and defense response (15). Specifically, the CEBiP membrane protein in rice has been shown to be an important receptor and transduction component in chitin recognition and response (9). Additionally, the membrane protein-kinase CERK1, described by Miya et al. (12) in *Arabidopsis thaliana*, is able to autophosphorylate and initiate a defense response in the presence of chitin. The defense processes triggered by oligomeric chitin may include hypersensitivity, increased glucansase and chitinase activity, lignification of plant cell walls and increase in phytoalexins. *FaChit1* is a class 1 chitinase from tall fescue that has a chitin binding domain and is activated in the presence of oligomeric chitin, thus tall fescue should have more chitinase activity when it is being parasitized by *Rhizoctonia solani* (18). Chitinase activity has been positively correlated with resistance to *Rhizoctonia solani* in other plant species (11). In one study, rice cultivars that were resistant to *Rhizoctonia solani* expressed more chitinase at a basal level and after the plants were inoculated when compared to cultivars that were more susceptible to *Rhizoctonia solani* (16). Plants that are more metabolically efficient would likely have the largest increase in chitinase activity when challenged with a fungal pathogen. Quantifying chitinase activity in tall fescue cultivars with different anatomical characteristics that vary in susceptibility to *Rhizoctonia solani* when infected with brown patch will help clarify the relationship among pathogen infection, plant enzymatic defense, and plant anatomical defense.

Research was conducted to evaluate chitinase activity in four grasses: 1 “Jaguar” tall fescue, a turf-type cultivar, 2 “Kentucky 31” tall fescue, which is a pasture-type tall fescue frequently used in turfgrass applications that is typically not as susceptible to brown patch as most turf-type tall fescues, 3 “Matador” tall fescue, which has very desirable agronomic qualities for turfgrass stands but is very susceptible to brown patch and 4 “Thermal Blue Blaze” hybrid bluegrass, which is typically resistant to *Rhizoctonia solani*. Chitinase levels were determined in both inoculated and non-inoculated plants to determine if the presence of *R. solani* increases defense mechanisms in tall fescue.

## Materials and Methods

Approximately 10 seeds of Kentucky 31, Jaguar, and Matador tall fescue and 50 seeds of Thermal Blue Blaze were planted in 3.8 cm diameter Conetainers™ (Steuwe & Son, Corvallis, OR) filled with profile media. Plants were grown in a greenhouse for 12 weeks before being placed in 4 humidity chambers. The greenhouse was equipped with cooling fans and light shutters in order to moderate temperatures. Plants were irrigated daily from an overhead mist system. Plants were treated with 20-20-20 NPK fertilizer at a rate of 96 kg ha$^{-1}$ during establishment. Grass plants were cut weekly to a height of 7 cm. Inoculum was made by incubating 250 g of sterilized Kentucky 31 tall fescue seed with five 5 mm plugs of *Rhizoctonia solani* grown on potato dextrose agar from anastamosis grouping AG2- 2IIIB at 27 C for 1 week. The isolates were collected from tall fescue and were given as a gift by Dr. Sajeewa Amaradassa.

Plants were transferred to four sealed humidity chambers in order to promote environmental conditions that would favor the infection process. The experimental design within each chamber was a randomized block with 5 replications and three samples per experimental unit. The main block treatment was humidity chamber, which either contained inoculum or did not. An experimental unit consisted of 3 conetainers. The treatment design was a factorial of cultivar by inoculation. Each experimental unit was planted with Kentucky 31, Jaguar, Matador tall fescue or Thermal Blue Blaze hybrid bluegrass and was treated with 1 gram of sterilized seed with or without inoculom. Chitinase activity was recorded 48 hours after inoculation. Percent disease was recorded 10 days after inoculation. The entire experiment was repeated and data were pooled.

### Protein Quantification and Chitinase Assay

Samples of grass tissue (400 mg) were homogenized in 800 ul of 0.2 M sodium acetate buffer (pH 5.0) and 0.1mM of phenyl methyl sulphonyl fluoride using a customized drill bit and mesh bags. The tissue extract was then centrifuged at 13,000xg for 10 min at $4^{o}$ C. Subsequently, the supernatant was decanted and centrifuged again under the same conditions. The remaining clear supernatant was then used for both total protein quantification and chitinase assays. Protein concentrations were determined based on colormetric calculations using a Pierce BCA Protein Assay kit and an albumin protein standard (Pierce Protein Research Products. 3747 N Meridian Rd, Rockford, IL, 61101). Chitinase activity was measured by incubating tissue extracts with Remazol Brilliant Violet-labeled chitin and measuring absorbance at 550 nanometers (19). Chitinase activity per sample was determined by the following equation: (Sample absorbance RBV chitin – absorbance RBV chitin with deionized water)/ (Total protein of sample)= Chitinase activity per unit protein.

### Data Analysis

All data were subjected to analysis of variance ($\alpha$= 0.05) using mixed model methodology (Statistical Analysis software (SAS) v. 9.1, Cary NC). Cultivar type and inoculom treatments were considered fixed effects and replication were considered random. Percent brown patch severity and chitinase activity were correlated using SAS.

## Results

Grass cultivars responded differently to inoculation with R. solani in terms of chitinase activity (Figure 1). Jaguar tall fescue had the greatest amount of chitinase activity at both a constitutive level and when challenged with *Rhizoctonia solani* (Figure 1). Chitinase activity in tissue extract from Jaguar was 0.57 units $mg^{-1}$ protein in non-inoculated plants and increased to 0.64 units $mg^{-1}$ protein in plants inoculated with *Rhizoctonia solani*. Greater chitinase activity in inoculated plants was also observed in Matador and Kentucky 31 compared to non-inoculated plants of the same cultivar; however, both cultivars had significantly lower basal level chitinase activity than Jaguar. Chitinase activity in non-inoculated plants was 0.44 and 0.47 units $mg^{-1}$ protein in Kentucky 31 and Matador tall fescue respectively. Inoculating the plants resulted in chitinase activity of 0.49 and 0.51 units $mg^{-1}$ protein for Kentucky 31 and Matador tall fescue respectively. Chitinase activity did not increase in Thermal Blue hybrid bluegrass when the plants were inoculated. Chitinase activity in Thermal Blue hybrid bluegrass was approximately 0.57 units $mg^{-1}$ protein.

Grass cultivar and inoculation had a significant effect on brown patch severity ($p\text{-value}<0.05$) (Table 1). For the inoculated plants, Matador and Kentucky 31 tall fescue had visual brown patch ratings of 16% and 17% respectively, which was signifcantly greater than that seen in Jaguar tall fescue or Thermal Blue hybrid bluegrass. Jaguar leaves were covered with 10 % brown patch lesions, which was significantly less than the other two tall fescue cultivars but significantly more than Thermal Blue which had approximately 1% brown patch. Brown patch severity ratings were neglible in the non-inoculated plants, which indictates there was minimal contamination in the non-inoculated humidity chamber. Three weeks after inoculation percent brown patch was greater than 50% in all three tall fescue cultivars with no signifigant differences among cultivars (Data not shown). Tall fescue cultivars with high basal levels of chitinases may be less susceptiple to brown patch under low levels of inoculom compared low-chitinase cultivars. However, all tall fescue cultivars are susceptible to brown patch and multiple other physiological and anatomical components are important in plant defense.

## Discussion

Chitinases constitute an important component of plant defense agaisnt *Rhizoctonia solani* and other fungal pathogens. Chitinase activity in tissue extracts from tall fescue was negatively corrrelated with visual brown patch severity (Figure 2). The Pearsons coefficent in the simple correlation was -0.72 and the p-value was less than 0.05,  indicating that increased chitinase activity resulted in less disease and that the relationship was significant. These results compliment the findings of Shrestha et al. (16) who evaluated chitinase activity in different rice cultivars that were inoculated with *Rhizoctonia solani*. Correlating  rice chitinase activity with the number of infection cushions per sample resulted in an $R^2$ value of -0.92. Two important characterisitcs associated with resistance to *Rhizoctonia solani* in plants may be high basal level of chitinase activity and an efficient increase in chitinase activity during the infection process. Rice cultivars that were more resistant to *Rhizoctonia solani* expressed more chitinase when no pathogen was present and had a greater increase in chitianse activty after inoculation compared to the more sensitive cultivars. We observed similar trends in our study.

Jaguar tall fescue was the most resistant tall fescue cultivar to *Rhizoctonia solani*. Jaguar tall fescue had the greatest amount of chitinase activity when no pathogen was present and the greatest increase in chitinase activity 48 hours after inoculation. The hybrid bluegrass cultivar evaluated in our study had minimal brown patch and relatively high basal levels of chitinase but did not increase in chitinase activity after inoculation. Hybrid bluegrass is typically not a host for brown patch, thus a lack of compatibility between pathogen and plant as opposed to an increase in chitinase may be the reason for the lack of disease. Kentucky 31 tall fescue is considered to be one of the less susceptible tall fescue cultivars to brown patch. However, this may be due to anatomical characteristics such as its wide leaf blades rather than physiological characteristics. This would explain why Kentucky 31 tall fescue had similar chitinase activity as the denser, more susceptible cultivar Matador.

Tall fescue cultivars with desirable agronomic traits such as narrow blades and dense canopies have been associated with increased susceptibility to brown patch. Tall fescue canopy is believed to have a direct impact on disease incidence (8). A denser leaf canopy will increase relative humidity of the canopy and leaf wetness duration period, which creates an optimal environment for brown patch infection. Because this study was conducted in a humidity chamber, the potential advantage of Kentucky 31 tall fescue's wide leaf anatomy was negated. Matador tall fescue has the most desirable agronomic characteristics of the tall fescue cultivars evaluated in this study. Grass blades from Matador tall fescue were thinner and greener when compared to Kentucky 31 and darker green when compared to Jaguar (Data not shown). However, Jaguar has adequate agronomic qualities and initially was less susceptible to brown patch thus it may be a useful cultivar for the southern region of the tall fescue growing region when combined with appropriate cultural practices. Also of importance may be the recuperative ability of the tall fescue cultivar. High basal levels of chitinase activity may take away metabolic resources for growth and recovery of the tall fescue plant. Therefore, an ideal tall fescue cultivar may have low basal levels of chitinase but efficiently express high amounts of chitinase after perception of a pathogen.

Compared to rice, tall fescue did not exhibit a large increase in chitinase activity 48 hours after inoculation (16). Possible reasons for this reduced response could be the presence of virulence proteins in *Rhizoctonia solani* AG2-2IIIB anastomosis grouping that are analogous to Avr4 and EcP6 from *Cladosporium fulvum.* Avr4 is an effector protein that protects fungal cell walls by binding to long chains of chitin and preventing hydrolysis (17). Specifically, in tomatoes Avr4 appeared to reduce the effectiveness of plant chitinases on fungal chitin in the apoplast. Another fungal protein that reduces chitinase effectiveness is Ecp6. Ecp6 sequesters chitin oligosaccharides and prevents them from eliciting a defense response in the host plant (4). If similar proteins are present in the *Rhizoctonia solani* isolate used in this study, then chitinase activity would not be expected to increase much in tall fescue after inoculation. The conserved tall fescue chitinase gene *FaChit1* increases expression in the presence of chitin (18). Therefore, perturbation of interactions between tall fescue chitinases and chitin from *Rhizoctonia solani* may be the reason tall fescue does not increase in chitinase activity as much as rice as opposed to inferior perception by tall fescue receptor proteins.

Future research should focus on identifying tall fescue cultivars that constitutively express a high amount of chitinase and effectively increase chitinase levels after infection by *Rhizoctonia solani*. Screening for novel effector proteins in anastomosis groupings that impact tall fescue would elucidate the interaction between *Rhizoctonia solani* and tall fescue. Selection of a tall fescue cultivar that produces high levels of chitinase both before and after interaction with a fungal pathogen in combination with proper cultural practices will help reduce severity of brown patch.

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## Literature Cited

1. Armentrout, V.N. and A.J. Downer. 1987. Infection cushion development by *Rhizoctonia solani* on cotton. Phytopathology. 77:619-623.
2. Buckner, R., J. Powell, R. Frakes. 1979. Historical development, in: R. Buckner, L.P Bush (Eds.), Tall Fescue, Agronomy Monograph # 20, American Society of agronomy, Madison, WI, pp. 1-8.
3. Christou , T. 1962. Penetration and host-plant relationships of *Rhizoctonia solani* in the bean plant. Phytopathology. 52:291.
4. De Jonge, R., H. Peter van Esse, A. Kombrink, T. Shinya, Y. Desaki, R. Bours, S. Van der Krol, N. Shibuya, M. H. A. J. Joosten, B. P. H. J. Thomma. 2010. Conserved fungal L Lys M effector Ecp6 prevents chitin-triggered immunity in plants. Science. 329: 953-955.
5. Dickson, L.S. 1930. The effect of air temperatures on the pathogenicity of *Rhizoctonia solani* parasitizing grasses on putting green turf. Phytopathology. 20: 507-608.
6. Dong, S., L. Treadway, H.D. Shew, G.L. Wang, E. Sivamani, R. Qu. 2007. Resistance of transgenic tall fescue to two major fungal diseases. Plant Sci. 173: 501-509.
7. Fukutomi, M., and H. Takada. 1979. Ultrastructure of infection process of *Rhizoctonia solani* Kuhn in cucumber hypocotyls. Ann. Phytopath. Soc. Jpn 45:453-462.
8. Giesler, L.J., G.Y. Yuen, and G.L. Horst. 1996. Tall fescue canopy density effects on brown patch disease. Plant Dis. 80:384-88.
9. Kaku, H., Y. Nishizwa, N. Ishii-Minami, C. Akimoto-Tomiyama, N. Dohmae, K. Takio, E. Minami and N. Shibuya. 2006. Plant cells recognize chitin fragments for defense

signaling through a plasma membrane receptor. Proc. Natl. Acad. Sci. USA 103: 11086-11091.

10. Matsuura, K. 1986. Scanning electron microscopy of the infection process of *Rhizoctonia solani* in leaf sheats of rice plants. Phytopathology 76:811-814.
11. Metraux J.P., P.A. Goy, T. Staub ,J. Speich , A. Steinmann, J. Ryals, E. Ward. 1991. Induced systemic resistance in cucumber in response to 2,6-dichloro-isonicotinic acid and pathogens. In: Hennecke H, Verma DPS, eds. Advances in Molecular Genetics of Plant-Microbe Interactions Vol. 1.Dordrecht: Kluwer Academic Publishers, 432-439.
12. Miya, A., P. Albert, T. Shinya, Y. Desaki, K. Ichimura, K. Sirasu, Y. Narusaka, N. Kawkami, H. Kaku, and N. Shibuya. 2007. CERK1, a LysM receptor kinase, is essential for chitin elicitor signaling in Arabidopsis. Proc. Natl. Acad. Sci. USA., 104: 19613-19618.
13. Piper, C.V. and H.S. Coe. 1919. *Rhizoctonia* in lawns and pastures. Phytopathology. 9:89-92
14. Rowell, J.B. 1951. Observation on the pathogenicity of *Rhizoctonia solani* on bentgrass. Plant Dis. Reptr. 35:240-242.
15. Salzman, R.A., J.A. Brady, and S.A., Finlayson. 2005. Transcriptional profiling of sorghum induced by methyl jasmonate, salicylic acid, and aminocyclopropane carboxylic acid reveals cooperative regulation and novel gene responses. Plant Physiolol 138:352-368.
16. Shrestha, C.L., I. Ona, S. Muthukrishnan, and T.W. Mew. 2008. Chitinase Levels in Rice Cultivars Correlate with Resistance to the Sheath Blight Pathogen *Rhizoctonia solani*. Eur. J. Plant Pathol. 20:69–77.

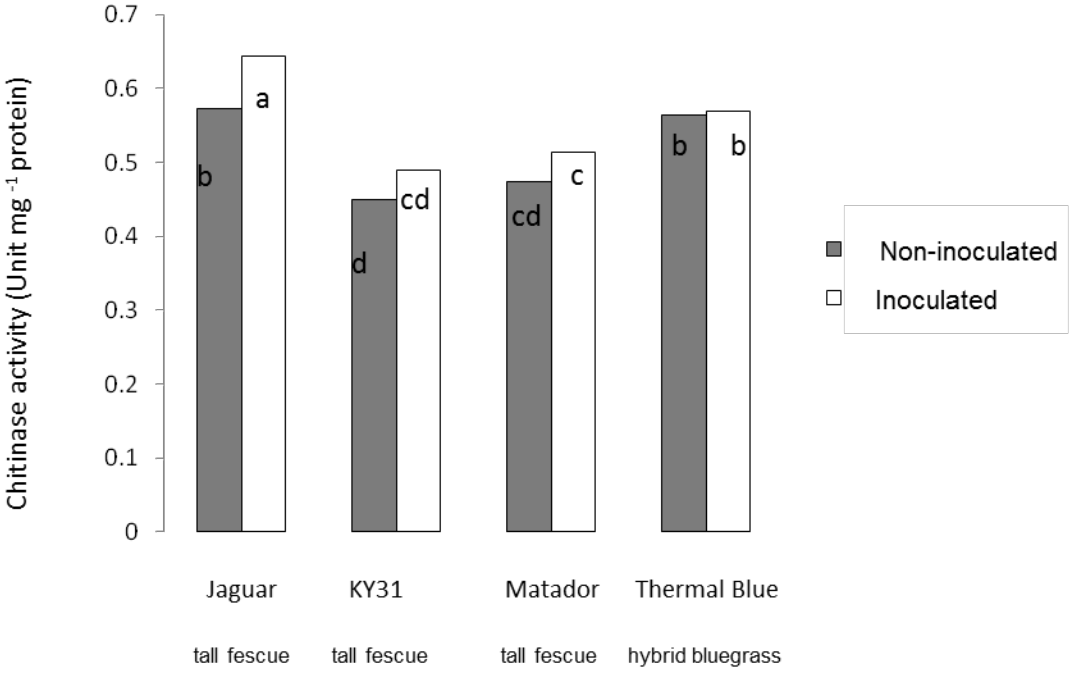
17. Van Esse, P.H., M.D. Bolton, I. Stergiopoulos, P. J. G. M. De Wit, B.P.H.J.T Thomma. 2007. The Chitin-binding *Cladosporium fulvum* effector protein Avr4 is a virulence factor. Mol. Plant Microbe Interact. 20: 1092.
18. Wang, J., N. Tian, X. Huang, L.Y. Chen, M. Schlappi, Z. Q., Xu. 2009. The tall fescue turf grass class I chitinase gene *FaChit1* is activated by fungal elicitors, dehydration, ethylene, and mechanical wounding. Plant Mol. Biol. Rep. 27:305-314.
19. Wirth, S.J. and G.A. Wolf. 1990. Dye labeled substrates for the assay and detection of chitinase and lysozyme activity. J. Microbiol Methods. 12: 197-205.

Table 1. Impact of grass cultivar on visual percent brown patch severity 10 days after inoculation with *Rhizoctonia solani* in a greenhouse setting.

| Grass Type | Percent brown patch[a] |
|---|---|
| Jaguar tall fescue | 9 b |
| Kentucky 31 tall fescue | 16 a |
| Matador tall fescue | 17 a |
| Thermal Blue hybrid bluegrass | 1 c |

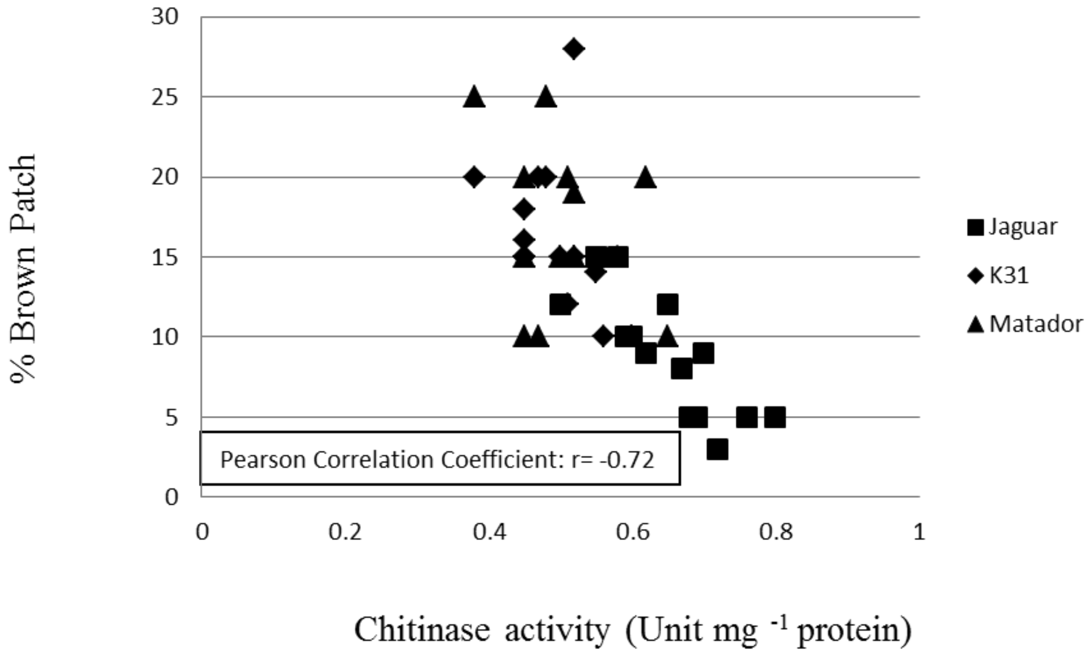
[a] Means within a column followed by the same letter group are not significantly different according to Fishers protected LSD mean separation technique at the 0.05 level.

Figure 1. Impact of grass cultivar and inoculation treatment on chitinase activity 48 hours after inoculation with Rhizoctonia solani in greenhouse setting[a].



[a] Means with the same letter group do not not significantly differ according to Fishers protected LSD mean separation technique at the 0.05 level.

Figure 2. Simple correlation of chitinase activity from inoculated tall fescue and percent brown patch severity ratings [a].



[a] Prob |r| under H0: p<0.0001

# Impact of Bispyribac-sodium Application on Annual Bluegrass Control and Brown Patch Severity in Tall Fescue.

## Abstract

Annual bluegrass (*Poa annua* L.) is a problematic weed in tall fescue (*Festuca arundinacea*), particularly if a preemergence herbicide application is ineffective or if the tall fescue has been overseeded in the fall. Currently, there are limited options available for postemergence control of annual bluegrass in tall fescue. A postemergence herbicide that has the potential to control annual bluegrass in tall fescue is bispyribac-sodium. However, bispyribac-sodium increases bentgrass species (*Agrostis spp.*) susceptibility to brown patch (*Rhizoctonia solani*), which is a very devastating disease in tall fescue. Field research was conducted to evaluate bispyribac-sodium application rates (37 or 74 g $ha^{-1}$) and timings (March, April or May) as well as iron supplementation on brown patch severity, annual bluegrass control, and tall fescue quality in 2009, 2010, and 2011. In a greenhouse experiment, bispyribac-sodium at 37 and 74 g $ha^{-1}$ was applied to brown patch inoculated tall fescue plants. Plant height and brown patch lesions were recorded in the greenhouse studies. A chitinase assay was performed on tall fescue treated with bispyribac-sodium. Applying bispyribac-sodium to tall fescue did not result in significantly more brown patch than the untreated in field trials. Applying bispyribac in March or April resulted in numerically less brown patch and significantly higher annual bluegrass control than applications in May. In greenhouse studies under conditions of high inoculum and humidity, applications of bispyribac-sodium increased the number of brown patch lesions relative to untreated plants. Applications of bispyribac-sodium did not significantly reduce chitinase

activity. Tall fescue growth was initially reduced after being treated with bispyribac-sodium; however, six weeks after application the treated tall fescue plants exhibited more growth than the control.

## Introduction

Annual bluegrass (*Poa annua* L.) is a problematic weed in tall fescue [*Festuca arundinacea* Shreb synonym *Schedonorus phoenix* (Scop.) Holub] and other cool-season grasses. It is adapted to low mowed, irrigated, well-maintained turfgrass (Hall and Casey, 1992; McElroy et al., 2002). The yellow-green color and prominent seedheads of annual bluegrass negatively impact the aesthetic value of tall fescue stands. Typically, preemergence herbicides such as prodiamine [2,4-dinitro-N, N-dipropyl-6-(trifl uoromethyl)-1,3-benzenediamine] (Barricade 4FL, Syngenta Crop protection, Inc., Greensboro, NC) pendimethalin [N-(1-ethylpropyl)-3,4-dimethyl-2,6-di- nitrobenzenamine] (Pendulum AquaCap, BASF Agricultural Products, Research Triangle Park, NC) or dithiopyr [S,S'-dimethy 2-(difluoromethly)-4-(2-methylpropyl)-6-(trifluoromethyl)- 3,5-pyridinedicarbothioate] (Dimension Ultra, Dow AgroSciences LLC, Indianapolis, IN) are applied in early fall to control annual bluegrass (Bhowmik and Bingham, 1990). However, if tall fescue is overseeded in the fall then mitotic inhibiting herbicides can't be applied without damaging the tall fescue seedlings. Siduron is a preemergence herbicide that can be applied to tall fescue seedlings; however, this herbicide does not control annual bluegrass (Sensemen, 2007). Currently, limited postemergence herbicides are labeled for control of annual bluegrass in tall fescue. A postemergence herbicide that has potential to control annual bluegrass in tall fescue is bispyribac-sodium (sodium 2-6-bis[(4,6-dimethoxy-2pyrimidinyl)oxy]benzoate).

Bispyribac-sodium is in the pyramidinyloxybenzoic acid family and is herbicidal due to its ability to inhibit the acetolactase synthetase enzyme, which is responsible for the synthesis of the branched chain amino acids valine, leucine and isoleucine in plants (Sensemen, 2007). Bispyribac-sodium was first adopted for control of barnyardgrass (*Echinochloa crusgalli* L. Beauv) in rice production (McCarty and Estes, 2005). Bispyribac-sodium's selectivity is based on the species' ability to detoxify the herbicide. Bispyribac-sodium is effective at controlling annual bluegrass in creeping bentgrass fairways (Lycan and Hart, 2006). Studies have shown there is minimal phytoxicity when bispyribac-sodium is applied to tall fescue (Lycan and Hart, 2005). Additionally, phytotoxicity attributed to bispyribac-sodium in creeping bentgrass (*Agrostis stolonifera* L.) can be reduced when mixing chelated iron with the herbicide (McDonald et al., 2006). Interestingly, bispyribac-sodium has fungicidal properties. Application of bispyribac-sodium to creeping bentgrass has been shown to reduce dollar spot incidence, a disease caused by the fungal pathogen *Sclerotinia homoeocarpa* (McCarty and Estes, 2005). However, preliminary reports indicate that applications of bispyribac-sodium may increase brown patch disease incidence in bentgrass species (Kaminski and Putman, 2009).

Brown patch is caused by the fungal pathogen *Rhizoctonia solani* Kuhn (Piper and Coe, 1919), a basidiomycota or imperfect fungus that is problematic in multiple grass crops. In turfgrass infected with *R. solani*, leaves initially appear dark and water saturated and cream colored lesion form on the leaves; subsequently, the infected leaves dry out, wither, and turn a dark brown. Brown and black colored sclerotia may be found beneath the leaf or on roots. When no attempt is made to control brown patch, many plants will be damaged, which will lead to thinning of the turf and the encroachment of undesirable weedy species. Upon contact with the plant, rounded *R. solani* hyphae grow over the plant surface. Actual infection begins when the hyphae flatten out and press into the epidermal cells of the plant (Armentrout and Downer 1987; Christou;1962). Hyphal internodes shorten and form side branches at right angles, which are a distinguishing characteristic of *R. solani*. Branching of hyphae can form tightly packed dome-shaped infection cushions that adhere tightly to the surface of the plant. Infection pegs are formed from the swollen hyphal tips (Fukutomi and Takada 1979). It is believed that the hyphal tips function to find weak sites of the plant in which to initiate penetration (Matsuura 1986). Subsequently, the thin infection peg exerts enough pressure on the outside of the plant to penetrate the cuticle. In addition to mechanized pressure, enzymatic activity aides in penetration of the host plant. Throughout infection, carbohydrates from the fungal cell wall are being introduced into the plant, which can induce defense responses, specifically increased chitinase activity. Chitinase is an enzyme that degrades chitin, a major component of the fungal cell wall.

Resistance to *Rhizoctoni solani* has been positively correlated with chitinase activity in multiple plants (Metraux et al., 1991). If application of bispyribac-sodium reduces chitinase activity in tall fescue then this may explain any increased susceptibility to *Rhizoctoni solani*. One study looking at the transcriptome response of *Arabidopsis thaliana* determined that 478 genes were either up or down regulated in the presence of ALS inhbiting herbicides, including genes involved in defense (Das et al., 2010). Thus, application of bispyribac-sodium may have an impact on enzymatic defense mechanisms in tall fescue. In general herbicide applications can impact pathogen-plant interactions by altering the morphology and physiology of the host plant (Altman, 1997). Changes in plants due to herbicide application that may perturb disease incidence include alteration in nitrogen, glucoside, and carbohydrate metabolism as well as reduction or stimulation in plant growth. Pathogen populations in the soil can be altered by herbicide application as well. Pathogens that use the herbicide as a food source will flourish while pathogens injured by that the herbicide will decrease in number (Bollen, 1961).

The benefits of controlling annual bluegrass with bispyribac-sodium in overseeded tall fescue might be negated if the herbicide increased brown patch severity. If applications of bispyribac-sodium increase brown patch severity then the tall fescue stand may be thinned, this could lead to annual bluegrass infestations the following spring (Figure 1). If bispyribac-sodium is to be utilized in tall fescue it is important to optimize application strategies for effective annual bluegrass control while minimizing phytotoxicity and brown patch severity. Additionally, elucidating the impact of bispyribac-sodium on growth and defense in tall fescue would be important for determining the effectiveness of the compound in tall fescue. Research was conducted to evaluate the impact of bispyribac-sodium rate and timing on annual bluegrass control, brown patch severity, phytotoxicity and chitinase activity in tall fescue in field and greenhouse experiments.

## Materials and Methods

### Impact of Bispyribac-Sodium Application on Brown Patch and Annual Bluegrass Cover in Tall Fescue Field Trials

Research was conducted at the Virginia Tech Hampton Roads Agricultural Research and Extension Center located in Virginia Beach, Virginia. The study was established in the spring of 2009, 2010, and 2011. The experimental design was a randomized complete block with 4 replications. ‘Southern Belle’ tall fescue plots 2.13 m by 3.04 m were subjected to a factorial treatment of bispyribac-sodium applied at 37 or 74 grams per hectare on April 22nd or May 22nd with a repeat application two weeks later. In 2010 and 2011 a March application date was included in the study. Untreated plots were incorporated into the study. Plots were mowed at 10 cm and received 171 kg of N per hectare annually. Visual annual bluegrass control, turf quality and brown patch cover ratings were taken from April until the end of June. Visual turfgrass quality ratings were taken on a 1 to 9 scale where 1 indicates dead turf to 9 indicates lush green turf. All data were subjected to ANOVA (α= 0.05) in SAS (Statistical Analysis Software, Cary NC) using mixed model methodology.

### Impact of Chelated Iron with Bispyribac-Sodium on Phytotoxicity in Tall Fescue

An additional field experiment was conducted at the Virginia Tech Hampton Roads Agricultural Research and Extension Center evaluating the impact of chelated iron applications with bispyribac-sodium on phytotoxicity and brown patch severity in Southern Belle tall fescue. The treatments included an untreated check, bispyribac-sodium applied alone at 37 g per hectare and bispyribac sodium applied at the same rate tank mixed with chelated- iron. The liquid Fe + N product was tank-mixed with bispyribac-sodium to provide FeSO4 at 1.1 kg/ha + N at 2.2 kg/ha + S at 0.7 kg/ha + Mn at 0.4 kg/ha. Treatments were applied March 22nd, April, 22nd or May 22nd with a repeat application two weeks later. The plots were 2.1 by 3.0 m. The experimental design was a randomized complete block with 4 replications. The plots were mowed at 10 cm and received 171 kg of N per hectare annually from a 20-20-20 NPK fertilizer slow-release nitrogen source. Prodiamine preemergence herbicide was applied in October in order reduce the influence of weeds on the epidemiology of brown patch in tall fescue and allow for easier visual evaluations regarding the phytoxicity of bispyribac-sodium on tall fescue. All data were subjected to ANOVA (α= 0.05) using Agricultural Research Manager (Gylling Data Managing inc. 2008).

### Greenhouse study: Impact of Bispyribac-Sodium on Brown patch Lesions, Quality and Plant Regrowth.

Greenhouse studies were conducted at the Hampton Roads Agricultural Research and Extension Center and the Glade Road Research Center in Blacksburg, VA to evaluate the interaction between bispyribac-sodium, *Rhizoctonia* solani and 'Matador' tall fescue in a climate-controlled setting. The experimental design was a split block with 5 replications. Tall fescue plants were grown in profile media in pots 25 cm in diameter, one pot per plot. The greenhouse had light shutters and fans in order to moderate temperature. The tall fescue plants were cut to 9 cm weekly and after 3 months were placed in humidity chambers that received *R. solani* inoculum or no inoculum. Plants were grown in simulated summer conditions to approximate 35 C and irrigated with an overhead mist system. A protocol developed by Burpee et al. (1991) was followed to inoculate the plants. The *Rhizoctonia solani* isolates used were from anastamosis grouping AG2-2IIIB and were collected from tall fescue. Treatment design consisted of a factorial of plants receiving inoculum or no inoculum, and bispyribac sodium applied at 37 or 74 g ha$^{-1}$. Bispyribac-sodium was applied to the plants 6, 4 or 0 weeks before inoculation with a repeat application two weeks later. Non-inoculated and inoculated controls were incorporated into the study. Plant height was measured weekly and brown patch lesions were counted 14 days after inoculation. The experiment was repeated and data pooled over the two experiments. Tall fescue height was measured in plants receiving the bispyribac-sodium treatment at the 6 plus 4 week pre inoculation application. The plants were measured one week after the first herbicide application. Inoculation did not have a significant effect on plant height, thus the average of inoculated and non-inoculated plants is presented.

### Chitinase Assay: Impact of Bispyribac-Sodium Application on Chitinase Activity.

"Matador" tall fescue plants were grown in a greenhouse with light shutters and cooling fans to moderate temperature. Plants were grown in conetainers 3.8 cm in diameter. After 12 weeks the plants were arranged in a Completely Randomized Design (CRD) and were treated with 37 g of bispyribac-sodium or received no herbicide treatment. Each treatment was replicated 5 times. Chitinase activity was measured 2 and 7 days after treatment. The experiment was repeated and data pooled over the two experiments.

A colormetric assay was used to quantify chitinase activity. Samples of grass tissue (400 mg) were homogenized in 800 ul of 0.2 M sodium acetate buffer (pH 5.0) and 0.1 mM of phenyl methyl sulphonyl fluoride using an Agdia drill bit and Agdia mesh bags. The tissue extract was then centrifuged at 13,000xg for 10 min at $4^{o}$ C. Subsequently, the supernatant was decanted and centrifuged again under the same conditions. The remaining clear supernatant was then used for both total protein quantification and chitinase assays. Protein concentrations were determined based on colormetric calculations using a Pierce BCA Protein Assay kit and an albumin protein standard (Pierce Protein Research Products. 3747 N Meridian Rd, Rockford, IL, 61101); (Smith et al., 2005). Chitinase activity was quantified by incubating tissue extracts with Remazol Brilliant Violet-labeled chitin and the absorbance was measured at 550 nanometers (Wirth and Wolf, 1990). Chitinase activity per sample was determined by the following equation: (Sample absorbance of RBV chitin –deionized water absorbance of RBV chitin)/ (Total protein in sample) = Chitinase activity per mg protein.

## Results

Study year had a significant effect on annual bluegrass cover, thus the study years will be presented separately. Herbicide timing and herbicide rate had a significant effect on annual bluegrass cover depending on the rating date. On April 21st of the 2009 study, which was before any herbicide treatments were applied, annual bluegrass cover ranged from 26% to 29% (Table 1). The highest annual bluegrass control was achieved when bispyribac-sodium was applied at 74 g $ha^{-1}$ in April. Applying bispyribac-sodium in May regardless of rate resulted in unacceptable annual bluegrass cover in June. Due to the success of the April applications an earlier application date (March) was added in the 2010 study.

In 2010 herbicide rate or timing did not have a significant effect on annual bluegrass cover. Annual bluegrass cover in the untreated plots was approximately 50% on the first rating date, which was almost double the amount of annual bluegrass cover observed in the 2009 study. The March application of bispyric-sodium at 74 g $ha^{-1}$ initially reduced annual bluegrass cover numerically in April; however, the annual bluegrass recovered by the next rating date. April applications of bispyribac-sodium in 2010 were not as effective as the 2009 study. The reduced efficacy could be due to the larger annual bluegrass plants at treatment in 2010 compared to 2009.

In 2011 applying bispyribac-sodium, regardless of rate or timing resulted in significantly less annual bluegrass cover when compared to untreated plots (Table 1). Due to the reduced rainfall in 2011 compared to 2009 and 2010, the annual bluegrass naturally transitioned out of the tall fescue stand by the June rating date.

Study year had a significant effect on percent brown ratings as well, therefore the studies will be presented separately. Herbicide timing or herbicide rate did not have a significant effect on percent brown patch, though applying bispyribac-sodium in May resulted in a numerical increase in brown patch in all study years.

Brown patch ratings were 5% across all treatment plots on April 21st 2009 (Table 2). On May 21st the untreated plots had 18% brown patch. Applying bispyribac-sodium in May lead to a numerical increase in brown patch severity on the June rating date. In the 2010 study there was less brown patch than was observed in 2009. All brown patch brown severity ratings taken on April 21st and May 21st were minimal (1%). On June 21st, applying bispyribac-sodium in May resulted in 23 to 24% brown patch. Applying bispyribac-sodium in March and April resulted in brown patch ratings ranging between 12% and 15%. The most brown patch was observed in plots treated with bispyribac-sodium at 74 g $ha^{-1}$ in May. Percent brown patch severity was minimal in the 2011 study and application of bispyribac-sodium did not increase brown patch severity in tall fescue in 2011.

Study year and herbicide timing affected turfgrass quality ratings. In April and May of 2009, the untreated plots had a quality rating of 7.1 (Table 3). Initially, applications of bispyribac-sodium resulted in a yellow chlorosis in tall fescue that reduced the quality rating of the plots. However, two months after bispyribac-sodium application, the treated plots were darker green than the control, thus the quality of the April-treated plots are greater than the control on the June rating date. Different trends for quality were observed in 2010. On April 21st the quality of tall fescue in the untreated check was 7.0. Applying bispyribac-sodium in March at 37 g and 74 g $ha^{-1}$ resulted in turfgrass quality ratings of 4.0 and 3.8, respectively on April 21st. No increase in green color was observed two months after bispyribac-sodium application in the 2010 trial. On some dates in 2011, an increase in green color was observed following application of bispyribac-sodium. In 2011 a rate and timing effect was observed on the May 21st date. Applying bispyribac-sodium on the March application date at 74 g $ha^{-1}$ resulted in significantly darker green plots compared to the untreated check plots. For later application dates, increasing the rate generally led to lower quality ratings.

## Impact of Bispyribac-Sodium Application Timing and Iron Supplementation

Study year, herbicide timing and iron supplements affected quality ratings. Applications of bispyribac-sodium alone in March resulted in turfgrass quality ratings of 6.5 on April 21st (Table 4). The turfgrass quality in the untreated check plots and plots treated with bispyribac-sodium and chelated iron in March was 7.0, thus the iron masked the yellow discoloration occurring after bispyribac-sodium application. However, on some rating dates, iron supplementation resulted in lower quality ratings. In April of 2011, applications of bispyribac-sodium and iron resulted in lower quality on the May rating date than plots treated with bispyribac-sodium alone.

Percent brown patch severity was minimal in April and May of 2010. On June 21st 2010 percent brown patch severity in the untreated check was 10% (Table 5). Applications of bispyribac-sodium increased brown patch severity numerically, though the increase was not significant. Applications of chelated iron in May appeared to reduce brown patch severity on June 21st; however, the reduction was not significant. Percent brown patch severity was minimal in April, May and June of 2011. Bispyribac-sodium did not have any impact on brown patch severity in 2011. Fifty percent less rain fell in the spring of 2011 compared to the spring of 2009 and 2010, which could explain the differences in brown patch severity among study years.

Based on the results of the field studies, applying bispyribac-sodium in April at the high rate would maximize annual bluegrass control and minimize brown patch severity. Generally, there was better quality in tall fescue in June when the herbicide was applied in April versus May. Less phytotoxicity and brown patch occurred from an April applications compared to May applications. Additionally, the increase in green color observed two months after the April application in 2009 and 2011 did not occur two months after the May applications (data not shown). Applying bispyribac-sodium in April or March provided better annual bluegrass control when compared to May applications. Applying bispyribac-sodium in the cooler March temperatures may allow the annual bluegrass plants to recover. If the applications must be made in March then a third application should be considered. In addition to recuperative ability of annual bluegrass plants, the size of the plants should be considered as well. Applying bispyribac-sodium in May was not as effective in some years because the plants were able to grow longer before herbicide application, thus they were larger and harder to control. Applications of bispyribac-sodium were not as effective in the 2010 study when compared to the 2009 study. The differences in herbicide efficacy may be attributed to differences in annual bluegrass size between the two study years. Rainfall from October through November of 2008 was 26.97 cm; comparatively, rainfall from October through November of 2009 was 49.96 cm. Therefore, the annual bluegrass plants were more robust coming into the spring of 2010 compared to the spring of 2009, which would make the plants harder to control in 2010. Annual bluegrass plants did not cover much of the untreated check plots by June of 2011. The reason for the decrease of annual bluegrass cover in the 2011 study may be due to decreased spring rainfall when compared to the other study years. In 2011, only 25 cm of rain fell from March until June while 40 to 45 cm of rain fell during the spring in the other studies. The drought conditions lead to an overall decrease in annual bluegrass cover from May to June in 2011. The results of these studies are slightly different than other studies evaluating bispyribac-sodium timing on annual bluegrass control. In New Jersey, applications of bispyribac-sodium in July resulted in less annual bluegrass cover on a creeping bentgrass fairway than April applications (Lycan and Hart, 2006). The differences in efficacy may be attributed to the cooler temperatures in New Jersey, where April application allowed the plants to recover, compared to the warmer Virginia Beach site. Other studies showing the effectiveness of bispyribac-sodium applied at 74 g ha$^{-1}$ with repeat applications in the summer on annual bluegrass control occurred in the cooler climates of Blacksburg, VA, New Jersey, and Maryland (Askew et al. 2004; Dernoeden et al. 2004; Lycan et al. 2003).

Spraying earlier in the year typically resulted in numerically less brown patch than spraying later in the year with the exception being 2011, where drought resulted in minimal brown patch in all plots. Nevertheless, more research is needed on March or earlier timing applications of bispyribac-sodium on annual bluegrass control. Based on these studies, applying bispyribac-sodium in May not only leads to reduced annual bluegrass control but also increases brown patch incidence. There was not much increase in brown patch severity when increasing the herbicide rate. Applying chelated iron numerically masked brown patch symptoms on some treatment dates in addition to masking phytotoxicity from the herbicide. Based on these studies, we would recommend applying bispyribac-sodium in April at 74 g $ha^{-1}$ with chelated iron. Also, due to the phytoxicity caused by the initial bispyribac-sodium application and the flush of green growth seen 4 to 6 weeks after application, we would recommend only broadcast application. Spot spraying bispyribac-sodium may create a mottled pattern in the turf stand.

**Greenhouse Study**

Bispyribac-sodium rate did have a significant effect on plant height on some of the measuring dates. One week after herbicide application the plant height for untreated control plants was 15 cm (Figure 2). Plants treated with bispyribac-sodium were approximately 8 cm tall regardless of rate one, two, and three weeks after herbicide treatment. The first symptoms of ALS-inhibiting herbicides is a cessation of mitosis, thus the reduction in plant growth was expected. Four weeks after application, there was no significant differences among treatments and the range of plant height was between 8 and 10 cm. Five weeks after treatment, the height of the untreated control plants was 8.5 cm and plants treated with 37 g $ha^{-1}$ of bispyribac-sodium had increased to 13 cm. Six weeks after application, plants treated with either rate of bispyribac-sodium had grown to 13 cm while plants in the untreated control were shorter than 10 cm.

All plants treated with bispyribac-sodium had more brown patch lesions compared to the untreated check (Table 6). Typically, a greater number of brown patch lesions were recorded on plants treated with bispyribac-sodium 6 plus 4 weeks before inoculation when compared to application timings close to the inoculation date. For most of the applications, rate did not have an effect on brown patch lesions. However, increasing the herbicide rate at inoculation and two weeks after inoculation resulted in an increase of brown patch lesion counts compared to the low rate.

### Impact of Bispyribac-Sodium on Chitinase Activity

Applications of bispyribac-sodium appeared to reduce chitinase activity in treated plants two days after treatment (Table 7). There were about 0.2 units of chitinase activity mg$^{-1}$ protein less in the treated plants versus the untreated plants two days after treatment. Chitinase activity assayed 7 days after treatment revealed minimal numeric differences between the treated and untreated plants.

### Cause of Increased Brown Patch in Tall fescue

It is difficult to determine the exact mechanism that increases tall fescue susceptibility to *Rhizoctonia solani*. Under conditions of high humidity and high levels of inoculum in a growth chamber, bispyribac-sodium increased brown patch incidence in tall fescue. In field studies, less humidity, more microbial competition, and cooler nighttime temperatures could reduce the impact of bispyribac-sodium on brown patch severity. Applications of bispyribac-sodium numerically reduced chitinase activity two days after application but chitinase activity 7 days after application did not differ between untreated and treated plants. Thus, if bispyribac-sodium was applied while *R. solani* was actively parasitizing tall fescue, then the reduced chitinase activity in the host would make it more susceptible to the invading pathogen for the first few days. In the greenhouse study all plants treated with bispyribac-sodium had significantly more brown patch lesions than the plants that were not treated with bispyribac-sodium. Interestingly, plants treated with bispyribac-sodium 6 and 4 weeks before inoculation had the most brown patch.

Another reason for increased brown patch in treated plants could be the flush of growth observed 4 to 6 weeks after application. Bispyribac-sodium appears to have a paradigmatic effect on diseases in cool-season turf. Applications of bispyribac-sodium decreased dollar spot (*Sclerotinia homoeocarpa*) in cool-season grasses a month after application yet the most brown patch observed in the greenhouse occurred in plants a month after bispyribac-sodium application. Brown patch is a disease that thrives under conditions of high fertility (Burpee, 1995). Contrastingly, dollar spot is a disease that thrives under low fertility conditions (Vargas, 1981). The increased growth seen in both greenhouse studies and field studies is one of the physiological mechanisms that bispyribac-sodium catalyzes, which may be the reason for the increase in brown patch severity in tall fescue and the decrease of dollar spot incidence in cool-season grasses. Studies have shown that some herbicide applications result in an accumulation of products upstream of the enzyme being inhibited. Application of mesotrione, a herbicide that inhibits carotenoid biosynthesis, resulted in increased levels of carotenoids in sweet corn six weeks after treatment (Mitchell et al., 2001; Kopsell et al., 2009). A similar process could be occurring in plants treated with ALS-inhibiting herbicides. Threonine dehydratase catalyzes the first reaction in the biosynthetic pathway of branched chain amino acids and is one step upstream of the ALS reaction. Threonine dehydratase catalyzes the deanimation and dehydration of threonine to produce 2-ketobutryate and ammonia (Sing and Shaner, 1995). Isoleucine is involved in negative feedback inhibition of threonine dehydratase, indicating that if a herbicide is inhibiting ALS then more biosynthesis of ammonia may be occurring because less isoleucine will be present. Ammonia is a mobile nitrogen source that can be converted to glutamine by glutamine synthatase and transported to growing tissues (Lam et al., 1995). Additionally, the increased growth observed 4 to 6 weeks after herbicide application could be due to bispyribac-sodium becoming unbound from the ALS enzyme, resulting in increased synthesis of branched chain amino acids. Future research should focus on quantification of branched chain amino acids and ammonia in tall fescue treated with bispyribac-sodium 6 weeks after application.

### Conclusion

Based on this study using Matador and Southern Belle tall fescue, bispyribac-sodium has the potential to be labeled for use in tall fescue. In field studies, there was typically not a significant difference for brown patch severity among treatments and the control. Furthermore, numerical reduction in brown patch occurred when the herbicide was applied in April compared to May, which was the same application timing where the most annual bluegrass control was observed. Finally, an additional research analysis should be performed to determine if there is an interaction between tall fescue cultivars and bispyribac-sodium on brown patch severity and phytotoxicity. If there is not much variability among cultivars, then bispyribac-sodium could be an important tool for controlling annual bluegrass in tall fescue.

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# Literature Cited

Altman, J. and C.L. Campbell. 1977. Effect of herbicides on plant disease. Ann. Rev. Phytopathol. 15: 361-385.

Armentrout, V.N. and A.J. Downer. 1987. Infection cushion development by *Rhizoctonia solani* on cotton. Phytopathology. 77:619-623.

Askew, S. D., J. B. Beam, D. S. McCall, W. L. Barker, H. B. Couch, and J. R. Chamberlin. 2004. Annual bluegrass, roughstalk bluegrass, and dollar spot control with bispyribac-sodium. Proc. Northeast. Weed Sci. Soc. 58: 124-126.

Bhowmik, C.P. and S.W. Bingham. 1990. Preemergence activity of Dinitroaniline Herbicides used for weed control in cool season grasses. Weed Technol. 4:387-393.

Bollen, W. B. 1961. Interaction between pesticides and soil microorganisms. Ann. Rev. Microbiol. 15:69-92.

Burpee, L. and B. Martin. 1991. Biology of *Rhizoctonia* species associated with brown patch symptoms. Plant Disease. 76:112-117.

Christou , T. 1962. Penetration and host-plant relationships of *Rhizoctonia solani* in the bean plant. Phytopathology. 52:291.

Das, M., J.R. Reichman, G. Harberer, G. Welz, F. F. Aceituno, M.T. Mader, L. S. Watrud, T.G. Pfleeger, R.A. Gutie´rrez, A.R. Scha¨ffner, D. M. Olszyk. 2010. A composite transcriptional signature differentiates responses towards closely related herbicides in *Arabidopsis thaliana* and *Brassica napus*. Plant. Mol. Biol. 72: 545- 556.

Dernoeden, P H., J. E. Kaminski, and S. J. McDonald. 2004. Preemergence smooth crabgrass and postemergence annual bluegrass control in turf grass. Proc. Northeast. Weed Sci. Soc. 58:119-120.

Fukutomi, M., and H. Takada. 1979. Ultrastructure of infection process of *Rhizoctonia solani* Kuhn in cucumber hypocotyls. Ann. Phytopath. Soc. Jpn 45:453-462.

Hall, J.C., and C.K. Carey. 1992. Control of annual bluegrass (*Poa annua*) in Kentucky bluegrass (*Poa pratensis*) turf with linuron. Weed Technol. 6:852-857.

Kaminski, J.E., and A.I. Putman. 2009. Safety of bispyribac-sodium on colonial bentgrass and influence on brown patch severity. Int. Turf. Soc. Res. J. 11:219-226.

Kopsell, D.A., G.R. Armel, T.C. Mueller, C.E. Sams, D.E. Deyton, J.S. McElroy and D.E. Kopsell. 2009. Increase in nutritionally important sweet corn kernel carotenoids following mesotrione and atrazine applications. J. Agric. Food. Chem. 57: 6362-6368.

Lam, H.-M., Coshigano, K., Schultr, C., Melo-Oliveira, R., Tjaden, O., Oliveira, I., Ngai, N., Hsleh, M.-H., and Coruui, G.1995.Use of Arabidopsis mutants and genes to study amide amino acid biosynthesis. Plant Cell 7:887-898.

Lycan, D.W. and S.E. Hart. 2006. Seasonal effects of annual bluegrass control in creeping bentgrass with Bispyribac-Sodium. Weed Technol. 20:722-727.

Lycan, D.W. and S.E. Hart. 2005. Cool-season turfgrass response to bispyribac-sodium Hortsci. 40:1552-1555.

Lycan, D. W., S. E. Hart, and J. Fausey. 2003. Potential use of V-10029 for Weed control in cool-season turf grass. Proc. Northeast. Weed Sci. Soc. 57:96.

Matsuura, K. 1986. Scanning electron microscopy of the infection process of *Rhizoctonia solani* in leaf sheats of rice plants. Phytopathology 76:811-814.

McCarty, B., and A. Estes. 2005. A new weapon in the fight against *Poa annua*. Golf Course Manage. 73(2):106-109.

McDonald, S.J., P.H. Dernoeden, and J.E. Kaminski. 2006. Creeping bentgrass tolerance and annual bluegrass control with bispyribac-sodium tank-mixed with iron and nitrogen. Online. Applied Turfgrass Sci. Doi:10.1094/ATS-2006-0811-01-RS.

McElroy, J.S., R.H. Walker, and E.V.Santen. 2002. Patterns of variation in *Poa annua* as revealed by canonical discriminate analysis of life history traits. Crop Sci. 32: 513-517.

Metraux J.P., P.A. Goy, T. Staub, J. Speich, A. Steinmann, J. Ryals, E. Ward**.** 1991. Induced systemic resistance in cucumber in response to 2,6-dichloro-isonicotinic acid and pathogens. In:Hennecke H, Verma DPS, eds. Advances in Molecular Genetics of Plant-Microbe Interactions Vol. 1.Dordrecht: Kluwer Academic Publishers, p. 432-439.

Mitchell, G., D.W. Bartlett, T.E.M. Fraser, T.R. Hawkes, D.C. Holt, J.K. Townson, R.A. Wichert. 2001. Mesotrione: a new selective herbicide for use in maize. Pest Manage. Sci. 57: 120–128.

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

Senseman, S.A., 2007. Herbicide Handbook, ninth ed. Weed Sci. Soc. Am., Champaign, IL. 53,174 p.

Sing, B.K., and D.L. Shaner. 1995. Biosynthesis of branched chain amino acids: From test tube to field. Plant Cell. 7: 935-944.

Smith, P. K, R. L Krohn, G. T. Hermanson, A. R. Mallia, & F. H. Gartina. 1985. Measurement of protein using bicinchoninic acid. Analytical Biochemistry, 150:76–85.

Vargas, J.M. 1981. Management of Turfgrass Diseases. Burgress Publishing Co., Minneapolis, MN. 204 pp.

Wirth, S.J. and G.A. Wolf. 1990. Dye labeled substrates for the assay and detection of chitinase and lysozyme activity. J. of Microbiol Methods. 12: 197-205.

Table 1 Impact of bispyribac-sodium rate and timing on annual bluegrass cover in tall fescue in the 2009, 2010 and 2011 trials.

| Study Year | Bispyribac-sodium timing | Bispyribac-sodium rate | Annual bluegrass percent cover | | |
|---|---|---|---|---|---|
| | | | April 21[a] | May 21 | June 19th |
| 2009 | April 22nd + May 7th | 37 g $ha^{-1}$ | 26 a | 8 ab | 4 bc |
| | April 22nd + May 7th | 74 g $ha^{-1}$ | 26 a | 2 b | 1 c |
| | May 22nd + June 6th | 37 g $ha^{-1}$ | 27 a | 24 a | 15 a |
| | May 22nd + June 6th | 74 g $ha^{-1}$ | 29 a | 28 a | 11 ab |
| | Untreated | Untreated | 26 a | 26 a | 18 a |
| 2010 | March 22nd + April 6th | 37 g $ha^{-1}$ | 34 a | 34 a | 38 a |
| | March 22nd + April 6th | 74 g $ha^{-1}$ | 19 a | 28 a | 33 a |
| | April 22nd + May 7th | 37 g $ha^{-1}$ | 39 a | 28 a | 31 a |
| | April 22nd + May 7th | 74 g $ha^{-1}$ | 45 a | 25 a | 26 a |
| | May 22nd + June 6th | 37 g $ha^{-1}$ | 45 a | 40 a | 35 a |
| | May 22nd + June 6th | 74 g $ha^{-1}$ | 40 a | 45 a | 24 a |
| | Untreated | Untreated | 47 a | 45 a | 40 a |
| 2011 | March 22nd + April 6th | 37 g $ha^{-1}$ | 10 a | 7 b | 0 a |
| | March 22nd + April 6th | 74 g $ha^{-1}$ | 7 a | 6 b | 0 a |
| | April 22nd + May 7th | 37 g $ha^{-1}$ | 18 a | 4 b | 0 a |
| | April 22nd + May 7th | 74 g $ha^{-1}$ | 7 a | 5 b | 0 a |
| | May 22nd + June 6th | 37 g $ha^{-1}$ | 9 a | 14 a | 0 a |
| | May 22nd + June 6th | 74 g $ha^{-1}$ | 18 a | 15 a | 0 a |
| | Untreated | Untreated | 23 a | 19 a | 0 a |

[a] All means within a column followed by the same letter in the same year are not significantly different according to Fishers protected LSD at the 0.05 level

Table 2. Impact of bispyribac-sodium rate and timing on percent brown patch severity in tall fescue in the 2009, 2010, 2011 trials.

| Study Year | Bispyribac-sodium timing | Bispyribac-sodium rate | Percent brown patch severity | | |
|---|---|---|---|---|---|
| | | | April 21 [a] | May 21 | June 19th |
| 2009 | April 22nd + May 7th | 37 g ha$^{-1}$ | 5 a | 16 a | 44 a |
| | April 22nd + May 7th | 74 g ha$^{-1}$ | 5 a | 20 a | 43 a |
| | May 22nd + June 6th | 37 g ha$^{-1}$ | 5 a | 26 a | 64 a |
| | May 22nd + June 6th | 74 g ha$^{-1}$ | 5 a | 25 a | 60 a |
| | Untreated | Untreated | 5 a | 18 a | 40 a |
| 2010 | March 22nd + April 6th | 37 g ha$^{-1}$ | 1 a | 1 a | 14 a |
| | March 22nd + April 6th | 74 g ha$^{-1}$ | 1 a | 1 a | 12 a |
| | April 22nd + May 7th | 37 g ha$^{-1}$ | 1 a | 1 a | 15 a |
| | April 22nd + May 7th | 74 g ha$^{-1}$ | 1 a | 1 a | 15 a |
| | May 22nd + June 6th | 37 g ha$^{-1}$ | 1 a | 1 a | 23 a |
| | May 22nd + June 6th | 74 g ha$^{-1}$ | 1 a | 1 a | 24 a |
| | Untreated | Untreated | 1 a | 1 a | 10 a |
| 2011 | March 22nd + April 6th | 37 g ha$^{-1}$ | 1 a | 1 a | 3 a |
| | March 22nd + April 6th | 74 g ha$^{-1}$ | 1 a | 3 a | 3 a |
| | April 22nd + May 7th | 37 g ha$^{-1}$ | 1 a | 1 a | 3 a |
| | April 22nd + May 7th | 74 g ha$^{-1}$ | 1 a | 2 a | 3 a |
| | May 22nd + June 6th | 37 g ha$^{-1}$ | 1 a | 4 a | 3 a |
| | May 22nd + June 6th | 74 g ha$^{-1}$ | 1 a | 1 a | 3 a |
| | Untreated | Untreated | 1 a | 1 a | 3 a |

[a] All means within a column followed by the same letter in the same year are not significantly different according to Fishers protected LSD at the 0.05 level

Table 3. Impact of bispyribac-sodium rate and timing on tall fescue quality in the 2009, 2010 and 2011 trials

| Study Year | Bispyribac-sodium timing | Bispyribac-sodium rate | Tall fescue quality (1-9) | | |
|---|---|---|---|---|---|
| | | | April 21[a] | May 21 | June 21 |
| 2009 | April 22nd + May 7th | 37 g $ha^{-1}$ | 7.0 a | 3.8 b | 7.5 a |
| | April 22nd + May 7th | 74 g $ha^{-1}$ | 7.1 a | 2.9 b | 8.0 a |
| | May 22nd + June 6th | 37 g $ha^{-1}$ | 6.9 a | 6.6 a | 2.0 d |
| | May 22nd + June 6th | 74 g $ha^{-1}$ | 7.1 a | 6.9 a | 2.8 c |
| | Untreated | Untreated | 7.1 a | 7.1 a | 6.5 b |
| 2010 | March 22nd + April 6th | 37 g $ha^{-1}$ | 4.0 b | 7.1 a | 7.0 a |
| | March 22nd + April 6th | 74 g $ha^{-1}$ | 3.8 b | 7.0 a | 7.5 a |
| | April 22nd + May 7th | 37 g $ha^{-1}$ | 7.0 a | 4.0 b | 6.5 b |
| | April 22nd + May 7th | 74 g $ha^{-1}$ | 7.0 a | 2.9 b | 7.6 a |
| | May 22nd + June 6th | 37 g $ha^{-1}$ | 6.9 a | 6.5 a | 3.0 c |
| | May 22nd + June 6th | 74 g $ha^{-1}$ | 7.0 a | 6.9 a | 2.8 c |
| | Untreated | Untreated | 7.0 a | 7.0 a | 7.5 a |
| 2011 | March 22nd + April 6th | 37 g $ha^{-1}$ | 5.5 b | 6.7 b | 6.0 a |
| | March 22nd + April 6th | 74 g $ha^{-1}$ | 4.8 b | 7.9 a | 6.0 a |
| | April 22nd + May 7th | 37 g $ha^{-1}$ | 7.0 a | 5.9 bc | 6.0 a |
| | April 22nd + May 7th | 74 g $ha^{-1}$ | 7.1 a | 5.4 c | 6.0 a |
| | May 22nd + June 6th | 37 g $ha^{-1}$ | 7.1 a | 6.6 b | 6.0 a |
| | May 22nd + June 6th | 74 g $ha^{-1}$ | 7.6 a | 6.0 bc | 6.0 a |
| | Untreated | Untreated | 7.0 a | 6.3 b | 6.0 a |

[a] All means within a column followed by the same letter in the same year are not significantly different according to Fishers protected LSD at the 0.05 level

Table 4. Impact of bispyribac-sodium timing and iron supplementation on visual tall fescue quality.

| Study Year | Bispyribac-sodium timing | Iron | Quality Ratings | | |
|---|---|---|---|---|---|
| | | | April 21[a] | May 21 | June 19th |
| 2010 | | | | | |
| | March 22nd + April 6th | No | 6.5 a | 7.0 a | 7.6 a |
| | March 22nd + April 6th | Yes | 7.0 a | 7.0 a | 6.5 ab |
| | April 22nd + May 7th | No | 7.0 a | 6.0 b | 6.5 ab |
| | April 22nd + May 7th | Yes | 7.0 a | 7.0 a | 7.0 a |
| | May 22nd + June 6th | No | 7.0 a | 7.0 a | 5.3 b |
| | May 22nd + June 6th | Yes | 7.0 a | 7.0 a | 5.1 b |
| | Untreated | Untreated | 7.0 a | 7.0 a | 7.1 a |
| 2011 | | | | | |
| | March 22nd + April 6th | No | 6.0 b | 7.0 a | 6.0 a |
| | March 22nd + April 6th | Yes | 6.5 b | 7.0 a | 6.0 a |
| | April 22nd + May 7th | No | 8.0 a | 7.1 a | 6.0 a |
| | April 22nd + May 7th | Yes | 8.0 a | 6.1 b | 6.0 a |
| | May 22nd + June 6th | No | 8.0 a | 6.6 a | 6.0 a |
| | May 22nd + June 6th | Yes | 8.0 a | 7.0 a | 6.0 a |
| | Untreated | Untreated | 8.0 a | 7.0 a | 6.0 a |

[a] All means within a column followed by the same letter in the same year are not significantly different according to Fishers protected LSD at the 0.05 level

Table 5. Impact of bispyribac-sodium timing and iron supplementation on visual brown patch severity.

| Study Year | Bispyribac-sodium timing | Iron | Percent Brown Patch | | |
|---|---|---|---|---|---|
| | | | April 21[a] | May 21 | June 19th |
| 2010 | | | | | |
| | March 22nd + April 6th | No | 1 a | 1 a | 20 a |
| | March 22nd + April 6th | Yes | 1 a | 1 a | 13 a |
| | April 22nd + May 7th | No | 1 a | 1 a | 14 a |
| | April 22nd + May 7th | Yes | 1 a | 1 a | 14 a |
| | May 22nd + June 6th | No | 1 a | 1 a | 31 a |
| | May 22nd + June 6th | Yes | 1 a | 1 a | 23 a |
| | Untreated | Untreated | 1 a | 1 a | 10 a |
| 2011 | | | | | |
| | March 22nd + April 6th | No | 1 a | 3 a | 3 a |
| | March 22nd + April 6th | Yes | 1 a | 3 a | 3 a |
| | April 22nd + May 7th | No | 1 a | 3 a | 3 a |
| | April 22nd + May 7th | Yes | 1 a | 3 a | 3 a |
| | May 22nd + June 6th | No | 1 a | 3 a | 3 a |
| | May 22nd + June 6th | Yes | 1 a | 3 a | 3 a |
| | Untreated | Untreated | 1 a | 3 a | 3 a |

[a] All means within a column followed by the same letter in the same year are not significantly different according to Fishers protected LSD at the 0.05 level

Table 6. Impact of bispyribac-sodium application timing and rate on brown patch lesion counts 14 days after inoculation.

| Application Timing | Herbicide Rate | Brown Patch Lesions per 70 shoots[a] |
|---|---|---|
| 6,4 weeks before inoculation | 37 g ha$^{-1}$ | 24.3 a |
| 6,4 weeks before inoculation | 74 g ha$^{-1}$ | 25.0 a |
| 4,2 weeks before inoculation | 37 g ha$^{-1}$ | 19.3 bc |
| 4,2 weeks before inoculation | 74 g ha$^{-1}$ | 15.5 cd |
| 0,2 weeks after inoculation | 37 g ha$^{-1}$ | 19.0 bc |
| 0,2 weeks after inoculation | 74 g ha$^{-1}$ | 23.5 ab |
| Untreated Check | | 11.3 d |

[a] All means with the same letter group are not significantly different according to Fishers protected LSD at the 0.05 level.

Table 7. Impact of bispyribac-sodium on chitinase activity in tall fescue 2 and 7 days after treatment averaged across two assays (DAT).

| Herbicide Treatment | Chitinase Activity Unit mg$^{-1}$ protein [a] | |
|---|---|---|
| | 2 DAT | 7 DAT |
| Untreated | 0.58 a | 0.59 a |
| Treated | 0.42 a | 0.55 a |

[a] All means with the same letter group in the same column are not significantly different according to Fishers protected LSD at the 0.5 level.

Figure 1. Potential problems of bispyribac-sodium application on tall fescue.

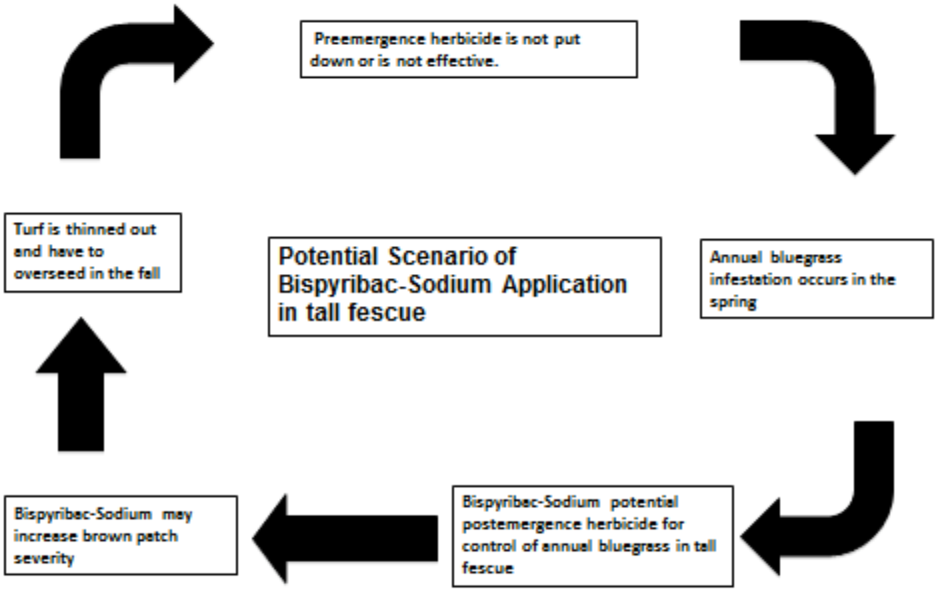
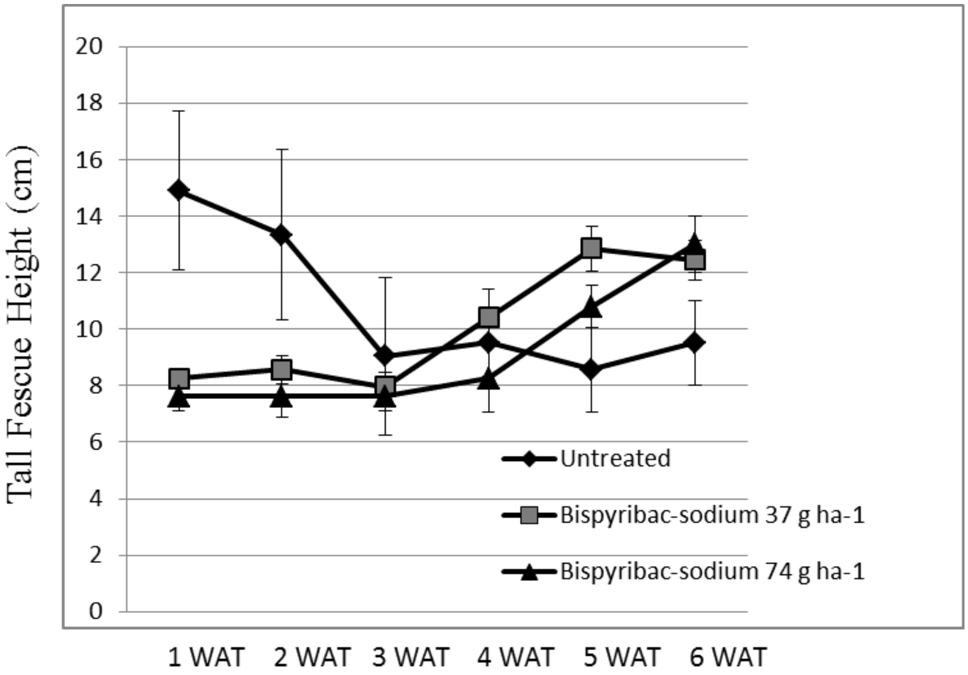


Figure (2) Impact of bispyribac-sodium on tall fescue height (cm) 1 to 6 weeks after initial treatment (WAT) averaged across two greenhouse assays and inoculation treatment.



# Impact of Mowing Height and Nitrogen Fertility on Crabgrass Cover in 'RTF' Tall Fescue

## Abstract

Tall fescue has exceptional utility as a low maintenance lawn in the transition zone. However, during the summer crabgrass infestation can reduce the aesthetic value and function of the turf and lead to a general decline of the tall fescue stand after the crabgrass plants have senesced. Research was conducted to evaluate the impact of mowing height and nitrogen fertility on crabgrass plant counts and tall fescue cover in Virginia Beach, VA. Plots were mowed at either 10 cm or 6cm and received 49, 171, or 220 kg of nitrogen annually per hectare. Mowing at 10 cm with the high level of fertility resulted in the most turfgrass cover among all the treatment combinations. Generally, mowing at 10 cm as opposed to 6 cm resulted in less crabgrass plants.

## Introduction

Tall fescue [*Festuca arundinacea* Shreb synonym *Schedonorus phoenix* (Scop.) Holub] is one of the more versatile cool-season grasses for use in home and commercial lawns in the United States. Tall fescue is relatively drought tolerant for a cool-season grass, requires minimal fertility inputs, and is resistant to most diseases. However, tall fescue is susceptible to *Rhizoctonia solani*, the fungal pathogen that causes brown patch. Brown patch can thin out tall fescue stands during the summer and allow for increased crabgrass (*Digitaria* spp.) infestations (Ferrel et al., 2003). Proper cultural practices and preemergence herbicide application will reduce crabgrass infestations in tall fescue stands.

Nitrogen fertility and mowing height are two practices that are performed frequently and can have an impact on weed densities in tall fescue stands. Generally, mowing cool-season grasses higher in the summer will alleviate stress associated with reduced photosynthetic efficiency and reduce the competitive advantage of warm season grasses. Increasing nitrogen fertility generally leads to less crabgrass infestation, specifically when applied in fall and early spring (Busey, 2003). Gray and Call (1993) observed a synergistic effect on broadleaf weed control in tall fescue when mowing height and nitrogen levels were both increased. Research was conducted in Virginia Beach, VA to evaluate the impact of mowing height and nitrogen fertility on crabgrass cover in tall fescue.

## Materials and Methods

The study was conducted at the Hampton Roads Agricultural Research and Extension Center in Virginia Beach, Virginia. Plots were 3.7 m by 1.5 m in dimension. The experiment was arranged as a split block with 4 replications per treatment combination. The trial was initiated on April 1st for both trials. Treatments consisted of a factorial design with plots being mowed at either 6 or 10 cm with subplots receiving treatments of 49 (low), 171 (medium), and 220 (high) kg ha$^{-1}$rates of nitrogen annually per hectare in each plot within the strip. The low nitrogen treatment consisted of one treatment of 49 kg ha$^{-1}$ of nitrogen in November. Plots in the medium fertility program received 49 kg ha$^{-1}$ of nitrogen in October, 49 kg ha$^{-1}$ of nitrogen in November, 49 kg ha$^{-1}$ of nitrogen in December and 24 kg ha$^{-1}$ in May. The high nitrogen fertility program consisted of 49 kg ha$^{-1}$ of nitrogen in October, 49 kg ha$^{-1}$ of nitrogen in November, 49 kg ha$^{-1}$ of nitrogen in December, 24 kg ha$^{-1}$ in May, 24 kg ha$^{-1}$ in June and 24 kg ha$^{-1}$ in August. All nitrogen applications were made on the 1st of the assigned month with the exception of August application, which was made on the 15th of that month. Smooth crabgrass counts were recorded in June, July and August while percent turfgrass cover was recorded 6, 12, 18, and 24 months after the . All data was subjected to analysis of variances using SAS mixed model methodology (SAS institute, Cary, NC).

## Results and Discussion

### Impact of Mowing Height and Nitrogen Application on Crabgrass Stands in 2008

Mowing height had a significant effect on smooth crabgrass plant counts taken throughout the summer. Nitrogen application did not have a significant effect on crabgrass counts and there were no significant interactions between mowing height and fertility on crabgrass counts. In July of 2008 the most crabgrass plants were observed in plots mowed at 6 cm receiving the high fertility treatment. These plots contained approximately 14 crabgrass plants (Table 1). Plots mowed at 6 cm receiving low and medium fertility levels contained 8 and 13 crabgrass plants respectively. Minimal crabgrass plants contained was observed in the plots mowed at 10 cm. All crabgrass counts in the higher mowing height were less than 2 regardless of fertility.

In August of 2008, mowing tall fescue at 6 cm treated with low, medium or high levels of nitrogen resulted in approximately 41 crabgrass plants per plot. Plots mowed at 10 cm contained 6 to 9 crabgrass plants when treated with low, medium or high levels of nitrogen.

September was the last month that crabgrass cover was recorded. In September of 2008 plots mowed at 6 cm receiving the low fertility treatment were covered with 53 crabgrass plants. Plots mowed at 6 cm treated with the medium rate of nitrogen had approximately 54 crabgrass plants. There were approximately 51 crabgrass plants counted in plots mowed at 6 cm treated with the high rate of nitrogen in September of 2008. Plots mowed at 10 cm contained approximately 14 crabgrass plants when treated with low, medium or high rates of nitrogen.

### Impact of Mowing Height and Nitrogen Application on Crabgrass Encroachment in the 2009 Trial.

In 2009 mowing height had a significant effect on percent crabgrass cover taken on every rating date. More crabgrass counts were observed in 2009 versus 2008. In July of 2009, mowing at 6 cm resulted in 30, 27, and 25 crabgrass plants when treated with low, medium and high rates of nitrogen (Table 2). Mowing at 10 cm resulted in around 5 crabgrass plants regardless of nitrogen treatment in July of 2009.

Plots mowed at 6 cm receiving the medium level of nitrogen contained 56 smooth crabgrass plants in August, which was the highest total number of crabgrass plants recorded for August out of all the treatment combinations. Crabgrass plants in plots mowed at 6 cm treated with low and high levels of fertility ranged from 44 to 50. Crabgrass counts in plots mowed at 10 cm receiving the low, medium and high levels or nitrogen was approximately 13. In September, plots mowed at 6 cm were almost completely covered in crabgrass. All plots mowed at 6 cm contained greater than 80 crabgrass plants. Plots mowed at 10 cm receiving low, medium and high levels of fertility contained 20 to 27 crabgrass plants.

### Impact of Mowing Height and Nitrogen Application on Turfgrass Cover

In the 2008 study, greater tall fescue turf cover was observed in the 10 cm plots compared to the 6 cm mowed plots on all evaluation dates (Figure 1). Reduction in turfgrass cover was observed between 12 and 18 months after establishment. During the latter part of the study, a fertility effect was noticeable. Twenty-four months after the trial was established, tall fescue mowed at 10 cm treated with the high nitrogen treatment contained significantly more turf when compared to all other treatment combinations. Turfgrass cover decreased at least 20% in all treatments between 6 and 24 months after trial establishment. Similar trends were observed in the 2009 study, though the turfgrass coverage was not as high as was seen in the 2008 study. Mowing at 10 cm resulted in greater turfgrass cover compared to 6 cm until 18 months after establishment (Figure 2). No fertility effect was observed in the 2009 study. A large reduction of turfgrass cover was observed between 12 and 18 months after the study was established. Twenty four months after establishment mowing at 10 cm resulted in approximately 10% turf cover while mowing at 6 cm resulted in approximately 5% turf cover.

## Conclusions and Recommendations

Growing tall fescue in the hot, humid summers of southeastern Virginia is difficult. Optimizing cultural practices is important for maintaining the integrity of tall fescue stands. Based on this study, mowing at 10 cm with higher fertility will limit crabgrass infestations. Additionally, tall fescue cover was superior in the plots mowed at 10 cm. These results compliment the studies cited in the review by Busey (2003). After two years, none of the plots in these studies had desirable turf cover, which means chemical input is likely necessary. Therefore, a preemergence herbicide applied in the spring with implementation of a 10 cm high mowing program and high nitrogen fertility for tall fescue would be optimal for reducing crabgrass infestations and maintaining acceptable turfgrass cover in the transition zone. One of the major difficulties about implementing this strategy is the lack of commercially available mowers that can adjust to a 10 cm height of cut. Most mowers available to homeowners cut below 10 cm due to safety and lack of demand for mowers with raised height of cut. This research suggests that more mowers with increased range of cut height should be manufactured in order to effectively manage tall fescue grown in stressful summer conditions.

## Literature Cited

Busey, P. 2003. Cultural management of weeds in turfgrass: A review. Crop Sci. 43:1899-1911.

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.

Gray, E., and N.M. Call. 1993. Fertilization and mowing on persistence of Indian mockstrawberry (*Duchesnea indica*) and common blue violet (*Viola papilionacea*) in a tall fescue (*Festuca arundinacea*) lawn. Weed Sci. 41:548–550.

Table 1. Impact of mowing height and fertility on smooth crabgrass plant counts in July, August and September of the 2008 Virginia Beach Trial.

| Mow Height (cm) | N kg $ha^{-1}$ | July counts[a] | August counts | September counts |
|---|---|---|---|---|
| 10 | 49 | 1.8 b | 5.8 b | 15.7 b |
| 10 | 171 | 0.8 b | 6.5 b | 18.5 b |
| 10 | 220 | 2.3 b | 8.5 b | 10.5 b |
| 6 | 49 | 8.3 ab | 42.5 a | 52.5 a |
| 6 | 171 | 13.3 a | 39.5 a | 53.5 a |
| 6 | 220 | 14.5 a | 41.5 a | 51.5 a |

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

Table 2. Impact of mowing height and fertility on smooth crabgrass plant counts in July, August and September of the 2009 Virginia Beach Trial.

| Mow Height (cm) | N kg $ha^{-1}$ | July counts[a] | August counts | September counts |
|---|---|---|---|---|
| 10 | 49 | 5.2 b | 15.1 b | 35.0 b |
| 10 | 171 | 5.4 b | 12.4 b | 37.2 b |
| 10 | 220 | 5.8 b | 12.7 b | 30.1 b |
| 6 | 49 | 30.4 a | 44.5 a | 93.2 a |
| 6 | 171 | 27.3 a | 56.1 a | 94.5 a |
| 6 | 220 | 25.2 a | 50.2 a | 88.2 a |

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

Figure 1. Impact of mowing height and nitrogen fertility on percent turf cover 6 to 24 months after the trial was initiated (MAI) in the 2008 trial.

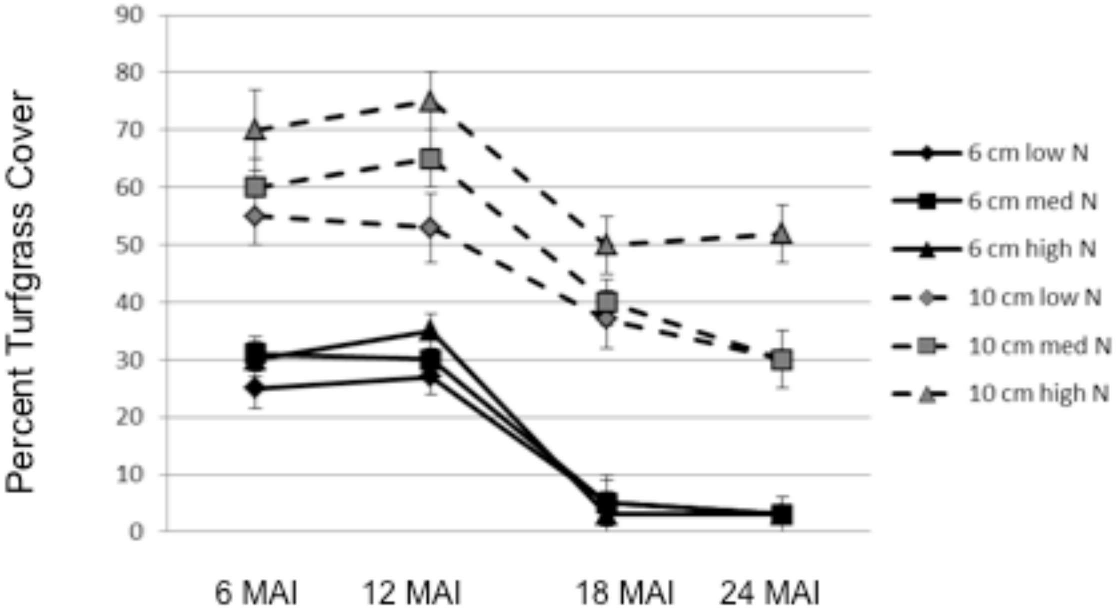


Figure 2. Impact of mowing height and nitrogen fertility on percent turfgrass cover 6 to 24 months after the trial was initiated (MAI) in the 2009 trial.