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TRINEXAPAC-ETHYL AND OVERSEEDING EFFECTS ON SHEAR STRENGTH AND TOLERANCE TO SIMULATED TRAFFIC OF FOUR BERMUDAGRASS CULTIVARS GROWN ON A SAND-BASED SYSTEM

Michael Todd Deaton
University of Kentucky, mtdeat2@uky.edu

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ABSTRACT OF A THESIS

TRINEXAPAC-ETHYL AND OVERSEEDING EFFECTS ON SHEAR STRENGTH AND TOLERANCE TO SIMULATED TRAFFIC OF FOUR BERMUDAGRASS CULTIVARS GROWN ON A SAND-BASED SYSTEM

Bermudagrass (*Cynodon dactylon* L.) is often used for athletic fields due to its wear tolerance and recuperative ability. Studies were conducted May 2007 through November 2008 in Lexington, Kentucky. The cultivars ‘Quickstand’, ‘Tifway’, ‘Riviera’, and ‘Yukon’ grown in a sand-based medium were used to investigate differences in wear tolerance and shear strength. Trinexapac-ethyl (TE) was applied at label rates and frequencies or untreated. Overseeding treatments were perennial ryegrass (*Lolium perenne* L.) at 0, 612, and 1225 kg PLS ha^{-1}. Traffic treatments were applied with a Brinkman traffic simulator 3 d wk^{-1} August through October. Shear tests were conducted using the Clegg shear tester once wk^{-1} for the same period. The main effect of cultivar was significant ($p<0.05$) in traffic tolerance (Tifway=Riviera > Quickstand=Yukon) and overseeding at the medium and high rates. Significant differences ($p<0.05$) in shear strength indicated Quickstand= Riviera > Tifway =Yukon (2007) and with Riviera ≥ Quickstand > Tifway = Yukon (2008). Significant differences ($p<0.05$) in shear strength due to overseeding were not observed in 2007 and only for the last three observation dates in 2008. Applications of TE did significantly improve turfgrass quality, but were not significant ($p>0.05$) in either year for traffic tolerance or shear strength.

Key words: Bermudagrass, Sand-based System, Traffic Tolerance, Shear Strength, Trinexapac-ethyl

Michael Todd Deaton

29 April 2009

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By

Michael Todd Deaton

David W. Williams

Director of Thesis

Charles Dougherty

Director of Graduate Studies

29 April 2009

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THESIS

Michael Todd Deaton

The Graduate School

University of Kentucky

2009

TRINEXAPAC-ETHYL AND OVERSEEDING EFFECTS ON SHEAR STRENGTH AND TOLERANCE TO SIMULATED TRAFFIC OF FOUR BERMUDAGRASS CULTIVARS GROWN ON A SAND-BASED SYSTEM

THESIS

A thesis submitted in partial fulfillment of
the requirements for the degree of Masters of Science
in the College of Agriculture
at the University of Kentucky

By

Michael Todd Deaton

Lexington, Kentucky

Director: Dr. David W. Williams, Associate Professor of Agronomy

Lexington, Kentucky

2009

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CHAPTER I

LITERATURE REVIEW

Sand-based Athletic Field Systems

Athletic fields today are largely established in native soil due to the large cost associated with constructing or converting to sand-based systems. Even with the high cost of construction, sand-based athletic fields have become more common (Schmaderer, 2001). Sand-based systems hold several distinct advantages over native soil root zones. Some of these advantages originate with the physical characteristics of the sand itself. The consistent particle size, high porosity and infiltration rates, and resistance to compaction make sand-based systems one of the best growing mediums for turfgrass playing surfaces (Xiong et al., 2006).

The USGA published its first recommendations for putting green construction in the early 1960's. These recommendations set the standard for construction that allows for optimum playing conditions while maintaining acceptable appearance and tolerating traffic while resisting compaction (Xiong et al., 2006). The current USGA putting green specifications consist of a 30 cm deep, 9:1 sand-peat mix over a 10 cm layer of pea gravel. This system will enable the root zone to be at or near saturation before water will penetrate into the coarser pea gravel. The sand-peat mix will provide adequate water holding capacity and the coarser pea gravel will assist drainage to prevent oversaturation of the root zone (Xiong et al., 2006). This widely-adopted method of construction allows for quicker drainage of water and effectively increases the field use capacity.

Increased capacity for field events on sand-based systems makes wear tolerance and shear strength very important issues for field managers. Visual appearance of an athletic field is also of major importance and is one of the criteria by which fields are judged. This is especially true in the high end athletic fields and stadiums of today.

How much play or wear can a particular field support or tolerate? This is a question that has been investigated with no definitive answers produced. Field wear is a function of several factors such as size of athletes, intensity of use, turf density, turf re-growth and soil moisture at the time of events (Powell, 2006). There are no standards or "rules of thumb" that can be applied to answer this question. Wear tolerance of a particular field can certainly be tied to several factors that include the root zone material, species and management of turfgrass, and intensity of use.

Wear tolerance of a particular field will be greatly influenced by the root zone. Soil characteristics that promote or resist compaction will directly influence plant health and wear tolerance (Beard, 1973). Most of the recent investigations in this area have been conducted in native soils. With the increasing popularity of sand based systems, a few recent studies have been conducted using sand and sand/peat mixtures as root zones. In addition to their many advantages, sand based systems have some disadvantages also. Improved drainage provided by the sand root zone encourages healthy turfgrass growth; however surface instability becomes an issue when turfgrass cover is lost (Sherratt et al., 2005).

Turf shear strength, or divoting potential, affects the footing and risk of athlete injury on sand-based turf systems. Divoting occurs from different mechanical forces that tear and remove a section of turf such as a golf club head striking the ground or the force of a cleated shoe shearing the turf when an athlete makes a sharp change in direction (Turgeon, 2005). Surface stability and tolerance to these stresses become an issue due to the inherent poor surface stability of the sand (McNitt and Landschoot, 2003; Sherratt et al., 2004).

Turfgrass Selection

Selection of the appropriate turf species and or cultivar will play a critical role in minimizing traffic damage and maximizing shear strength. Studies have shown that there are specific differences in the mechanisms of wear tolerance among turfgrass species (Trenholm et al., 2000). Cool season turfgrasses are typically less wear tolerant than warm season grasses (Trenholm et al., 2000). In the southern United States, bermudagrass is the most commonly used species of turf for areas of intensive use such as golf tees, fairways and athletic fields. Its popularity is due to the high recuperative potential from divots and other damage incurred during play. It responds well to management practices and forms a dense, fine textured turf while performing well under moderate wear and compaction (Karcher et al., 2005).

The genus *Cynodon* [L.] Rich contains 10 species, of which a few are often established to produce interspecific hybrids used for turf (Turgeon, 2005; Watson and Dallwitz 2000). The common term ‘hybrid bermudagrasses’ are crosses of (*Cynodon dactylon* [L.] Pers. var. *dactylon x C. transvaalensis* Burtt-Davey). They have superior quality and dense coverings which typically make them the turf of choice for highly maintained landscape areas, golf courses, and athletic turf (Trenholm et al., 2000;

Turgeon, 2005). Bermudagrass, a warm season species, is best suited to the more tropical and subtropical climates of the southern portions of the United States. It has been established that bermudagrass is an excellent choice for athletic turf. Miller (2004) reported that “bermudagrass is the ideal turfgrass surface for Florida’s athletic fields. It forms a tight, resilient playing surface with high wear tolerance and fast recuperative potential”. Both hybrid and more common-type bermudagrasses are also being used in the transition zone because of the excellent playing surfaces they provide for golf courses and athletic fields (Munshaw et al., 2006). The area termed the transition climatic zone is the boundary between the temperate or cool and subtropical or warm climates in the eastern and middle United States (Turgeon, 2005; Beard, 1973).

Recent studies completed by Williams et al., (2009 personal communication) and Bayrer (2006) were conducted in the transition climatic zone and on native soil. Both studies reported significant differences in bermudagrass cultivars response to wear tolerance. These studies also reported that in native soil conditions, the finer textured, denser cultivars performed better under simulated athletic traffic.

OVERSEEDING BERMUDAGRASS ATHLETIC FIELDS

The transition zone poses many problems for athletic field managers growing bermudagrass. Transition zone climatic conditions define the northern limits for bermudagrass survival and usage. Bermudagrass will enter dormancy and loose its color as the temperatures decline and frosting begins to occur in the autumn (Goddard et al., 2008). This dormancy period is one of the only disadvantages of using bermudagrass for sports turf applications in the northern regions. For this reason, many field managers have used overseeding as a tool to provide and actively growing, aesthetically pleasing turf that can withstand traffic (Richardson et al., 2007).

Overseeding is an old and accepted practice for retaining fall color on bermudagrass golf courses and athletic fields regardless of the root zone material. Bermudagrass fields are often overseeded with perennial ryegrass to mask the dormant color. The ryegrass will provide a dense, green, aesthetically pleasing, and uniform playing surface while helping to reduce weed encroachment and thinning of the existing dormant bermudagrass turf from foot and equipment traffic (Horgan and Yelverton, 2001; Powell, 2005; Morris, 2004).

Other viewpoints indicate that overseeding dormant bermudagrass is mainly just an aesthetic fix. Because the oveseeding treatment is completed in the early fall, the perennial ryegrass turf remains as a weak seedling throughout the fall and may not contribute to increased wear tolerance or shear strength of the turf (Powell, 2006). Whether or not overseeding for fall color will actually increase wear tolerance and shear strength is an area currently being studied for both natural soil and sand-based systems.

Traffic Tolerance

Turf injury caused by direct pressure that crushes the leaves, stems, and crowns in concentrated traffic areas is termed turfgrass wear (Beard, 1973). Wear or traffic tolerance of the turf could be defined as the ability of the exposed plant matter to withstand traffic (Bayrer, 2006). Many factors may attribute to a species ability to tolerate traffic stress. These factors can be categorized into two major groups: anatomical and morphological characteristics (Brosnan et al., 2005). Strengthening tissues such as but not limited to sclerenchyma along with lignin content have a direct effect on a species ability to withstand traffic (Beard, 1973). Sclerenchyma are cells with thick secondary walls primarily functioning as mechanical support to plant parts that are no longer elongating (Taiz and Zeiger, 2006). Photosynthates are precursors to many plant generated compounds, one of which is lignin that is used foremost for cell wall structural components (Beard, 1973). Shearman (2006) reported traffic tolerance was closely associated with lignin content, sclerenchyma fibers, other cell wall components, leaf tensile strength, and leaf width. Studies have shown that turfgrass species that have both rhizomes and stolons along with dense above ground growth are better adapted to withstand greater amounts of traffic (Beard, 1973).

Wear and compaction are the two major components that comprise turfgrass stresses from traffic (Beard, 1973; Trenholm et al., 2000; Turgeon, 2005). Wear or traffic damage on football fields tends to be concentrated between the hash marks and the twenty yard lines (Miller, 2004; Powell 2006). The repetitive and concentrated play in these areas accelerates the damage to the field.

Traffic simulators for turf research have been designed and constructed in a variety of configurations. Their designs range from machines to impose wear stress and compaction together to machines that will impose these components separately. The effects of traffic simulators have been well documented since their arrival in research in the late 1950’s. Some designs such as a studded drum roller do not produce damaging horizontal forces as with real wear and this brought about the development and use of a differential-slip wear machine (Canaway 1976).

Brinkman Traffic Simulator

Cockerham and Brinkman (1989) developed the Brinkman Traffic Simulator (BTS) to perform traffic simulation from cleated shoe traffic which occurs as a result of wear, compaction and lateral shear injury. The device was designed to perform these operations and be easy to use, easy to maintain, and cover large areas in a time efficient manner. The device consists of two differentially connected studded drum rollers that will be pulled by mechanical means across the test plots. With an elaborate set of measurements from game play based on field use area, number of players, and number of cleats per shoe, etc., they calculated, quantified and linked the simulated wear rate to the actual play wear rate a field would endure following one National Football League game at the forty yard line. Younger (1961) stated that in order to produce viable and creditable information, traffic studies must be replicable and uniform under an increasing rate of wear. The BTS has been shown to provide creditable information relating to wear stress incurred during athletic field use (Minner, 1989; Vanini et al., 2007).

Shear Strength

Roche et al. (2008) discussed the importance of playing surfaces that are safe for the athletes. Playability and safety are the main objectives, but before these can be scientifically evaluated, objective and reproducible methods must be defined. Little previous research has been conducted in this area. Limited studies have been conducted especially for sand-based athletic fields. Surface stability of the sand-based system is a major component involved in shear strength. Gaussoin et al. (2002) defines shear strength as "a measurement of the natural turf surface's capacity to resist the stress and shearing of vertical and horizontal force applied by a participant during athletic competition, recreational play and other activities routinely conducted on turfgrass." Shear strength can be defined as the relationship of the athlete with the playing surface in a "player-to-shoe-to-surface interaction" where traction affects this interaction directly (McNitt, 2000). Anatomical characteristics of the plant species with respect to stolon and rhizome production also influence the shear strength. Rhizome, stolon, and general root growth are the major constituents that comprise the amount of traction a particular turf will provide (Roche et al., 2008). Several devices have been developed and are currently being used to quantify traction or shear strength of the turf. One of these instruments is the Clegg Turf Shear Tester (TST) that measures the amount of force required to displace the turf using a horizontal motion. Limited information concerning this particular shear tester is available with regards to it use and results. Sheratt et al. (2005) used the TST in a study examining the effects of biomass accumulation on stabilized systems used for sports fields. They reported comparable results between the TST and the Ohio State University's traction device also used in their study.

TRINEXAPAC-ETHYL

There are multiple factors, many of which are outside the scope of this study, involved in how well an athletic field performs. Gaining every advantage possible to increase safety and visual performance is the field manager's highest priority. Some plant growth regulators (PGR) provide a means to control growth without having detrimental effects on quality. PGRs were developed and introduced for growth suppression for utility turf over forty years ago (Turgeon, 2005). The gibberellic acid (GA) inhibitors are the group of PGRs that have been shown to be the most feasible and essential for turf managers (Fagerness and Yelverton, 2000; Beasley and Branham 2007). GA inhibitors such as trinexapac ethyl (TE) a structural mimic of 2-oxoglutarate, prevent the 3β-hydroxylase conversion of GA_{20} to GA_1, which effectively reduces cell elongation (Rademacher, 2000; Ervin and Koski, 2001). Reduced cell elongation produces shorter more compact plants with increased cell densities. Reducing the leaf area concentrates the chlorophyll within the leaves resulting in an overall darker green appearance of the plants (Ervin and Koski, 2001). TE applications have been shown to have little effect on the roots while promoting above ground plant material in the form of more tillers and stolons (Beasley and Branham, 2007; Turgeon, 2005). The compact plants form a denser canopy that yields greater efficiency in the form of capturing more available light energy. This would result in increased chemical energy conversion and higher yields of net carbohydrates (Ervin and Zhang, 2007). Increasing the amount of non-structural plant carbohydrates with lower demands for consumption for cell elongation would lead to greater transport of excess carbohydrates to storage organs in the basil sink tissues such as rhizomes and roots (McCullough et al., 2005; Ervin and Zhang, 2007; McCann and Huang, 2007). This re-allocation of resources, in direct relation to TE applications, has been linked to faster recovery from heat, drought and mechanical (divoting and ball marks on greens) stresses (Turgeon, 2005; McCann and Huang, 2007). A recently completed study by Williams et al., 2009 (personal communication) found that TE applied at label rates and frequencies generally produced a greater level of tolerance to simulated traffic than the untreated controls for several cultivars of bermudagrass grown in native soil. The effects of TE applications on bermudagrass turf grown in a sand-based root zone on wear tolerance and shear strength have not been reported.

SUMMARY

Safe and aesthetically appealing athletic fields are the greatest demands placed on field managers (Richardson, 2002). These pressures are extending beyond the professional and collegiate stadiums down to small, local high schools and public fields. With growing pressure to achieve the best fields possible; the higher use, lower budget facilities need every advantage and all of the information available to accomplish these goals. Sand-based fields are becoming more common due to their desirable characteristics. Faster drainage and reduced compaction problems enable these systems to accommodate more play over the course of a year. The increase in available time for use then creates additional problems with respect to wear stress and loss of turf. Additionally, sand based systems can decline rapidly under heavy use due to the unstable nature of the sand (Sherratt et al., 2005). This unstable nature may lead to easier divoting and loss of traction or footing which in return may increase the chances of athlete injury. Turf choice then becomes an important issue and as proposed earlier, bermudagrass is fast becoming the dominant species for athletic field turf. This is in large part due to its excellent recuperative potential and the dense, uniform playing surface it provides. Previous work completed by Williams et al., (2009 personal communication) and Bayrer (2006) reported significant differences in wear tolerance when bermudagrass cultivars were subjected to simulated traffic when grown in native soil. Gibberellic acid inhibitors such as TE are quickly becoming standard practice in maintenance programs for athletic turf (Beasley and Branham, 2007) due to the desirable traits they infer. Reductions in clippings, increased density, darker green color, and increased traffic tolerance in native soil systems are some of the published benefits of TE applications. Regardless of the cultivar used, bermudagrass has limitations in the transition zone and areas further north due to the winter dormancy period. Oveseeding is the most commonly utilized tool for turf managers to retain color for late season athletic activities on bermudagrass fields. Extending the seasons and increasing the field use capacity creates more wear stress and potential loss of turf.

OBJECTIVES

Bermudagrass athletic fields grown on USGA sand-based systems are the focus of this study. The objectives of these studies were to evaluate the effects of cultivars, applications of TE, and overseeding with perennial ryegrass on traffic tolerance and shear strength of bermudagrass grown on a USGA sand-based system. The significance of this study is that even though all of these parameters (wear tolerance, shear strength, overseeding, bermudagrass cultivars, and TE) have been studied, evaluated and published; no studies have been completed that investigates these parameters together in sand-based systems. With the movement toward sand-based bermudagrass athletic fields, this study investigates several management parameters in an effort to define the best management practices for athletic field managers in the transitional climatic zone.

CHAPTER II

MATERIALS & METHODS

Study Sites

Studies were conducted in 2007 and 2008 at the UK Turfgrass Research Center located on the Spindletop Research Farm in Fayette County, Kentucky. The study sites were constructed in the autumn of 1997 to meet USGA putting green specifications. USGA specifications consist of a 30 cm deep, 9:1 sand-peat mix over a 10 cm layer of pea gravel. Prior to the establishment of the bermudagrass turf June of 2006, the sites were managed as creeping bentgrass (*Agrostis stonolifera* L.) putting greens. The sites were 11.6 m x 25.6 m and 11.6 m x 32.9 m for the traffic tolerance and shear strength tests, respectively.

The bermudagrasses used in this study consisted of two seeded ('Riviera' and 'Yukon') and two vegetatively propagated ('Quickstand' and 'Tifway') cultivars. The four cultivars were chosen based both on previous studies (Bayrer, 2006; Trappe et al., 2007; Williams et al., 2009), and for the public popularity of Quickstand and Tifway for athletic fields in the transitional climatic zone. Bermudagrasses were established 28 June 2006. Seed was hand-broadcasted at 24 kg pure live seed ha^{-1}. Vegetative cultivars were sprigged by hand at 822 bu (30 m^3) ha^{-1}. Polyspun fabric covers (Remay®) were used to cover the plots during germination of seeds and sprigs. Irrigation was applied as needed to enhance establishment. Nitrogen was applied at 24 kg N ha^{-1} beginning at establishment and every two weeks until 15 August 2006 (Munshaw, et al. 2001).

Prior to and throughout the study the sites received normal bermudagrass athletic field maintenance in respect to mowing, fertilization and weed control. Normal maintenance consisted of mowing daily at a height of 1.5 cm during peak growth and every other day in slower growth periods excluding dormant periods. Monthly fertilizer applications were split into 2 bi-weekly applications of 24 kg N ha $^{-1}$ for a monthly total of 49 kg N ha $^{-1}$ beginning in May and concluding in August of both years. This resulted in 196 kg actual N applied annually in both years. Urea (46-0-0) was used as the source of N. Irrigation was applied as needed to prevent any drought stress for the duration of the experiments. Applications to control crabgrass were made 18 and 25 July 2007, and 25 July, 6 and 22 August 2008. Monosodium acid methanearsonate (MSMA) was applied at a rate of 3.18 L ha $^{-1}$ of formulated product for each application.

Traffic Tolerance Experiments

The experimental design was a randomized block-split plot with a whole plot factor and a 3 x 2 subplot factorial structure (Cornelius, 2008. personal communication). The experimental blocks (whole plots) were 2.1 m x 11.6 m and each block contained 6 experimental units. The split plots or sampling units were 1.8 m X 2.1 m. The treatment factors for the experiment were the four cultivars (whole plot treatments), trinexapac-ethyl (TE) applied at 0.8 L ha $^{-1}$ or untreated, and no overseeding (OS) or overseeding at 612 kg ha $^{-1}$ or 1225 kg ha $^{-1}$ rates (TE [2] x OS rates [3] subplot factorial treatments).

TE was applied at three-week intervals throughout the bermudagrass growing season beginning 30 May and ending 5 October in 2007 and beginning 13 June and ending 15 October in 2008. Applications were made with a CO_2 sprayer using four Tee-Jet #8004 spray tips at a pressure of 207 kPa and a carrier rate of 486 L ha^{-1}. Primo MAXX (Syngenta Professional Products) was applied at a rate of 0.8 L ha^{-1} of formulated product. Applications of TE were delayed in 2008 due to difficulties with residual perennial ryegrass from the 2007 overseeding treatments. Three applications of foramsulfuron were applied at a rate of 1.32 L ha^{-1} with a 4:1 (v/v) non-ionic surfactant on 21 April, and 7 and 23 May 2008 before acceptable results were achieved in removing residual perennial ryegrass.

High-rate overseeding treatments were applied in split treatments in both years. All plots receiving medium and high rates were overseeded at the medium rate of 612 kg ha^{-1}on 14 September 2007 and 28 September 2008. The high rate plots received the remaining 612 kg ha^{-1} on 21 September 2007 and 7 October 2008 resulting in a total of 1224 kg ha^{-1}. Double Eagle Blend perennial ryegrass (Lesco-John Deer Landscapes, Troy Michigan) was used for all overseeding treatments in both years. The blend consisted of 33.35% ‘Prototype’ perennial ryegrass, 32.07% ‘Pacesetter’ perennial ryegrass, and 31.75% ‘Notable’ perennial ryegrass.

Simulated traffic treatments were applied three times per week September 10 through November 2 in 2007 and September 12 through November 14 in 2008. Traffic treatments consisted of making two passes in opposite directions over the same area covering the entire test site. Cockerham and Brinkman (1989) used an elaborate set of measurements from game play based on field use area, number of players, and number of cleats per shoe, etc., they calculated, quantified and linked the simulated wear rate of two passes with the BTS to the play wear rate received following one national football league game at the forty yard line. The response variable was a visual estimation of percent turfgrass cover (PTC) recorded weekly and rated on a 1 to 10 scale, where 1 represents bare soil and 10 represents 100% bermudagrass cover. For statistical analysis, all possible pairwise comparisons were performed using SAS© (SAS Inc., Cary NC.) F-Protected Least Significant Difference (LSD) ($p \leq 0.05$ at $\alpha = 0.05$), and PROC GLM.

Shear Strength Experiments

The experimental design was the same as described earlier with the simulated traffic tolerance study. The experimental blocks (whole plots) were 2.7 m X 11.6 m and each block contained 6 experimental units. The split plots or sampling units were 1.8 m X 2.7 m. The treatment factors for the experiment were cultivars (whole plot treatments), trinexapac-ethyl (TE) applied at 0.8L ha $^{-1}$ or untreated, and no overseeding (OS) or overseeding at 612kg ha $^{-1}$ or 1225kg ha $^{-1}$ rates (TE [2] x OS [3] subplot factorial treatments). The response variable for this study was shear strength measured in Kg-f (kilograms of force) and was obtained using the Clegg Shear Tester (CST),(Wembley DC, WA, Australia) model CCB1C with a 50mm knife width and set to a 30mm cutting depth.

Trinexapac-ethyl was applied at the same rates and frequencies as in the traffic study and began 30 May and ended 5 October in 2007 and began13 June and ended 15 October in 2008. Treatments for ryegrass removal were applied exactly as with the traffic study with regards to product, rate, and timing. Overseeding treatments were applied in split applications using the same seeding dates and trade name of blended cultivars as with the traffic study.

Shear strength data was collected weekly from 31 August through 19 November in 2007 and from 13 August through 10 November in 2008. Three sub-samples (measurements) were taken from sub plots each week and the mean of the three sub-samples was entered for analysis. For statistical analysis, all possible pairwise comparisons were performed using SAS© (SAS Inc., Cary NC.) F-Protected Least Significant Difference (LSD) ($p \leq 0.05$ at $\alpha = 0.05$), and PROC GLM.

CHAPTER III

RESULTS

Traffic Study

Turfgrass Quality

The main effect of cultivar was statistically significant ($p \leq 0.05$) across all observation dates in 2007 (Fig. 3.1; Table 3.1) and 2008 (Fig. 3.2; Table 3.2) with the exception of 10 August 07. Riviera and Quickstand across both years had statistically higher quality than Tifway and Yukon except for 31 August 07 and 3 September 08, where Riviera was statistically higher than the other three cultivars. The main effect of trinexapac-ethyl was statistically significant ($p \leq 0.05$) across all observation dates for 2007 (Fig. 3.3; Table 3.1). No significant effects from TE applications were observed in 2008 for any observation except for 3 September (Fig. 3.4; Table 3.2). The reasons for the different results of TE applications on turfgrass quality between the two years of the study years are unclear. There were no significant cultivar by TE interactions observed in either year of the study for turfgrass quality.

Turfgrass Cover

Percent turf cover (PTC) data indicates significant differences due to the main effects of cultivar. Cultivar had significant effects ($p \leq 0.05$) associated with every observation date for both 2007 (Fig. 3.5; Table 3.3) and 2008 (Fig. 3.6; Table 3.4). Initiation Initiation of traffic treatments quickly produced differences in traffic tolerance among cultivars as shown in Figures 3.5 and 3.6. Significant differences were not always observed

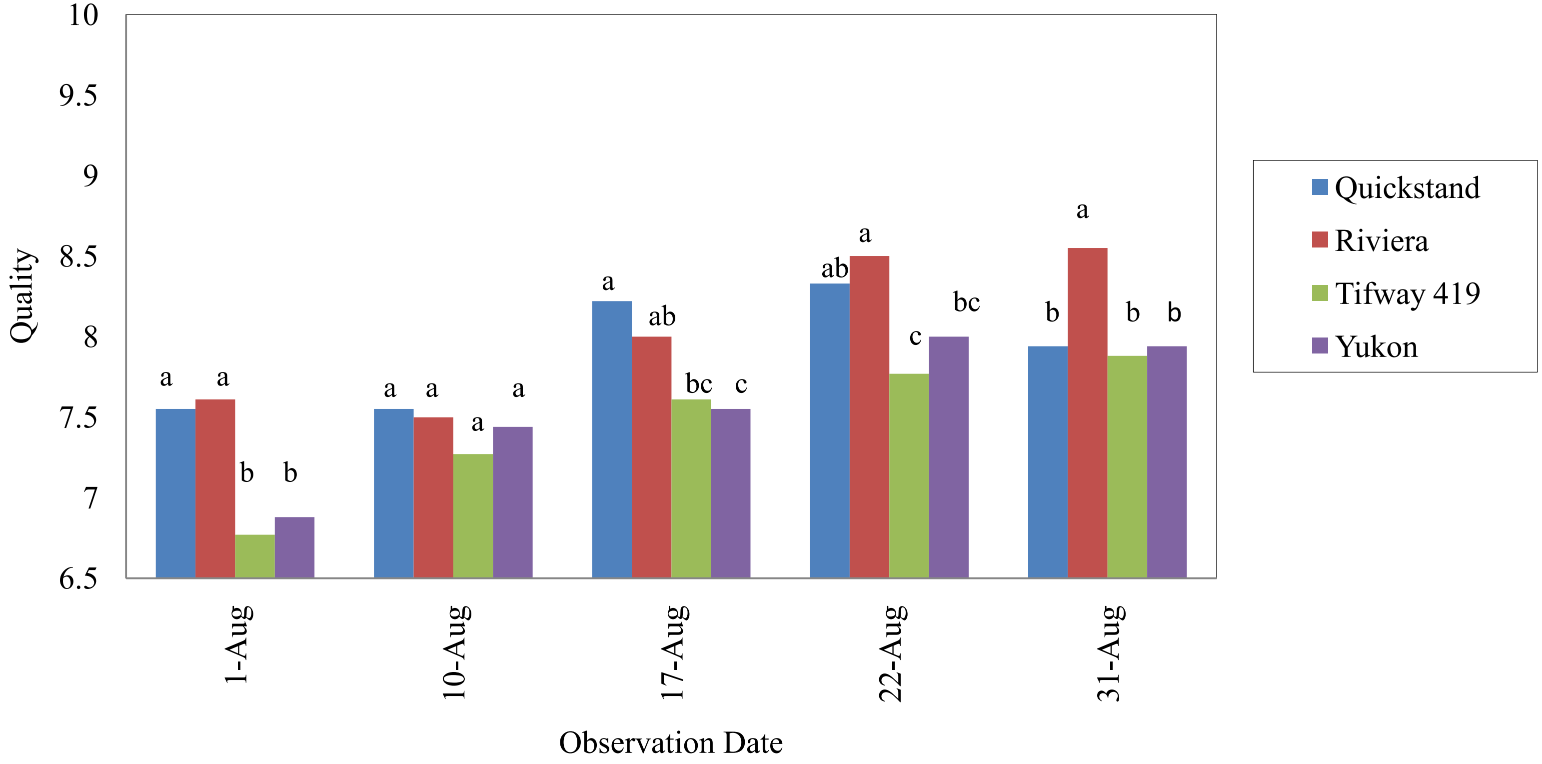

Figure 3.1. Mean visual quality of four bermudagrass cultivars evaluated in 2007. Scale 1 - 9; 1=dead turf 9=optimum quality. Bars labeled with the same letter within observation dates are not significantly different by F-protected Fisher's LSD (p>0.05).

Table 3.1. Analysis of variance statistics for the main effects of replication, cultivar, TE, and potential interactions between cultivar and TE for 2007 turfgrass quality evaluations.

	2007 Observation Dates									
	1-Aug		10-Aug		17-Aug		22-Aug		31-Aug	
Source	F	Pr>F	F	Pr>F	F	Pr>F	F	Pr>F	F	Pr>F
Rep	0.31	0.7373	0.42	0.6570	0.61	0.5491	5.08	0.0090	2.97	0.0010
Cultivar	8.38	< .0001	1.13	0.3447	4.19	0.0091	5.24	0.0028	6.10	0.0010
TE	0.03	0.8542	40.85	< .0001	14.05	0.0004	13.80	0.0004	27.18	< .0001
Cult. x TE	0.03	0.9915	1.69	0.1779	0.12	0.9499	0.34	0.7936	2.39	0.0772
CV (%)	8.86		6.43		8.41		7.39		6.71	

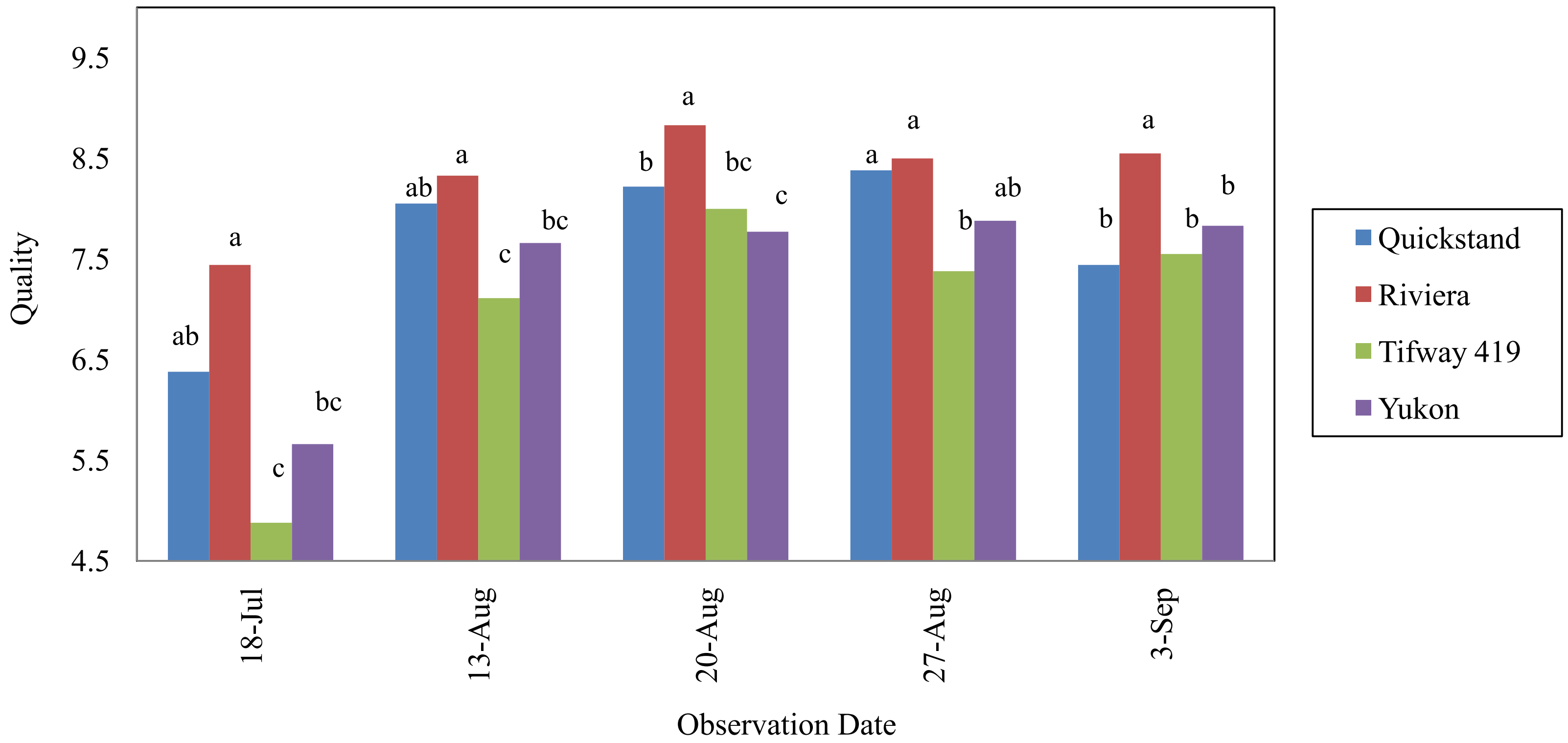

Figure 3.2. Mean visual quality of four bermudagrass cultivars evaluated in 2008. Scale 1 - 9; 1=dead turf 9=optimum quality. Bars labeled with the same letter within observation dates are not significantly different by F-protected Fisher's LSD (p>0.05).

Table 3.2. Analysis of variance statistics for the main effects of replication, cultivar, TE, and potential interactions between cultivar and TE for 2008 turfgrass quality evaluations.

	2008 Observation Dates									
	18-July		13-Aug		20-Aug		27-Aug		3-Sep	
Source	F	Pr>F	F	Pr>F	F	Pr>F	F	Pr>F	F	Pr>F
Rep	2.05	0.1377	0.80	0.4547	0.85	0.4339	0.76	0.4711	2.00	0.1440
Cultivar	7.78	0.0002	6.05	0.0011	8.39	< .0001	4.50	0.0064	10.11	< .0001
TE	0.41	0.5235	0.15	0.7002	0.03	0.8601	1.08	0.3021	16.53	0.0001
Cult. x TE	2.04	0.1178	0.59	0.6218	0.37	0.7780	0.55	0.6513	0.86	0.4643
CV (%)	27.11		11.72		8.10		12.67		8.49	

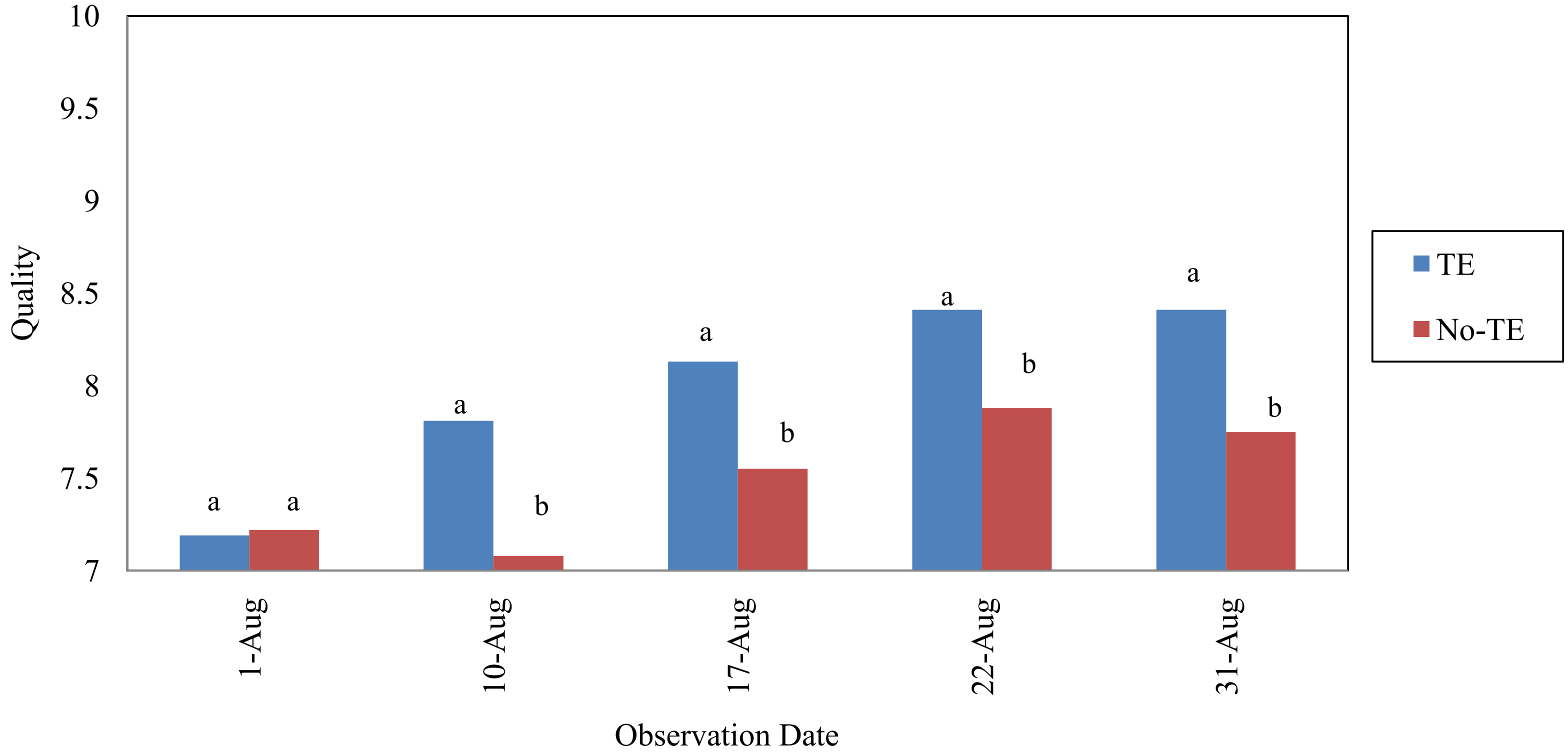

Figure 3.3. Mean visual quality across four bermudagrass cultivars under two TE treatment regimes evaluated in 2007. Scale 1 - 9; 1=dead turf 9=optimum quality. Bars labeled with same letter within observation date are not significantly different by F-protected Fisher's LSD (p>0.05).

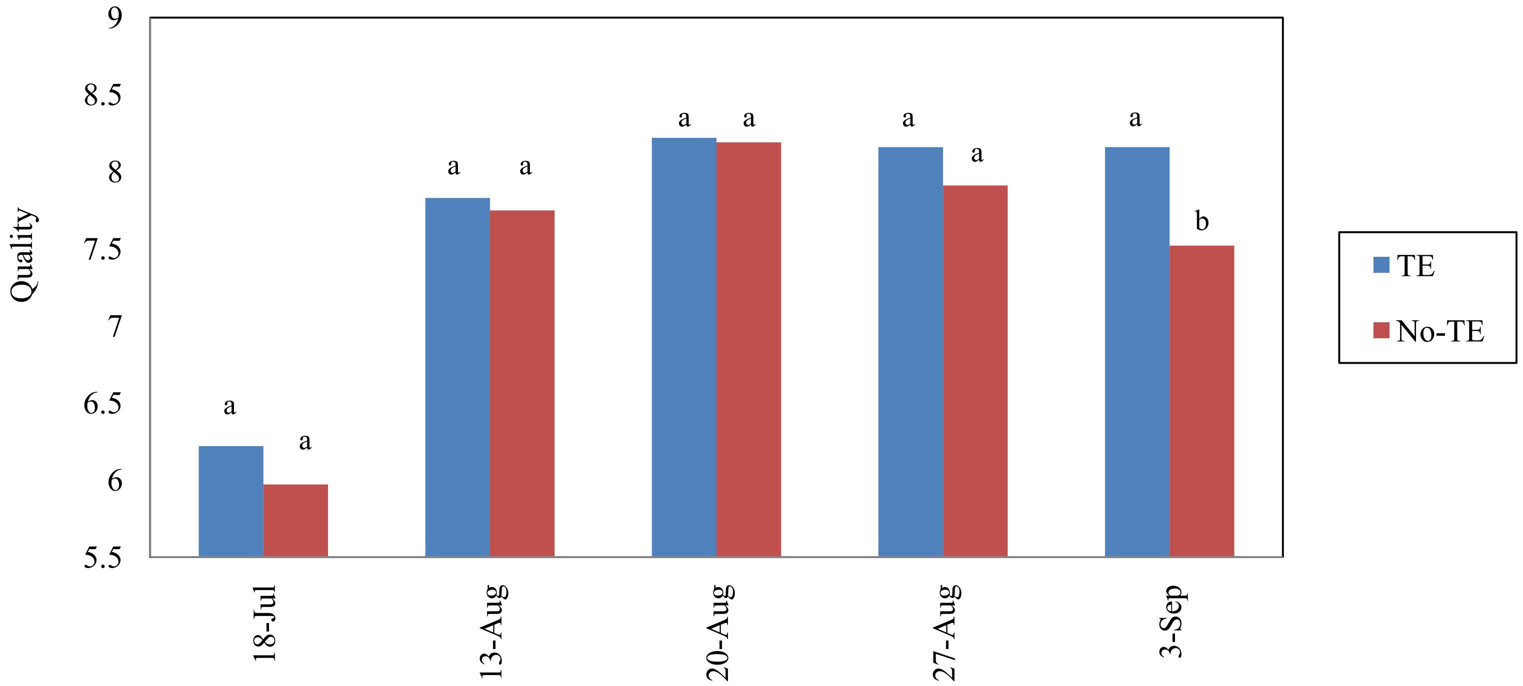

Figure 3.4. Mean visual quality across four bermudagrass cultivars under two TE treatments regimes in 2008. Scale 1 - 9; 1=dead turf 9=optimum quality. Bars labeled with same letter within observation date are not significantly diffierient by F-protected Fisher's LSD (p>0.05).

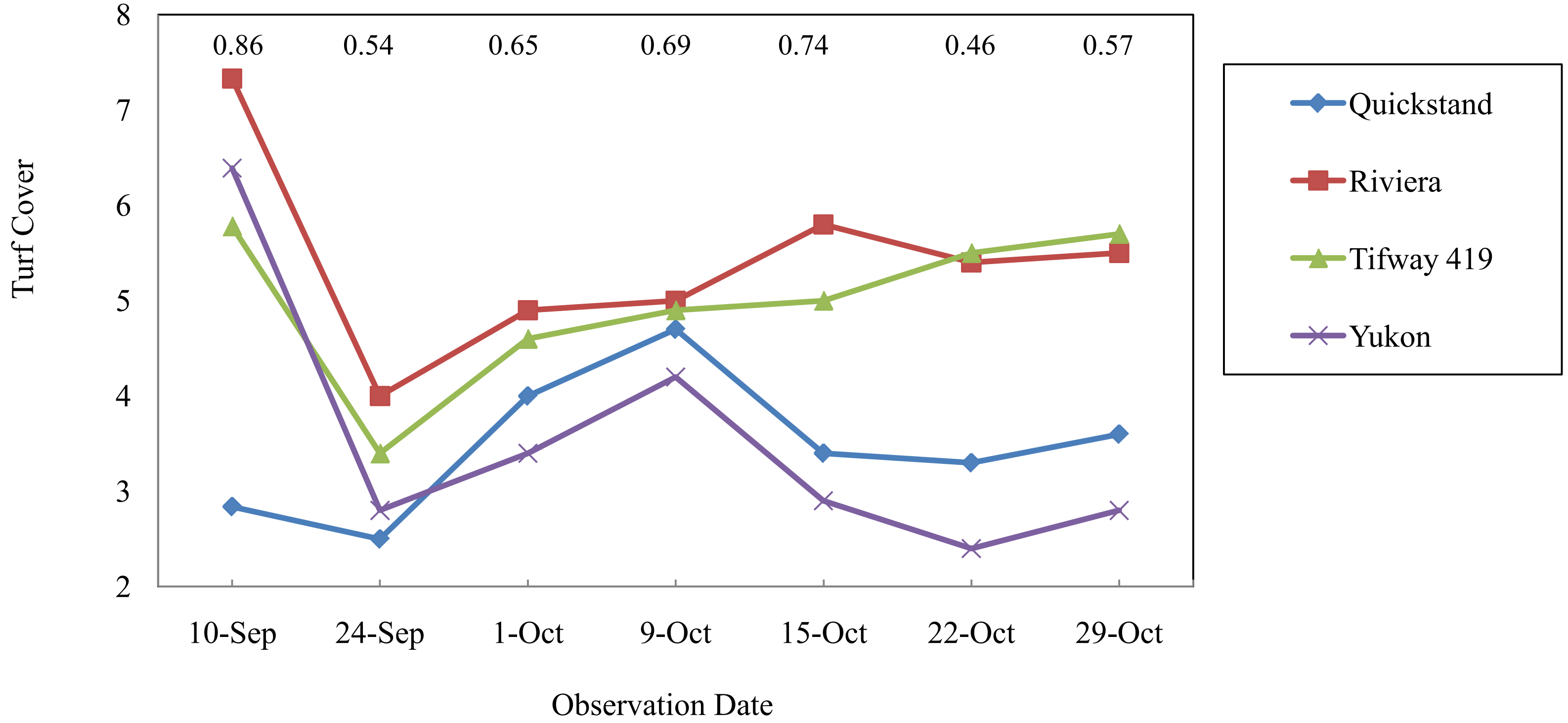

Figure 3.5. Level of simulated traffic damage (1=bare soil, 10= no damage) on four bermudagrass cultivars across all overseeding and TE applications in 2007. Numbers above the turf cover curves represent F-protected Fisher's LSD (p=0.05) at each observation date.

Table 3.3. Analysis of variance statistics for the main effects of treatments and potential interactions between cultivar, TE, and overseeding treatments for 2007 observation dates.

	2007									
	10-Sep		24-Sep		1-Oct		9-Oct		15-Oct	
Source	F	Pr>F	F	Pr>F	F	Pr>F	F	Pr>F	F	Pr>F
Rep.	1.88	0.1640	2.14	0.1295	7.45	0.0016	1.94	0.1557	0.65	0.5291
Cultivar	40.86	<.0001	13.48	<.0001	8.10	0.0002	1.97	0.1321	28.10	<.0001
TE	1.20	0.2782	2.14	0.1505	0.13	0.7188	1.85	0.1807	1.37	0.2478
Overseeding	1.30	0.2812	0.15	0.8614	7.02	0.0022	16.18	<.0001	3.09	0.0550
Cult. x TE	2.16	0.1053	1.97	0.1322	1.53	0.2190	2.80	0.0501	1.64	0.1927
Cult. x OS	0.26	0.9542	2.09	0.0730	1.45	0.2153	1.36	0.2492	4.50	0.0012
TE x OS	2.11	0.1332	0.15	0.8614	0.83	0.4419	0.27	0.7650	0.49	0.6176
Cult. x TE x OS	0.26	0.9542	1.18	0.3358	0.71	0.6396	0.82	0.5626	1.35	0.2559
CV (%)	29.18		11.84		16.93		19.61		19.40	

	22-Oct		29-Oct	
Source	F	Pr>F	F	Pr>F
Rep	0.38	0.6834	0.94	0.3980
Cultivar	85.43	<.0001	50.76	<.0001
TE	0.00	1.0000	0.17	0.6797
Overseeding	11.90	<.0001	26.84	<.0001
Cult. x TE	0.87	0.4655	1.14	0.3411
Cult. x OS	3.55	0.0057	3.92	0.0030
TE x OS	1.68	0.1971	1.55	0.2223
Cult. x TE x OS	1.60	0.1676	1.30	0.2771
CV (%)	11.64		15.20	

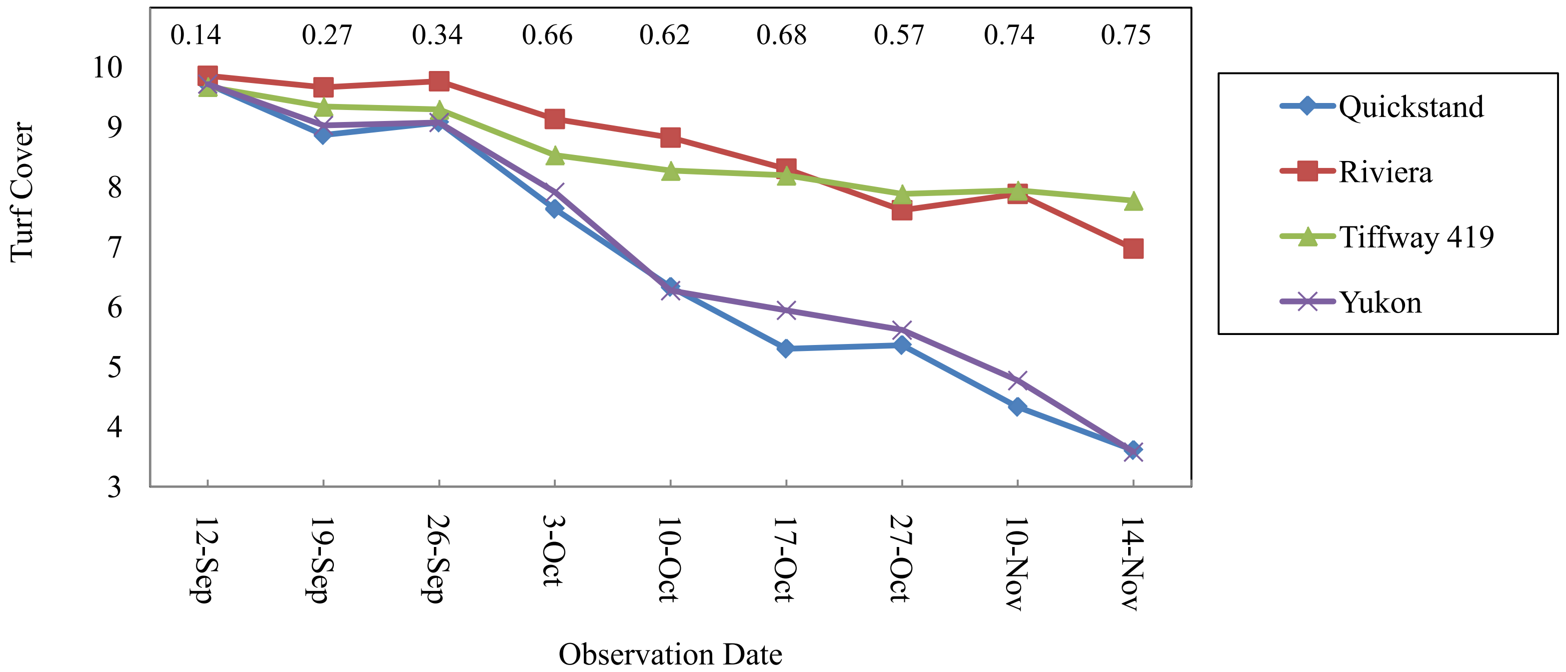

Figure 3.6. Level of simulated traffic damage (1=bare soil, 10= no damage) on four bermudagrass cultivars across all overseeding and TE treatments in 2008. Numbers above turf cover curves represents F-protected Fisher's LSD ($p<0.05$) for each observation date.

Table 3.4. Analysis of variance statistics for the main effects of treatments and potential interactions between cultivar, TE, and overseeding treatments for 2008 observation dates.

	2008									
	12-Sep		19-Sep		26-Sep		3-Oct		10-Oct	
Source	F	Pr>F	F	Pr>F	F	Pr>F	F	Pr>F	F	Pr>F
Rep.	1.22	0.3057	6.70	0.0028	0.37	0.6945	1.23	0.3009	10.72	0.0002
Cultivar	2.38	0.0821	13.80	<.0001	7.20	0.0005	8.17	0.0002	35.80	<.0001
TE	0.08	0.7837	1.22	0.2750	5.02	0.0299	8.17	0.0002	1.35	0.2509
Overseeding	1.77	0.1826	1.91	0.1600	2.59	0.0862	0.85	0.4355	15.57	<.0001
Cult. x TE	1.42	0.2498	0.86	0.4698	2.33	0.0872	1.52	0.2232	0.23	0.8768
Cult. x OS	1.91	0.0998	1.42	0.2285	2.32	0.0484	1.38	0.2415	5.00	0.0005
TE x OS	1.65	0.2034	0.47	0.6264	0.72	0.4936	0.85	0.4355	0.24	0.7893
Cult. x TE x OS	1.42	0.2285	0.69	0.6605	1.29	0.2823	0.78	0.5913	1.78	0.1234
CV (%)	2.19		4.39		5.54		11.96		12.55	

	17-Oct		27-Oct		10-Nov		14-Nov	
Source	F	Pr>F	F	Pr>F	F	Pr<F	F	Pr<F
Rep	2.01	0.1460	8.25	0.0009	1.50	0.2338	0.38	0.6872
Cultivar	41.24	<.0001	42.81	<.0001	55.85	<.0001	68.63	<.0001
TE	0.27	0.6043	0.12	0.7315	0.28	0.5969	0.17	0.6784
Overseeding	63.01	<.0001	105.10	<.0001	34.85	<.0001	32.44	<.0001
Cult. x TE	0.57	0.6389	1.47	0.2359	0.34	0.7936	0.31	0.8166
Cult. x OS	7.99	<.0001	22.52	<.0001	6.53	<.0001	7.66	<.0001
TE x OS	0.07	0.9320	0.35	0.7079	0.12	0.8855	0.21	0.8074
Cult. x TE x OS	0.98	0.4466	1.03	0.4191	0.62	0.7095	0.61	0.7179
CV (%)	14.65		12.89		17.74		20.59	

comparing just the denser, fine leaved cultivars or just the less dense, coarser cultivars. However, significant differences were consistently observed between these two groups of cultivars. The cultivars Riviera and Tifway tolerated simulated traffic significantly better ($p<0.05$) than Quickstand and Yukon in both 2007 and 2008.

The main effects of TE applications on PTC were not significant ($p>0.05$) in 2007 (Table 3.3) or 2008 (Table 3 4). Turfgrass cover declined almost equally over the course of the application of traffic treatments for TE treated and untreated plots as illustrated in Figure 3.7 for 2007 and Figure 3.8 for 2008.

The main effects of overseeding were significant ($p\leq0.05$) for 2007 (Fig. 3.9; Table 3.3) and 2008 (Fig. 3.10; Table 3.4). Ratings of PTC were evaluations of bermudagrass only prior to overseeding and of the combination of bermudagrass and ryegrass following overseeding. Highly significant differences were recorded for all dates after establishment of the ryegrass except 1 and 15 October in 2007 (Table 3.3) and for all dates after ryegrass establishment in 2008 (Table 3.4). Significant interactions were observed in PTC with increasing overseeding rates in 2008 (Fig. 3.10) also in 2007 except to a lesser magnitude (Fig. 3.9). The greatest increases were observed in the more open, less dense cultivars of Quickstand and Yukon (Figs. 3.11 and 3.12). The difference between the 2 years of the study may be directly related to the amount of irrigation the sites received. Irrigation differences between the two study years was due to the irrigation requirement to establish a NTEP trial on a bordering site in 2008. The extent of the increase in PTC may also be attributable to the ease of establishment of the ryegrass due to enhanced seed soil contact of the less dense cultivars.

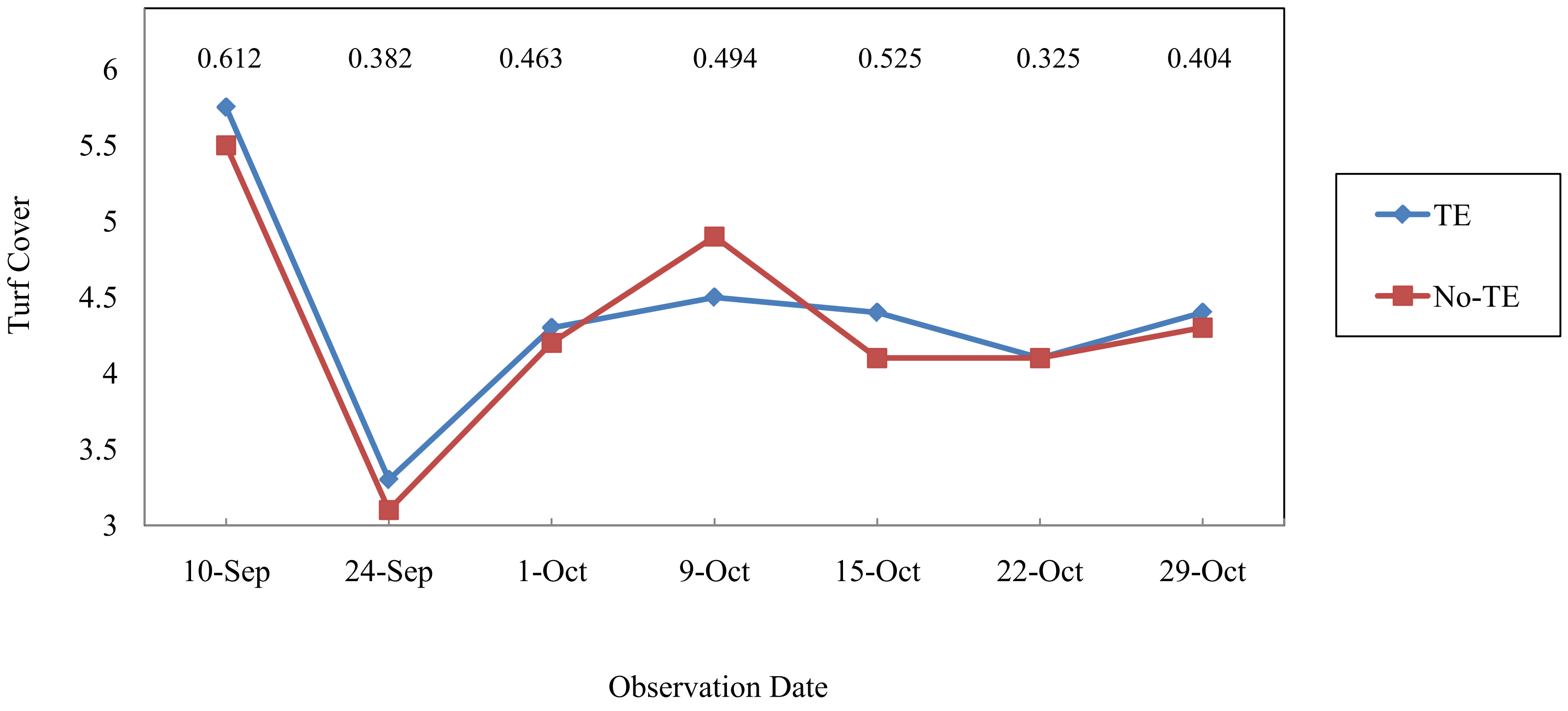

Figure 3.7. Level of simulated traffic damage (1=bare soil, 10= no damage) across four bermudagdrass cultivars and across all overseeding treatments evaluated in 2007. Numbers above turf cover curves represent F-protected Fisher's LSD (p=0.05) for each observation date.

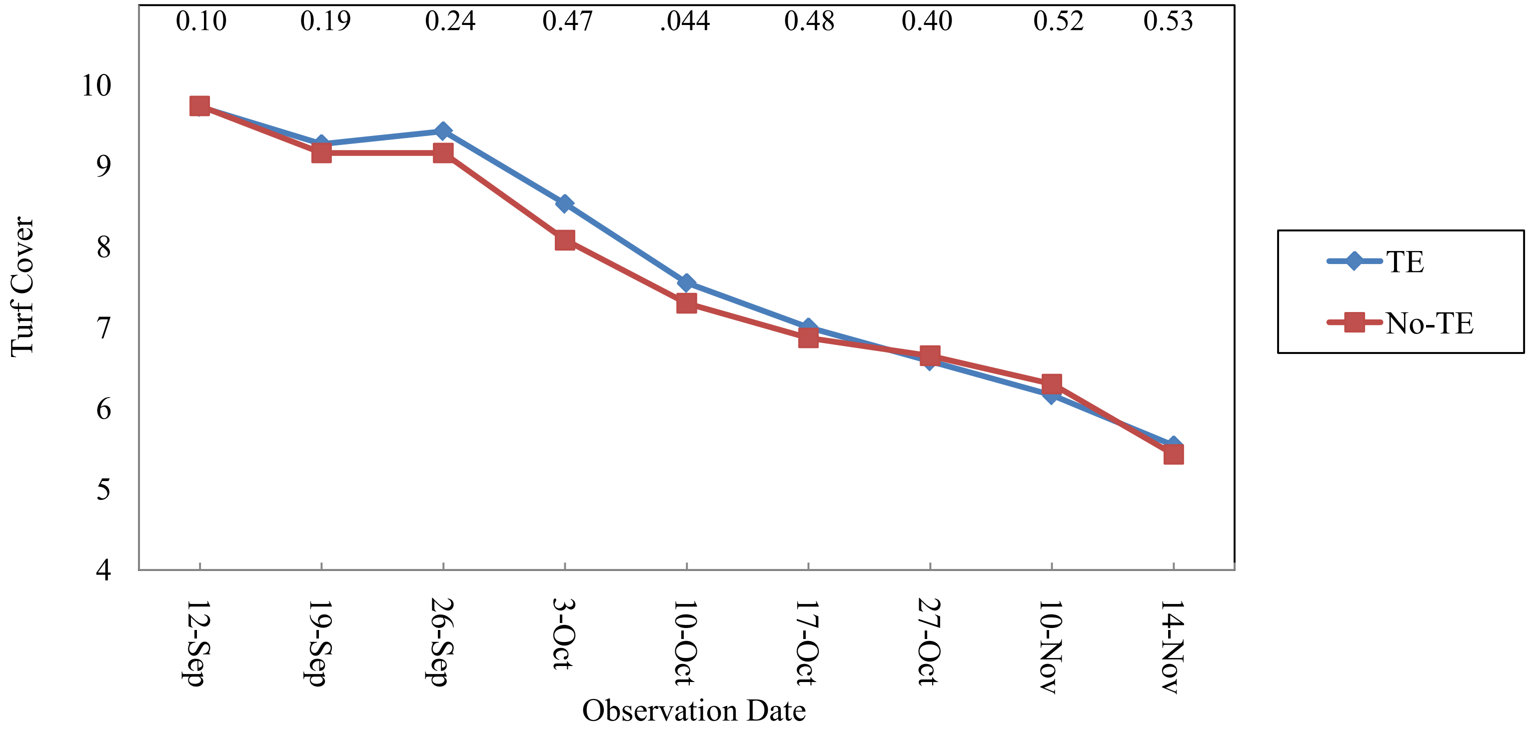

Figure 3.8. Level of simulated traffic damage (1=bare soil, 10= no damage) under two TE treatments across four bermudagrass cultivars and overseeding treatments evaluated in 2008. Numbers above turf cover curves represents F-protected Fisher's LSD (p=0.05) at each observation date.

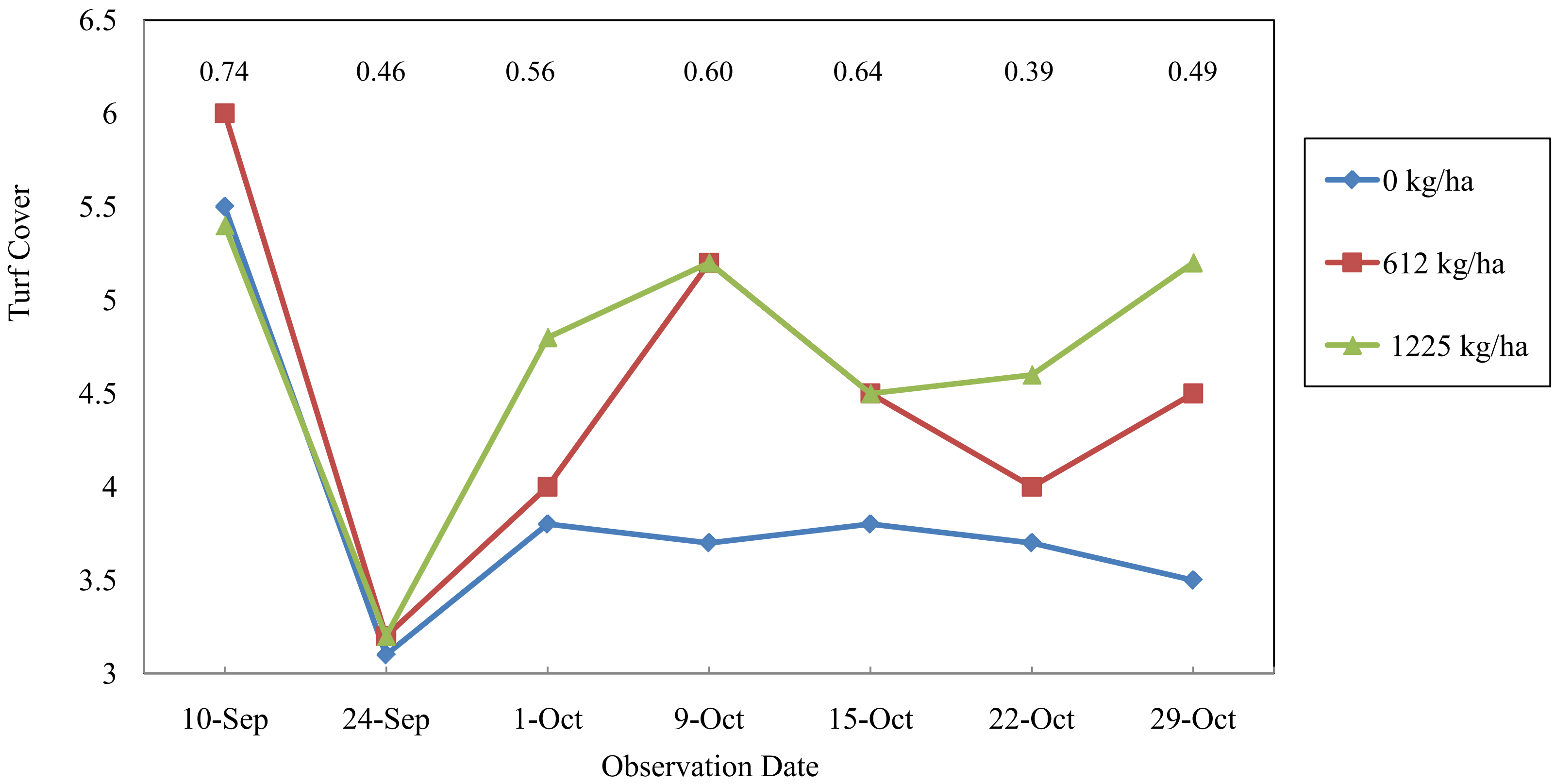

Figure 3.9. Level of simulated traffic damage (1=bare soil, 10=no damage) under three ryegrass overseeding treatments across four bermudagrass cultivars and across all TE applications evaluated in 2007. Numbers above turf cover curves represent F-protected Fisher's LSD (p=0.05) at each observation date.

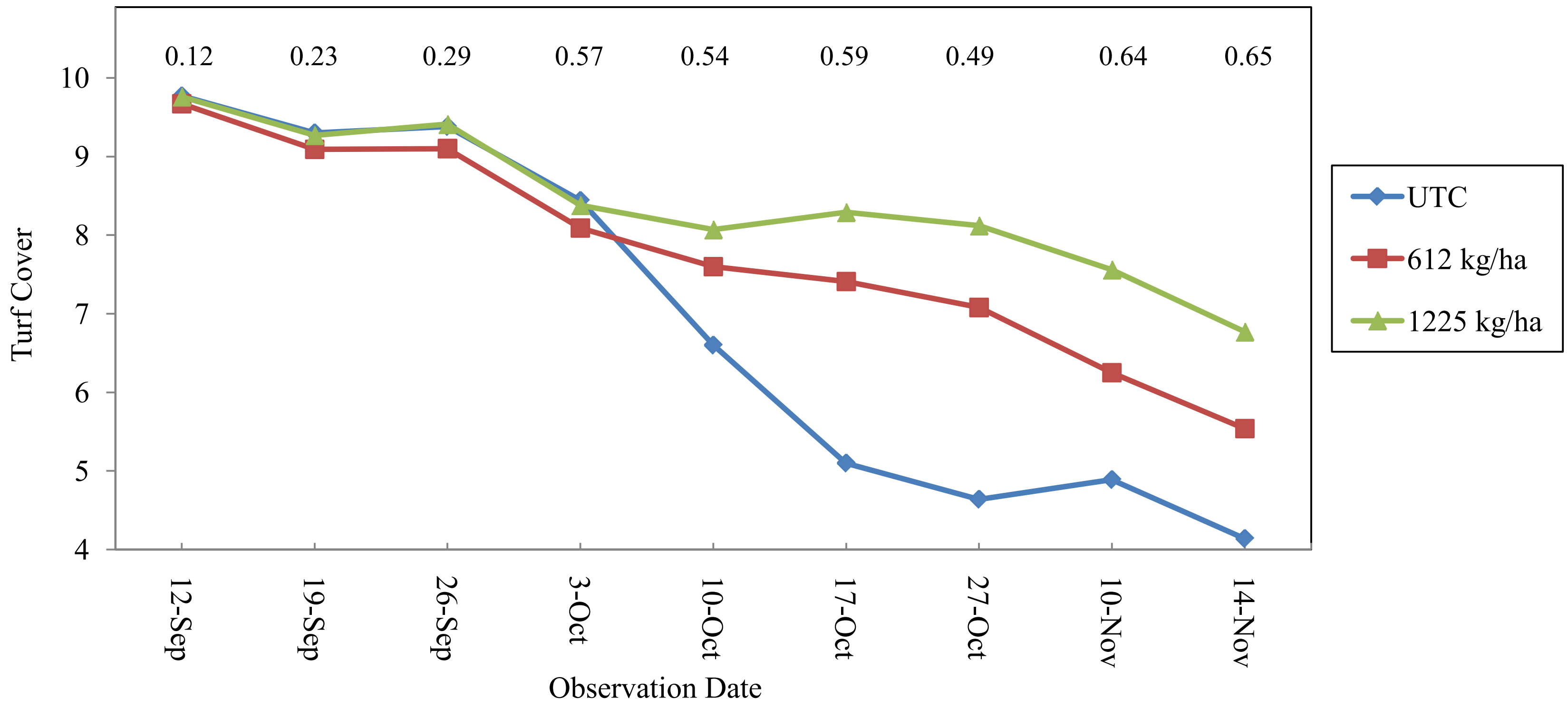

Figure 3.10. Level of simulated traffic damage (1= bare soil, 10= no damage) under three ryegrass overseeding treatments across four bermudagrass cultivars and TE treatments evaluated in 2008. Numbers above turf cover curves represent F-protected Fisher's LSD (p=0.05) at each observation date.

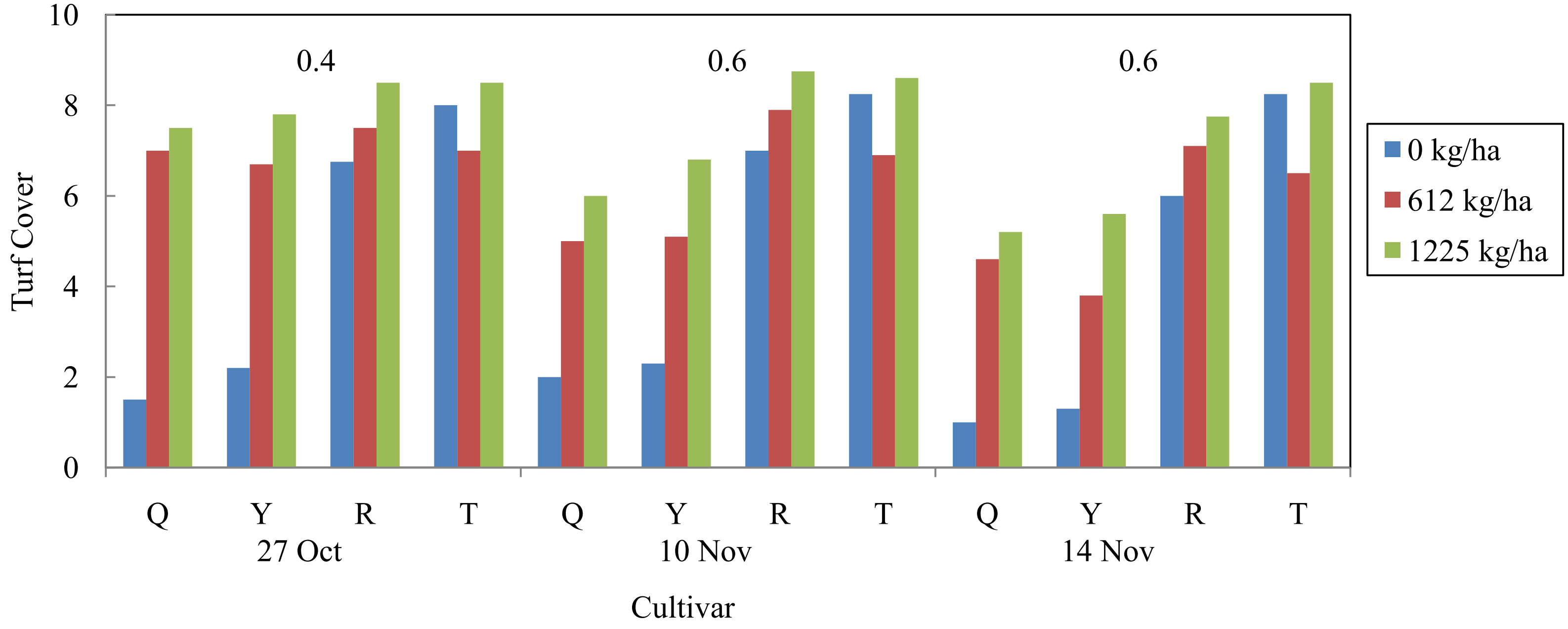

Figure 3.11. Quickstand (Q), Yukon (Y), Riviera (R), and Tifway 419 (T) traffic tolerance response to three ryegrass overseeding rates evaluated in 2008. Scale 1-10; 1= bare soil 10 = no damage. Numbers above bars for each observation date represent F-protected Fisher's LSD (p=0.05).

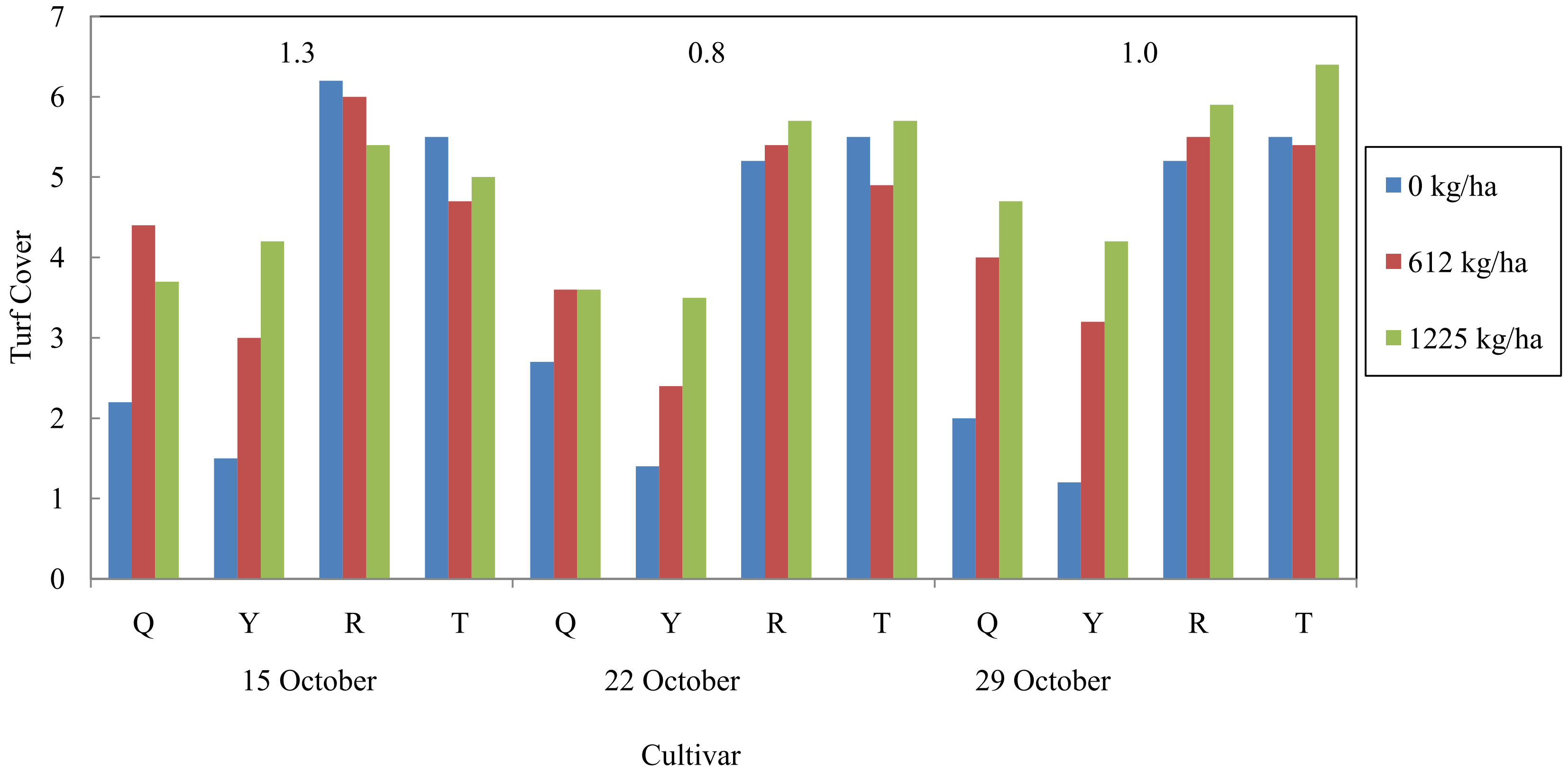

Figure 3.12. Quickstand (Q), Yukon (Y), Riviera (R), and Tifway 419 (T) traffic tolerance response to three ryegrass overseeding rates evaluated in 2007. Scale 1 - 10; 1=bare soil 10 = no damage. Numbers above bars for each observation date represent F-protected Fisher's LSD (p=0.05).

After establishment of the ryegrass in 2007 significant differences ($p \leq 0.05$) were identified for observation dates 15, 22, and 29 October (Table 3.3). Likewise for 2008 (Table 3.4), all observation dates had significant differences with all observations including and after 10 October being highly significant ($p < 0.0001$). Again, the data indicates that the less-dense cultivars were positively affected more than the denser cultivars with increasing rates of overseeding.

Shear Strength Study

Turfgrass Quality

The main effect of cultivar was statistically significant ($p \leq 0.05$) across all observation dates for both 2007 (Fig. 3.13; Table 3.5) and 2008 (Fig. 3.14; Table 3.6). Riviera exhibited consistently higher quality over the other cultivars in the study. In 2007, Riviera and Quickstand were statistically significant ($p \leq 0.05$) compared to both Tifway and Yukon. In 2008, Riviera and Tifway typically exhibited higher quality than Quickstand and Yukon. For 2008, with the exception of 18 July, Yukon exhibited the lowest quality over all observations (Fig. 3.14). The main effect of TE was statistically significant ($p \leq 0.05$) across all observations in 2007 (Fig. 3.15; Table 3.5) and all dates except 18 July 2008 (Fig. 3.16; Table 3.6). There were no significant ($p > 0.05$) cultivar by TE interactions (Tables 3.5, 3.6) observed for either year of the study for turfgrass quality ratings.

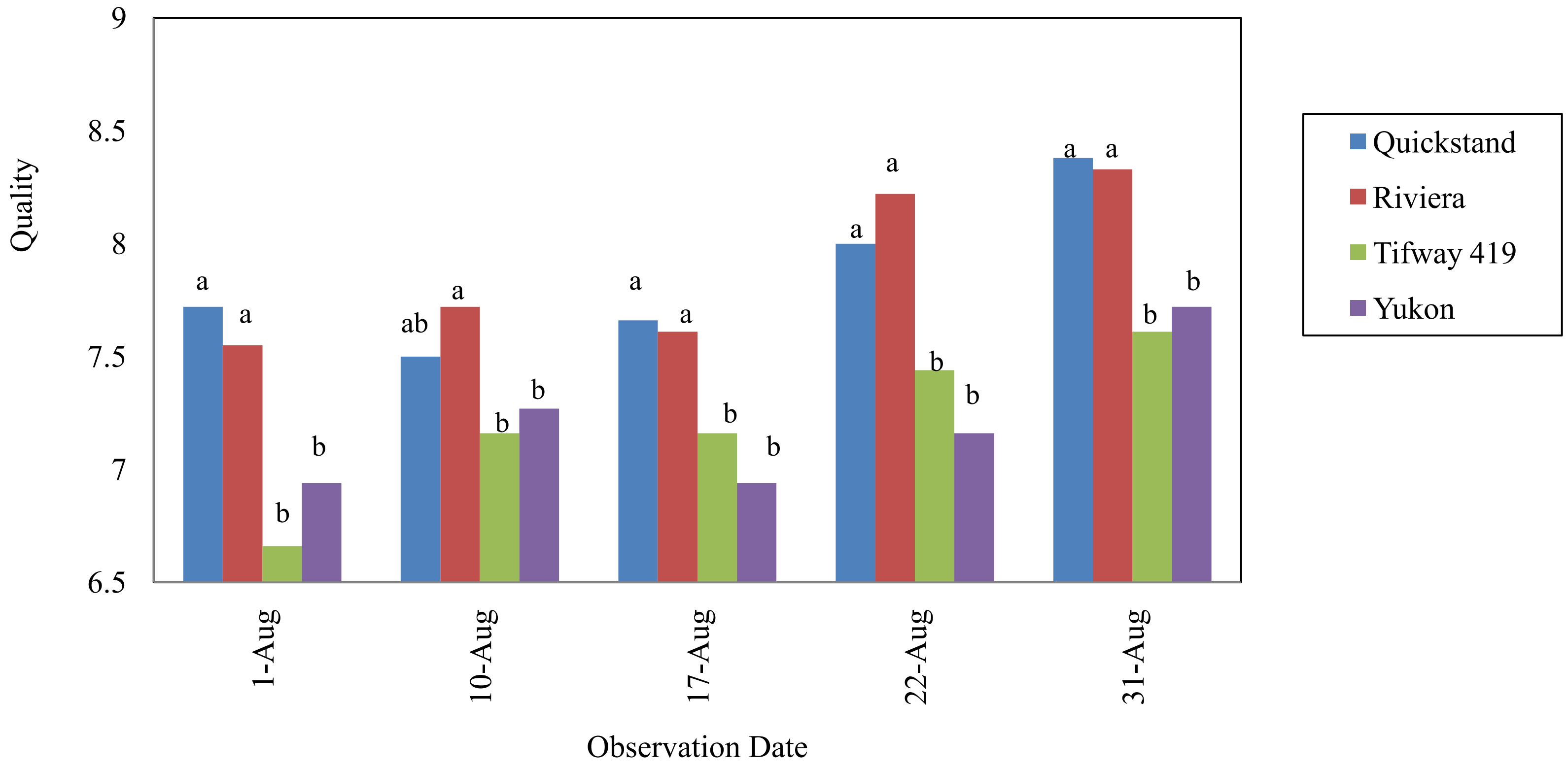

Figure 3.13. Mean visual quality of four bermudagrass cultivars evaluated in 2007. Scale 1 - 9; 1=dead turf 9=optimum turf. Bars labeled with same letter within observation date ar not significantly different by F-protected Fisher's LSD (p=0.05).

Table 3.5. Analysis of variance statistics for the main effect of cultivar and TE and potential interactions between cultivar and TE for turfgrass quality ratings in2007.

	2007 Observation Dates									
	1-Aug		10-Aug		17-Aug		22-Aug		31-Aug	
Source	F	Pr>F	F	Pr>F	F	Pr>F	F	Pr>F	F	Pr>F
Rep	2.43	0.0966	1.14	0.2364	1.98	0.1466	0.29	0.7495	0.47	0.6250
Cultivar	9.91	<0.0001	4.27	0.0083	6.40	0.0008	7.43	0.0003	7.71	0.0002
TE	9.95	0.0025	26.28	<0.0001	25.26	<0.0001	6.98	0.0104	19.27	<0.0001
Cult. x TE	3.15	0.0310	1.38	0.2586	2.30	0.0856	1.18	0.3235	0.72	0.5459
CV (%)	9.31		6.81		7.97		9.83		7.0	

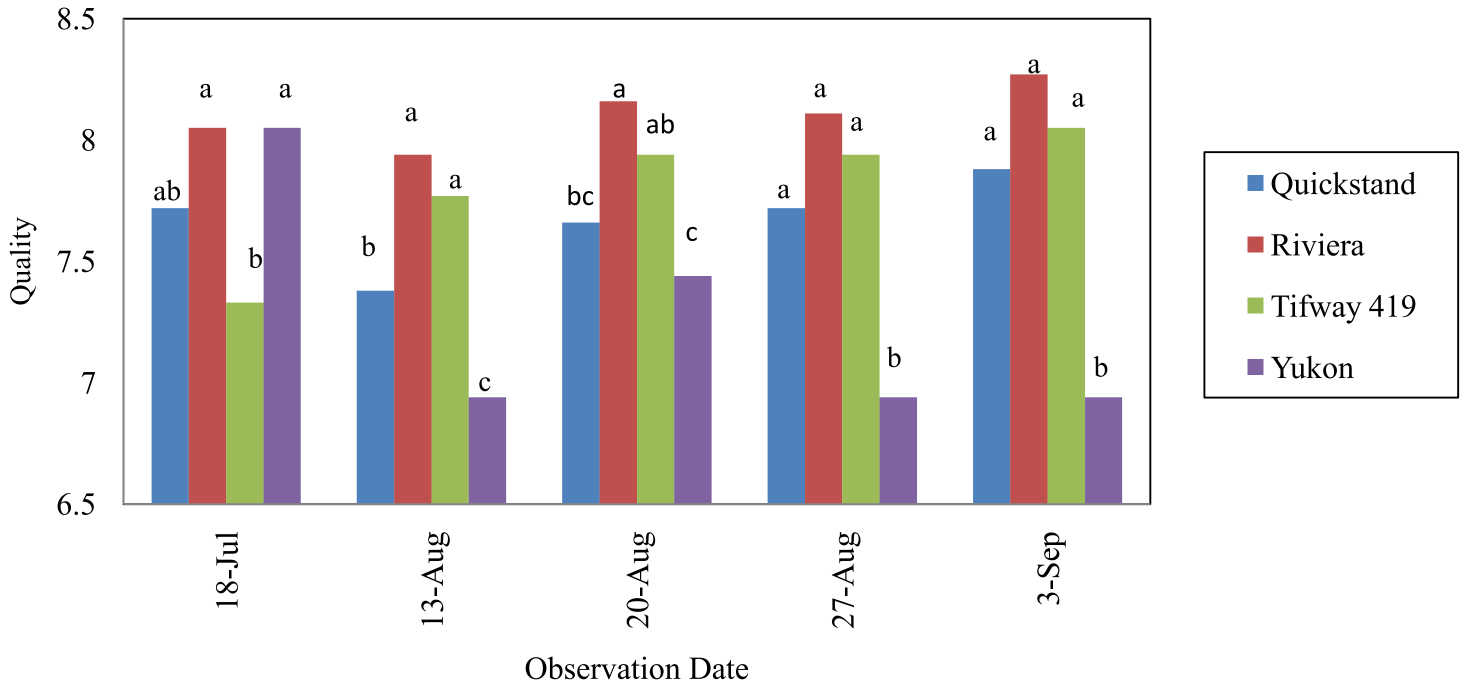

Figure 3.14. Mean visual quality of four bermudagrass cultivars evaluated in 2008. Scale 1 - 9; 1=dead turf 9=optimum quality. Bars labeled with same letter within observation date are not significantly different F-protected Fisher's LSD (p>0.05).

Table 3.6. Analysis of variance statistics for the main effect of cultivar and TE and potential interactions between cultivar and TE for turfgrass quality ratings in 2008.

	2008 Observation Dates									
	7-July		13-Aug		20-Aug		27-Aug		3-Sep	
Source	F	Pr>F	F	Pr>F	F	Pr>F	F	Pr>F	F	Pr>F
Rep	1.64	0.2018	8.03	0.0008	10.69	0.0001	2.43	0.0959	2.49	0.0913
Cultivar	2.70	0.0531	11.40	<0.0001	6.95	0.0004	12.54	<0.0001	17.63	<0.0001
TE	2.14	0.1488	23.46	<0.0001	5.37	0.0238	19.23	<0.0001	66.38	<0.0001
Cult. x TE	0.21	0.8918	1.58	0.2028	1.22	0.3108	2.07	0.1131	4.15	0.0096
CV (%)	11.38		7.44		6.51		8.04		7.61	

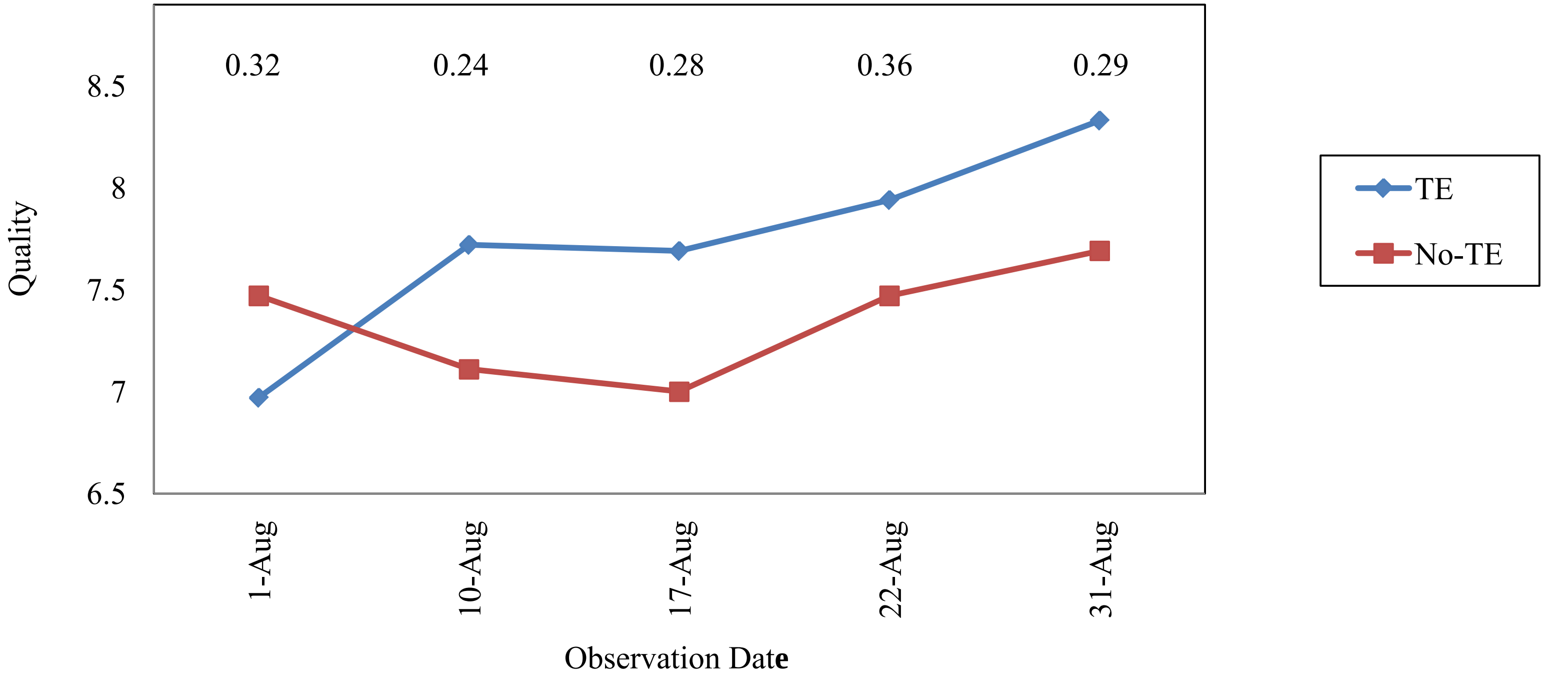

Figure 3.15. Visual quality across four bermudagrass cultivars under two TE treatment regimes for 2007. Scale 1 - 9; 1=dead turf 9=optimum quality. Numbers above quality curves represent F-protected Fisher's LSD (p=0.05) at each observation date.

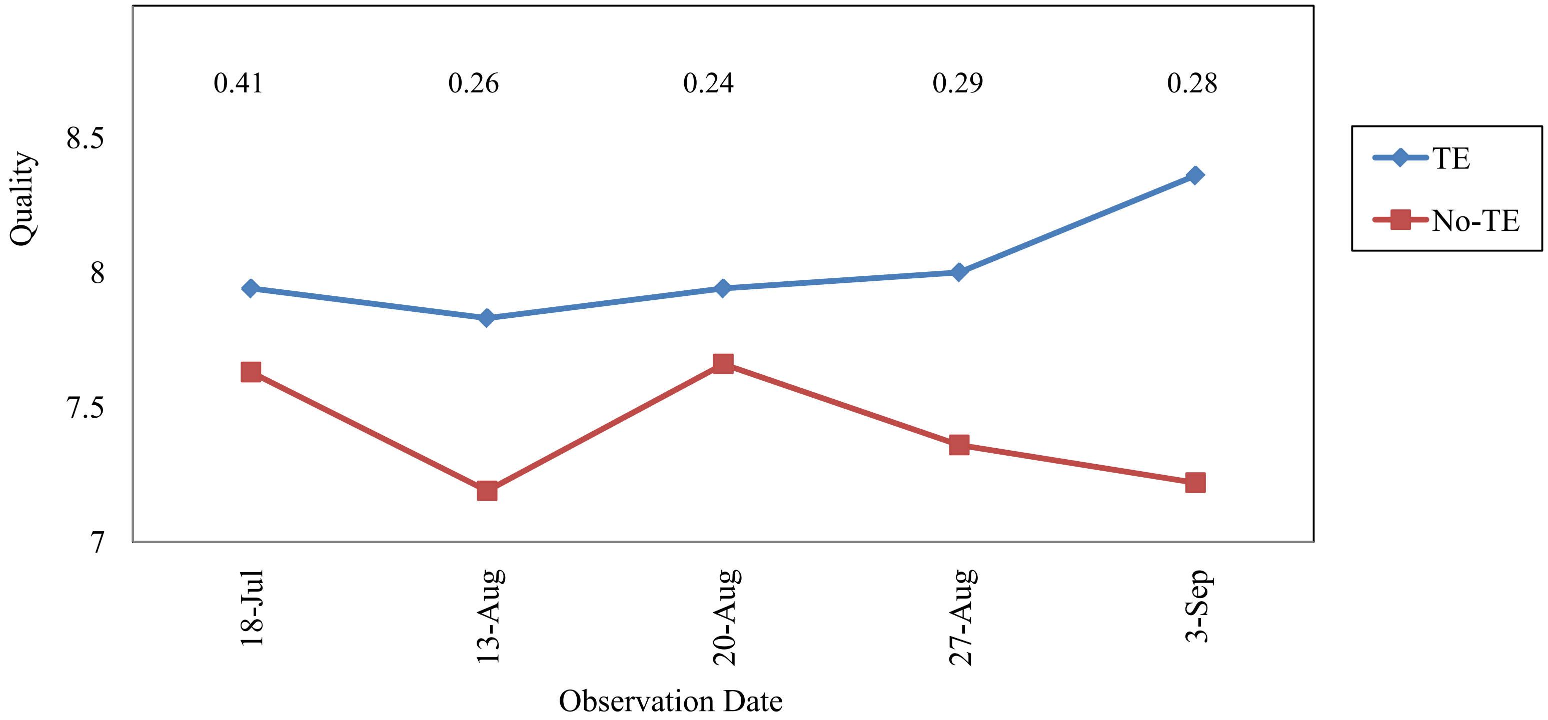

Figure 3.16. Visual quality of four bermudagrass cultivars across two TE treatment regimes for 2008. Scale 1-9; 1=dead turf 9=optimum quality. Numbers above quality curves represent F-protected Fisher's LSD (p=0.05) at each observation date.

Shear strength

Shear strength data indicate the main effect of cultivar was statistically significant ($p \leq 0.05$) for all observation dates in 2007 (Fig. 3.17; Table 3.7). The main effect of cultivar in 2008 (Fig. 3.18; Table 3.8) was also significant ($p \leq 0.05$) with the exception of 22 September and 6 October. Figure 3.17 illustrates highly significant differences between Quickstand / Riviera and Tifway /Yukon. Somewhat similar results were recorded in 2008 in that Riviera exhibited significantly ($p<0.05$) higher shear strength (Fig. 3.18).

The main effect of TE applications was not significant ($p>0.05$) (Tables 3.7 and 3.8). Four dates over the two year study, 12, 19 November 2007 and 6, 20 October 2008, were observed to have slightly significant differences. Shear strength as illustrated in Figure 3.19 for 2007 and Figure 3.20 for 2008 indicates no consistent trends in significant differences among TE treated and untreated plots.

The main effect of overseeding was not statistically significant ($p>0.05$) in 2007 (Table 3.7). Data for 2008 (Table 3.8) indicates significant differences for the last three observation dates. The main effects of overseeding in 2007 are illustrated in Figure 3.21 and in Figure 3.22 for 2008. The significant differences in 2008 may be attributable to an increase in irrigation frequency on the test site. The site received extra irrigation due to a NTEP trial that was being established during this time. The data suggest that ample irrigation in 2008 may have provided enhanced perennial ryegrass establishment relative to 2007. Unlike the traffic study, large and statistically significant differences were observed with decreasing overseeding rates in relation to shear strength in 2008 (Fig. 3.22), especially for the last three observations.

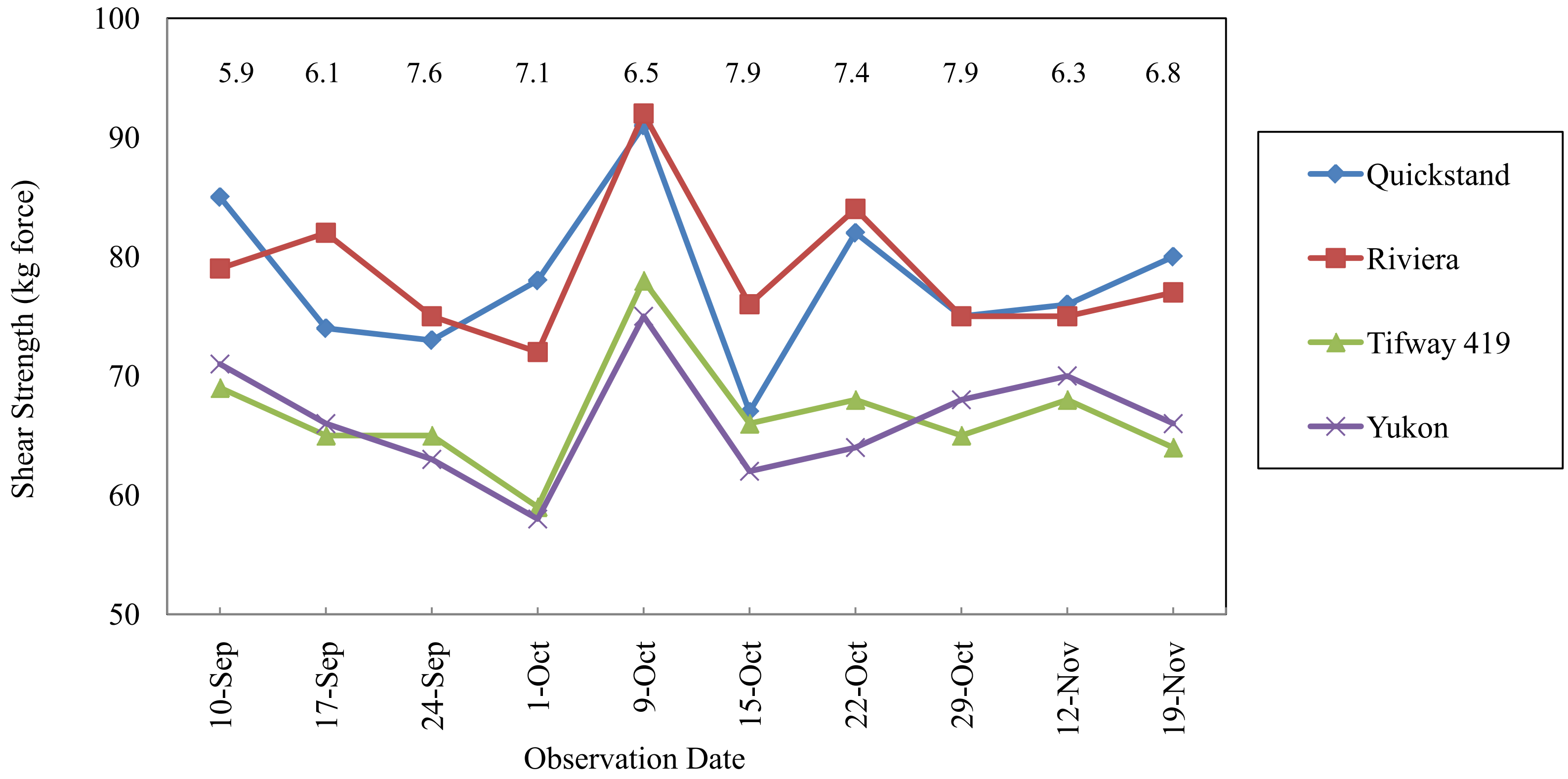

Figure 3.17. Shear strength measured in kilograms force (Kg-F) on 4 bermudagrass cultivars across all overseeding and TE applications in 2007. Numbers above shear strength curves represent F-protected Fisher's LSD (p=0.05) at each observation date.

Table 3.7. Analysis of variance statistics for replication, cultivar, TE, overseeding and potential interactions cult. x TE, cult. x OS, Te x OS, cult. x TE x OS for shear strength measurements in 2007.

	2007 Observation Dates									
	10-Sep		17-Sep		24-Sep		1-Oct		9-Oct	
Source	F	Pr>F	F	Pr>F	F	Pr>f	F	Pr>f	F	Pr>F
rep	0.33	0.7202	2.79	0.0719	0.73	0.4862	1.22	0.3052	1.07	0.3501
cultivar	12.52	<0.0001	13.48	<0.0001	5.30	0.0032	15.09	<0.0001	13.75	<0.0001
TE	3.74	0.0592	2.15	0.1490	3.32	0.0750	0.46	0.4987	2.60	0.1135
OS	0.70	0.5038	0.34	0.7166	0.02	0.9819	0.89	0.4161	0.11	0.9005
cult x TE	1.10	0.3600	0.09	0.9670	0.96	0.4203	1.04	0.3820	1.61	0.2008
cult x OS	0.40	0.8746	0.50	0.8067	1.22	0.3138	0.76	0.6069	1.73	0.1359
TE x OS	0.86	0.4285	1.90	0.1605	1.44	0.2485	0.29	0.7519	3.52	0.0377
cult x TE x OS	3.22	0.0101	0.52	0.7878	1.05	0.4046	1.46	0.2136	0.60	0.7287
CV (%)	11.67		12.87		16.29		15.73		11.49	

	15-Oct		22-Oct		29-Oct		12-Nov		19-Nov	
Source	F	Pr>F	F	Pr>F	F	Pr>f	F	Pr>f	F	Pr>F
rep	0.19	0.8269	5.63	0.0065	6.57	0.0031	2.91	0.0645	5.76	0.0059
cultivar	4.73	0.0058	14.79	<0.0001	2.98	0.0408	3.02	0.0392	10.56	<0.0001
TE	3.35	0.0738	0.63	0.4325	2.00	0.1641	8.06	0.0067	4.68	0.0358
OS	1.16	0.3210	0.40	0.6694	0.25	0.7766	4.16	0.0218	0.32	0.7301
cult x TE	0.05	0.9870	1.16	0.3351	0.72	0.5464	2.69	0.0569	1.86	0.1494
cult x OS	0.12	0.9934	0.88	0.5154	0.73	0.6313	0.36	0.8986	0.50	0.8027
TE x OS	0.39	0.6821	1.47	0.2402	1.68	0.1975	1.16	0.3218	1.60	0.2133
cult x TE x OS	1.06	0.4010	0.94	0.4785	0.70	0.6515	0.80	0.5717	0.19	0.9774
CV (%)	17.48		14.79		16.71		13.01		14.31	

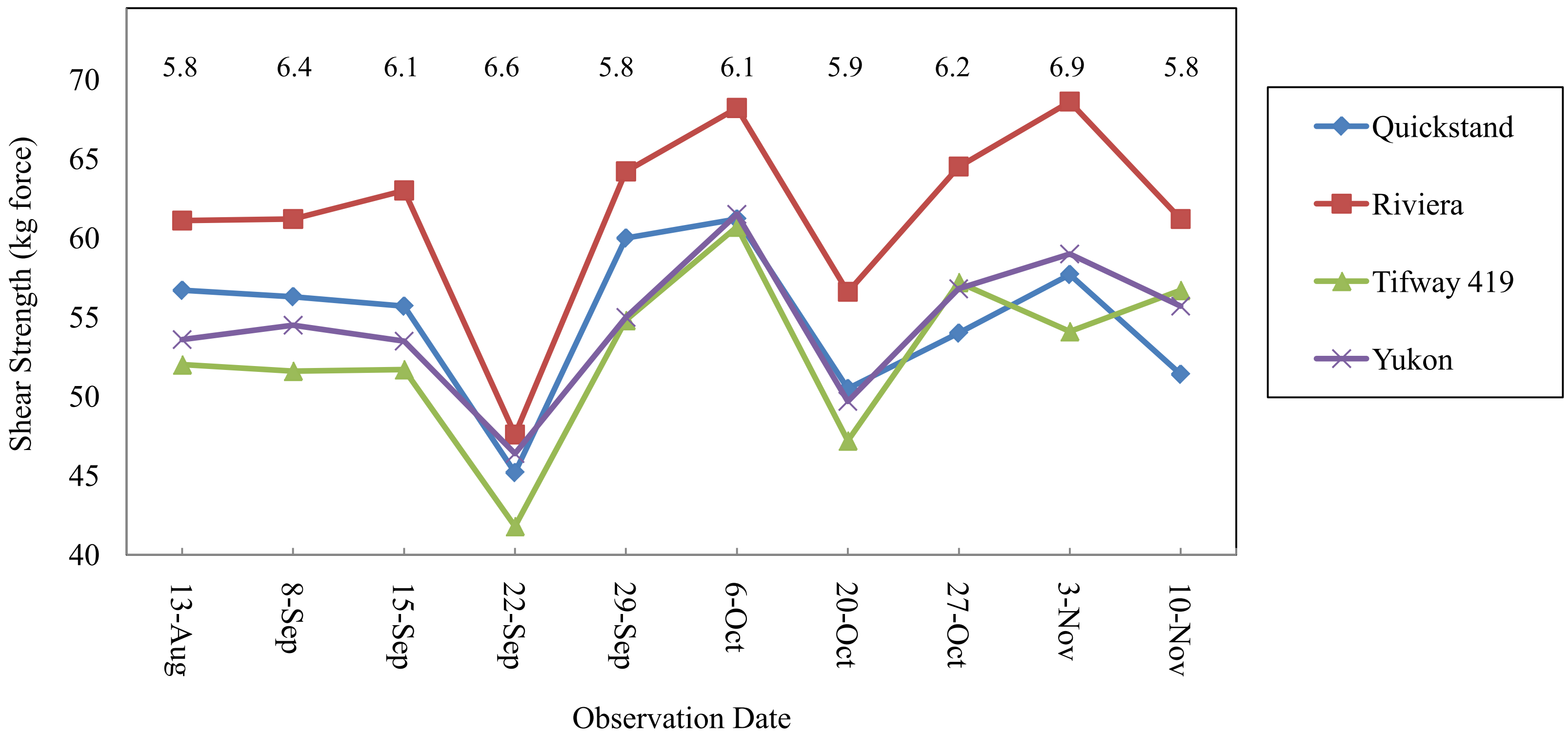

Figure 3.18. Shear Strength measured in kilograms force (Kg-F) on four bermudagrass cultivars across all overseeding and TE treatments in 2008. Numbers above shear strength curves represent F-protected Fisher's LSD (p=0.05) at each observation date.

Table 3.8. Analysis of variance statistics for replication, cultivar, TE, overseeding and potential interactions cult. x TE, cult. x OS, Te x OS, cult. x TE x OS for shear strength measurements in 2008.

2008 Observation Dates

	13-Aug		8-Sep		15-Sep		22-Sep		29-Sep	
Source	F	Pr>F	F	Pr>F	F	Pr>f	F	Pr>f	F	Pr>F
rep	6.73	0.0027	4.54	0.0128	0.90	0.4132	3.44	0.0404	0.93	0.4001
cultivar	3.86	0.0152	3.15	0.0337	5.44	0.0028	1.15	0.3393	4.80	0.0054
TE	1.65	0.2048	0.72	0.4017	0.89	0.3492	2.60	0.1135	0.03	0.8638
OS	5.93	0.0051	3.64	0.0342	0.18	0.8373	0.85	0.4329	1.65	0.2028
cult x TE	0.53	0.6647	1.33	0.2746	1.44	0.2437	3.07	0.0370	2.01	0.1260
cult x OS	0.70	0.6542	0.29	0.9376	0.33	0.9197	1.13	0.3580	2.35	0.0460
TE x OS	4.22	0.0208	2.30	0.1121	1.15	0.3248	1.00	0.3754	5.11	0.0099
cult x TE x OS	0.37	0.8933	10.33	0.2646	1.97	0.0893	0.43	0.8551	0.60	0.7255
CV (%)	15.52		17.20		16.17		21.74		14.85	

	6-Oct		20-Oct		27-Oct		3-Nov		10-Nov	
Source	F	Pr>F	F	Pr>F	F	Pr>f	F	Pr>f	F	Pr>F
rep	3.46	0.0397	4.32	0.0191	0.67	0.5158	1.59	0.2147	6.93	0.0023
cultivar	2.66	0.0592	3.64	0.0195	4.18	0.0107	6.66	0.0008	3.91	0.0144
TE	7.90	0.0072	4.55	0.0382	2.53	0.1185	1.45	0.2345	0.22	0.6381
OS	0.71	0.4973	2.06	0.1388	3.18	0.0509	8.97	0.0005	5.49	0.0072
cult x TE	4.84	0.0052	3.50	0.0229	1.28	0.2908	2.06	0.1180	4.29	0.0094
cult x OS	0.12	0.9939	0.20	0.9747	0.81	0.5650	0.59	0.7372	2.13	0.0683
TE x OS	4.53	0.0161	1.60	0.2128	2.23	0.1193	5.46	0.0074	1.33	0.2732
cult x TE x OS	1.14	0.3546	0.87	0.5207	0.27	0.9503	0.63	0.7061	1.55	0.1844
CV (%)	14.55		17.46		15.97		17.05		15.35	

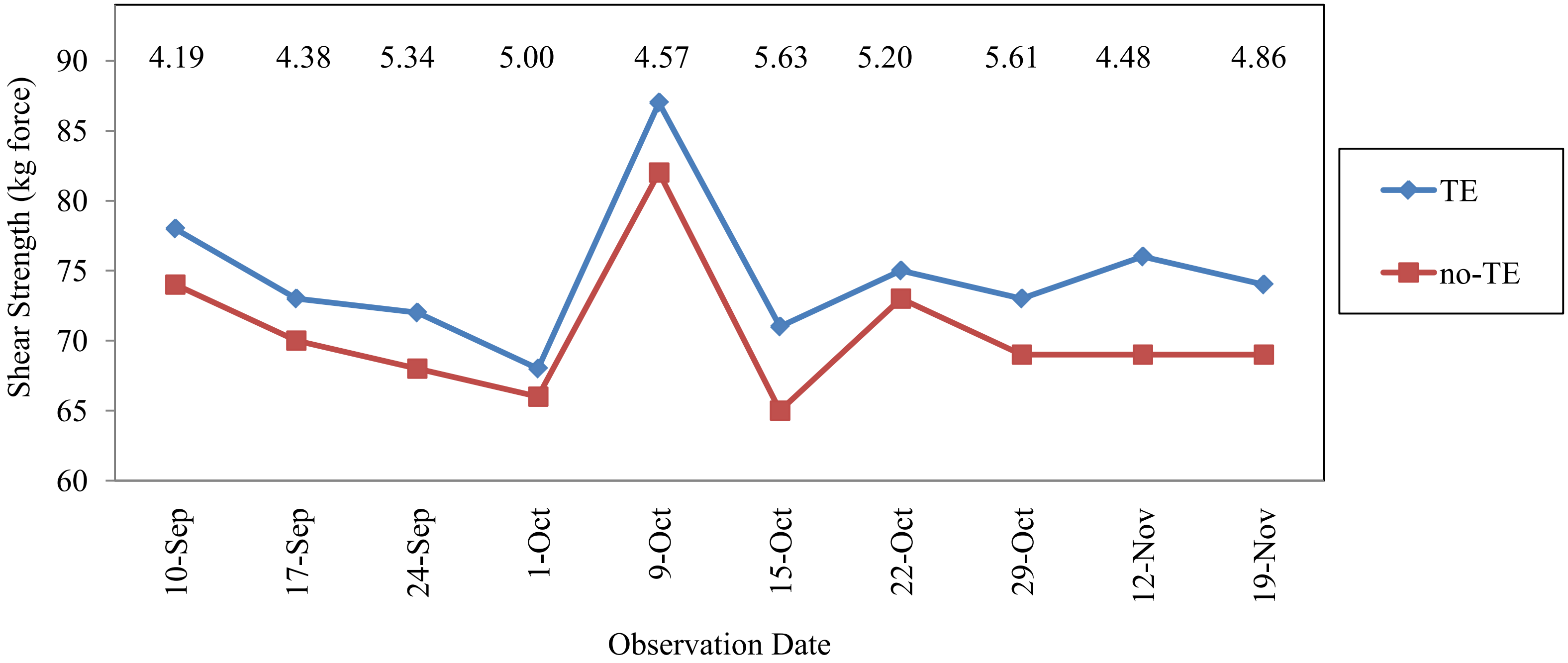

Figure 3.19. Mean shear strength measurements in kilograms force (kg-F) under two TE regimes across four burmudagrass cultivars and two overseeding treatments evaluated in 2007. Numbers above shear strength curves represents F-protected Fisher's LSD (p=0.05) at each observation date.

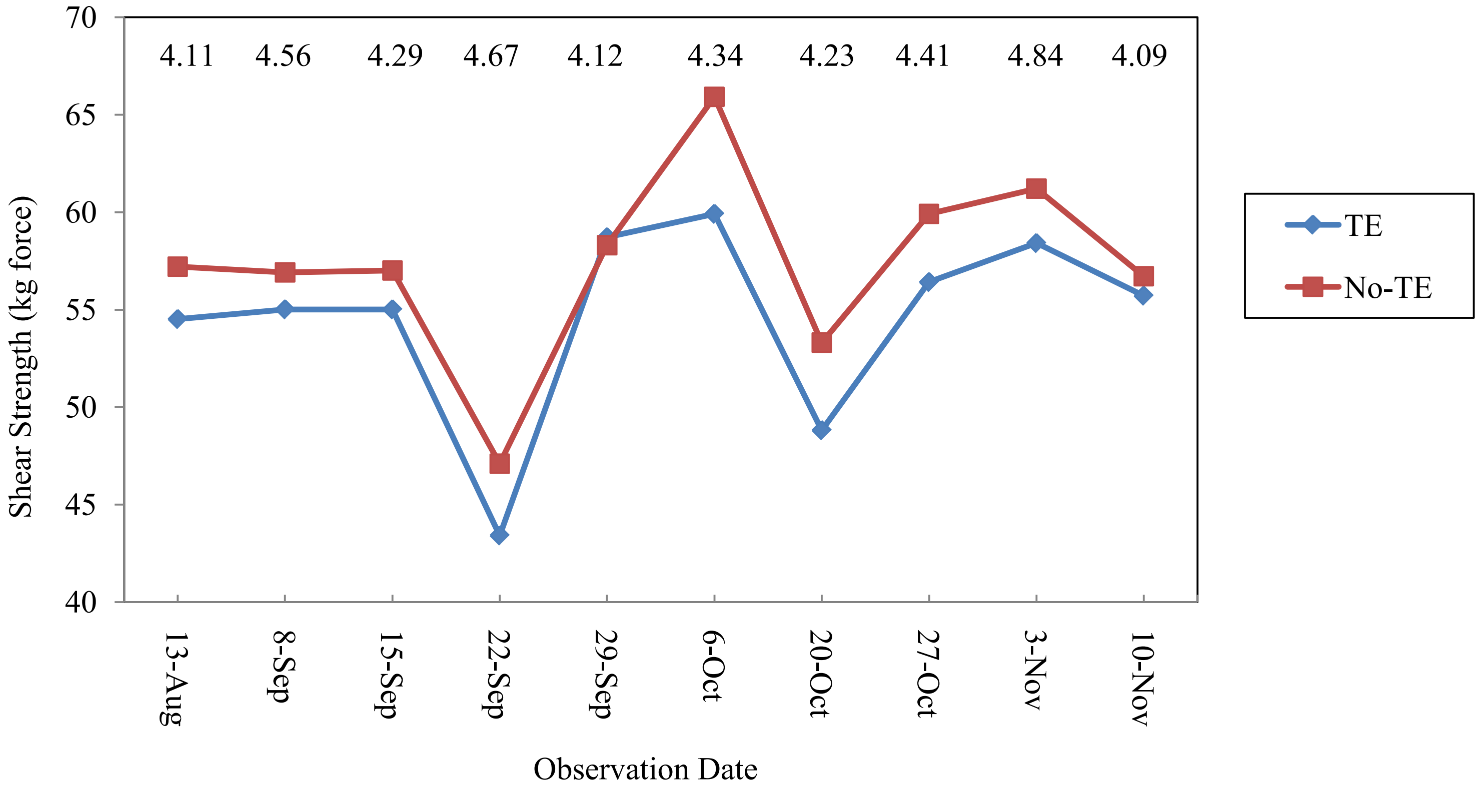

Figure 3.20. Shear strength measured in kilograms force (Kg-F) under two TE treatments across four bermudagrass cultivars and overseeding treatments in 2008. Numbers above shear strength curves represents F-protected Fisher's LDS (p=0.05) at each observation date.

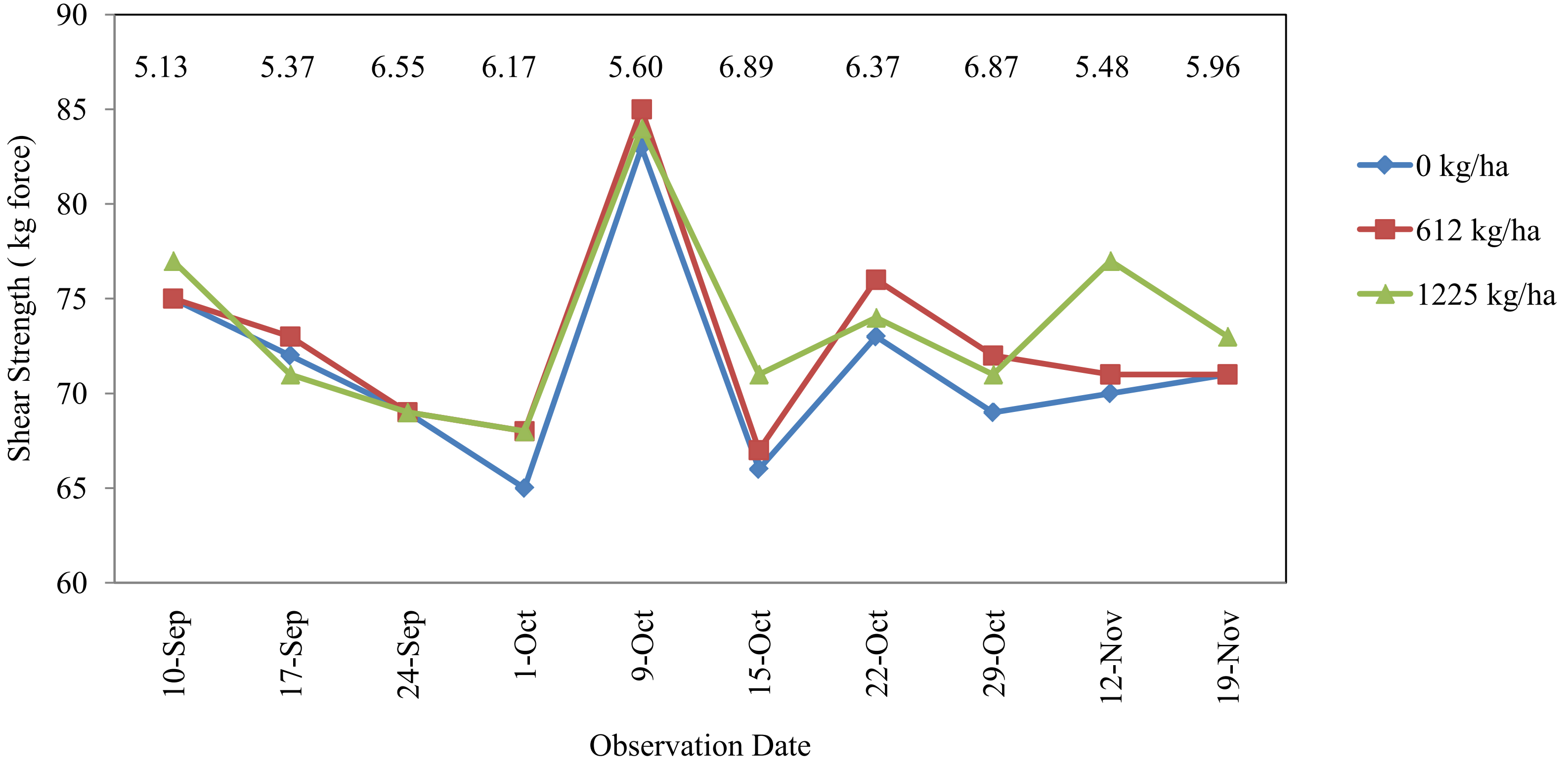

Figure 3.21. Shear strength means in kilograms force (kg-F) under three ryegrass overseeding treatments across all cultivars and TE treatment evaluated in 2007. Numbers above shear strength curves represent F-protected Fisher's LSD (p=0.05) at each observation date.

In 2007 (Table 7), the only statistically significant ($p<0.05$) interaction was 9 October. The TE by overseeding interaction was slightly significant ($p = 0.0377$). In 2008 (Table 8), four dates (22 September, 6, 20 October, and 10 November) had statistically significant ($p<0.05$) interactions between cultivar and TE treatments. For the dates listed, with the exception of 22 September where all cultivars were not statistically different, Riviera exhibited significantly higher shear strength than the remaining three cultivars. However, there were no indications of consistent and explainable interactions.

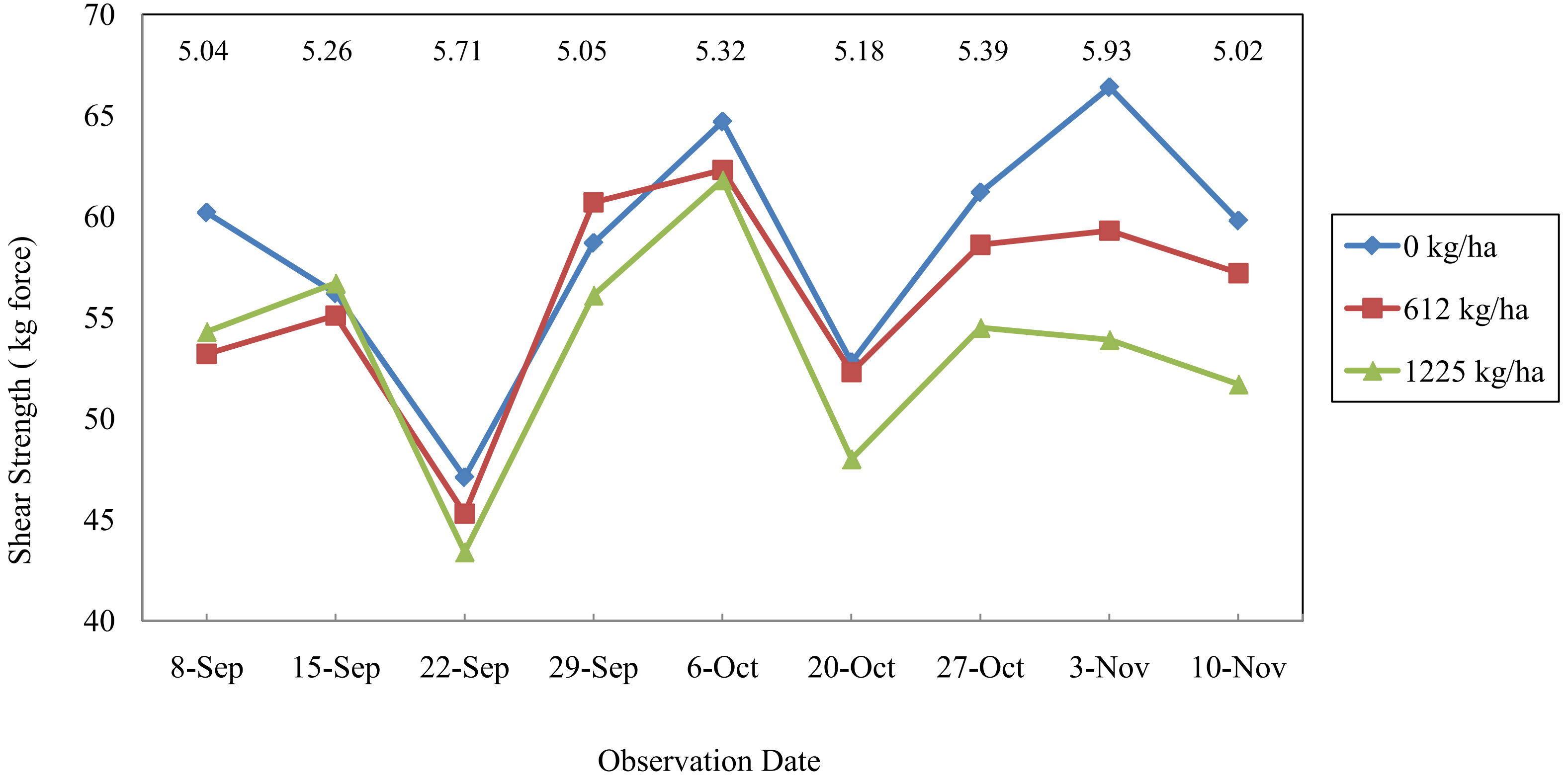

Figure 3.22. Shear strength measured in kilograms force for three ryegrass overseeding rates across all cultivars and TE treatments for 2008. Numbers above shear strength curves represent F-protected Fisher's LSD values (p=0.05) for each observation date.

CHAPTER IV

CONCLUSIONS

Traffic Study

In both years of the study, the main effects of cultivar in tolerance to simulated athletic traffic was significant ($p \leq 0.05$). Consistently throughout the study the finer textured, more-dense cultivars (Riviera and Tifway) outperformed the coarser textured, less dense cultivars (Quickstand and Yukon) under simulated traffic. This agrees well with earlier work (Bayrer, 2006, Williams et al., 2009) showing Riviera tolerating simulated traffic significantly better than some other cultivars when grown in native soil. It also agrees well with previous studies (Beard, 1990 and Sherman, 1975) concluding that the production of more above ground plant material in the form of tillers and stolons contributes positively to wear tolerance of the turf. The effect of cultivars across all observation dates was significant and across most of the observation dates the differences were highly significant ($p \leq 0.0001$). Riviera and Tifway were generally statistically equivalent and always outperformed the other varieties. Yukon, almost without exception, showed the poorest tolerance to simulated traffic across the entire study. This also agrees well with previous work (Bayrer, 2006). Cultivar selection for athletic turf grown on a sand-based system has been shown by this study to be significant and should be an important consideration before establishment of a new construction or renovation of an existing surface.

Trinexapac-ethyl applications across both years of the study were shown not to be significant when evaluating tolerance to simulated traffic. This is in contrast to recent work (Williams et al., 2009 personal communication) showing significant positive effects of TE applications when applied at label rates and frequencies on bermudagrass growing in native soil under simulated traffic. Percent turfgrass cover (PTC) over the course of this study was shown to decline with no significant difference between the plots that were not treated with TE. However, TE applications were shown to mostly have a significant positive effect across all cultivars on turf quality prior to the onset of simulated traffic treatments. No consistent significant interactions were observed with TE and any other factor in this study.

Overseeding across observation dates for both years of the study shows highly significant differences in PTC for most observations. The coarser textured, less dense cultivars Quickstand and Yukon were shown to respond much more positively to overseeding than the finer textured, more-dense cultivars. This is supported by the significant cultivar x overseeding interactions. These interactions were significant ($p<0.05$) in 2007 and highly significant ($p<0.0001$) in 2008 after establishment of the ryegrass. The more evident interactions between cultivar and overseeding for the 2008 study may be directly attributable to the extra irrigation the test site received. Irrigation was not a treatment in this study. The increase in irrigation frequency in 2008 was a result of the establishment of a NTEP trial on a site that directly bordered this study. This was the only controllable difference in the treatment years and was not quantitatively considered in the statistical analysis. The interactions observed for 2008 was almost an exponential increase in PTC as overseeding rates increased. Overseeding treatments made large favorable differences in the more open cultivars. However, even with large favorable increases, Riviera and Tifway consistently maintained higher PTC than the more open cultivars in this study, regardless of overseeding or the lack thereof.

Results obtained from this study would indicate that cultivar, as with previous work in native soil, is a factor of great importance in relation to wear tolerance of the turf. Riviera grown in various soil types has been shown to be the most wear tolerant of the cultivars tested while Yukon generally has the lowest wear tolerance.

Trinexapac-ethyl treatments were shown to be non-significant when evaluating tolerance to simulated traffic of bermudagrass grown on a sand-based root zone. This conclusion is in direct contrast to previous work that was completed in native soil. Little previous work has been completed with bermudagrass and sand-based root zones that would help to explain this contrast across soil types. The positive effects, as indicated by this study, are limited to the visual aspects and have no effect on wear tolerance. For sand-based athletic field managers, the application of TE for any purpose other than aesthetics has been shown by this study to be unnecessary.

Overseeding treatments were shown to have significant value for the more open, less dense cultivars. However, this work indicates that overseeding may only serve aesthetic purposes as was reported by Powell (2006). The more dense cultivars remained statistically more wear tolerant than the more open cultivars regardless of overseeding. Although overseeding treatments were significant for Quickstand and Yukon, the observations were based on PTC and with continuing traffic treatments these plots continued to show the effects of increased damage and wear across the overseeding treatments.

In summary, Riviera is indicated by this study to be an excellent choice for athletic field use in relation to wear tolerance for sand-based root zones. This was true whether TE was applied or not, and also regardless of overseeding. Tifway was statistically equivalent to Riviera in tolerance to simulated traffic, and both cultivars consistently outperform Quickstand and Yukon. Trinexapac-ethyl treatments had no significant value except improving initial turf quality. For athletic fields with more open, less dense cultivars, overseeding treatments will increase cover and TQ but not to the same magnitude of the denser, fine leaf cultivars tested in this study. Future research should continue to evaluate cultivars for high wear tolerance and best management practices for bermudagrass grown in sand-based systems.

SHEAR STRENGTH

Shear strength is the interaction between an athlete and the playing surface (McNitt, 2000) where this interaction is the natural ability of the turf to withstand the stress and shearing of directional forces (Gaussoin et al., 2002). Little previous research has been conducted in this area and especially in systems with sand-based root zones. Shear strength is influenced by many factors such as anatomical and morphological characteristics of the plant. Previous work has shown that rhizomes, stolons and general root growth above or just below the surface will influence shear strength and will greatly influence the amount of traction the turf can provide (Roche et al., 2008). The observations from this study conclude that the main effects of cultivars were statistically significant ($p \leq 0.05$) when evaluating shear strength. Riviera consistently provided higher shear strength measurements for both years of the study. Observations recorded for 2007 showed no significant differences ($p \leq 0.05$) in shear strength between Quickstand and Riviera, which were both significantly higher than Tifway and Yukon ($p \leq 0.05$). Observations for 2008 indicated significant differences between Riviera and the remaining three cultivars consistently throughout all of the observation dates. These data indicate superior shear strength for Riviera above the remaining cultivars tested.

The main effect of trinexapac-ethyl was not significant in relation to shear strength for either year of the study. As with the traffic study, TE treatments as a main effect did provide for significant differences in TQ, and TQ was statistically greater ($p \leq 0.05$) for TE treated plots across all cultivars compared to untreated plots.

The main effect of overseeding on shear strength for 2007 was shown not to be statistically significant, while for 2008 significant differences were observed over the last three observation dates. This contrast in terms of shear strength numbers may be associated with extra irrigation the test sites received in 2008. This extra irrigation was the only difference in treatment of the test site and was a result of establishment of a NTEP trial on a site that directly bordered the shear study. The seeding dates and subsequent germination correlates very well with the almost exponential decrease in shear strength values measured. In this study, the increased irrigation could have aided the germination and establishment of the overseeded ryegrass, and thus contributed to decreased shear strength with increasing seeding rates.

In summary, these studies indicate that cultivar is probably the most important consideration when choosing to propagate bermudagrass turf for athletic fields grown on sand-based systems. This study concluded that Riviera provided the most strength, stability and tolerance to simulated wear of the cultivars tested on a sand-based root zone.

Turf quality was significantly improved by TE applications. It is still unclear as to the exact effects of these applications on other parameters related to simulated wear and shear strength. Overseeding applications were shown by this study to greatly decrease shear strength in situations under increased irrigation periods during the germination and establishment of the ryegrass as opposed to normal irrigation patterns. Future research should continue to evaluate cultivars of bermudagrass grown on sand-based root zones for simulated wear tolerance and shear strength under different management practices. Specifically, work with other measured parameters, such as irrigation and nitrogen management, may help elucidate the best management practices to work towards improving athletic field turf performance on sand-based root zones.

APPENDIX A

Table A1. Table of means for cultivar x trinexapac-ethyl interactions for traffic study visual quality in 2007. Trinexapac-ethyl treatments are noted by (n) for non-treated and (y) for treated. Scale 1 – 9; 9=excellent turf quality.

		Observation Dates				
Cultivar	Trinexapac-ethyl	8/01	8/10	8/17	8/22	8/31
Quickstand	n	7.5	7.2	7.8	8.0	7.3
	y	7.5	7.8	8.5	8.0	7.3
Riviera	n	7.6	7.0	7.7	8.3	8.3
	y	7.5	8.0	8.2	8.6	8.7
Tifway 419	n	6.7	7.1	7.3	7.5	7.5
	y	6.7	7.4	7.8	8.0	8.2
Yukon	n	6.8	7.0	7.2	7.6	7.7
	y	6.8	7.8	7.8	8.3	8.1

Table A2. Table of means for cultivar x trinexapac-ethyl interactions for traffic study visual quality in 2007. Trinexapac-ethyl treatments are noted by (n) for non-treated and (y) for treated. Scale 1 – 9; 9=excellent turf quality.

		Observation Dates				
Cultivar	Trinexapac-ethyl	7/18	8/13	8/20	8/27	9/03
Quickstand	n	6.3	7.7	8.1	8.0	7.1
	y	6.4	8.3	8.3	8.7	7.7
Riviera	n	7.4	8.3	8.7	8.4	8.1
	y	7.4	8.3	8.8	8.5	9.0
Tifway 419	n	4.0	7.2	8.1	7.3	7.4
	y	5.7	7.0	7.8	7.4	7.6
Yukon	n	6.1	7.6	7.7	7.8	7.4
	y	5.2	7.6	7.7	7.8	8.2

Table A3. Table of means for cultivar x trinexapac-ethyl interactions for shear study visual quality in 2007. Trinexapac-ethyl treatments are noted by (n) for non-treated and (y) for treated. Scale 1 – 9; 9=excellent turf quality.

		Observation Dates				
Cultivar	Trinexapac-ethyl	8/01	8/10	8/17	8/22	8/31
Quickstand	n	7.7	7.0	7.1	7.6	8.2
	y	7.6	8.0	8.2	8.3	8.5
Riviera	n	7.5	7.4	7.1	7.7	7.8
	y	7.5	8.0	8.1	8.6	8.7
Tifway 419	n	7.0	7.0	7.0	7.4	7.2
	y	6.3	7.3	7.3	7.4	8.0
Yukon	n	7.5	7.0	6.7	7.0	7.4
	y	6.3	7.5	7.1	7.3	8.0

Table A4. Table of means for cultivar x trinexapac-ethyl interactions for shear study visual quality in 2007. Trinexapac-ethyl treatments are noted by (n) for non-treated and (y) for treated. Scale 1 – 9; 9=excellent turf quality.

				Observation Dates		
Cultivar	Trinexapac-ethyl	7/18	8/13	8/20	8/27	9/03
Quickstand	n	7.5	6.8	7.4	7.3	7.2
	y	7.8	7.8	7.8	8.1	8.5
Riviera	n	7.7	7.5	8.0	7.5	7.6
	y	8.3	8.3	8.3	8.6	8.8
Tifway 419	n	7.2	7.6	8.0	7.8	7.8
	y	7.4	7.8	7.8	8.0	8.2
Yukon	n	8.0	6.6	7.2	6.6	6.1
	y	8.1	7.2	7.6	7.2	7.7

APPENDIX B.

Table B1. Table of means for cultivar x trinexapac-ethyl x overseeding rates for simulated traffic tolerance in 2007. Trinexapac-ethyl (te) treatments designated by (n) for non-treated and (y) for treated. Overseeding (os) treatments designated as (1) 0 kg/ha, (2) 612 kg/ha, and (3) 1225 kg/ha. Scale 1 – 10; 1=bare soil 10= 100% turf cover.

							Observation Dates		
Cultivar	os	te	9/10	9/24	10/1	10/9	10/15	10/22	10/29
Quickstand	1	n	2.0	2.4	3.0	3.4	2.0	2.4	2.4
	1	y	3.7	2.7	4.4	3.7	2.4	3.0	1.7
	2	n	1.7	1.7	3.0	5.4	3.7	3.4	3.4
	2	y	4.0	3.4	4.4	5.4	5.0	4.0	4.7
	3	n	2.7	2.0	4.7	4.7	3.4	3.7	4.7
	3	y	3.0	3.0	4.7	5.7	4.0	3.7	4.7
Riviera	1	n	6.7	3.4	4.7	4.4	5.7	5.7	5.7
	1	y	7.4	4.4	5.0	4.7	6.7	4.7	4.7
	2	n	8.0	4.4	5.0	5.7	6.0	5.0	5.7
	2	y	7.7	4.4	4.7	5.4	6.0	5.7	5.4
	3	n	7.4	4.0	5.4	4.7	5.7	5.7	6.0
	3	y	7.0	4.0	5.0	5.4	5.0	5.7	5.7

Table B1(continued). Table of means for cultivar x trinexapac-ethyl x overseeding rates for simulated traffic tolerance in 2007. Trinexapac-ethyl (te) treatments designated by (n) for non-treated and (y) for treated. Overseeding (os) treatments designated as (1) 0 kg/ha, (2) 612 kg/ha, and (3) 1225 kg/ha. Scale 1 – 10; 1=bare soil 10= 100% turf cover.

					Observation Dates				
Cultivar	os	te	9/10	9/24	10/1	10/9	10/15	10/22	10/29
Tifway 419	1	n	5.7	4.0	4.7	5.4	6.4	6.0	5.7
	1	y	5.7	4.0	4.4	3.0	4.7	5.0	5.4
	2	n	6.7	3.4	5.0	5.0	5.0	4.7	6.0
	2	y	6.0	2.4	3.7	4.7	4.4	5.0	4.7
	3	n	6.0	5.4	4.7	6.4	4.7	5.7	6.0
	3	y	4.7	5.7	5.0	5.0	5.4	5.7	6.7
Yukon	1	n	5.7	2.0	2.0	2.7	1.0	1.0	1.4
	1	y	7.4	2.4	2.7	2.7	2.0	1.7	1.0
	2	n	6.4	3.0	3.4	5.7	2.0	2.4	2.7
	2	y	7 .0	5.4	3.4	5.4	4.0	2.4	3.7
	3	n	6.7	5.4	5.0	5.4	4.6	4.0	4.0
	3	y	5.7	2.7	4.4	4.7	4.0	3.0	4.4

Table B1. Table of means for cultivar x trinexapac-ethyl x overseeding rates for simulated traffic tolerance in 2008. Trinexapac-ethyl te) treatments designated by (n) for non-treated and (y) for treated. Overseeding (os) treatments designated as (1) 0 kg/ha, (2) 612 kg/ha, and (3) 1225 kg/ha. Scale 1 – 10; 1=bare soil 10= 100% turf cover.

			Observation Dates								
Cultivar	os	te	9/12	9/19	9/26	10/3	10/10	10/17	10/27	11/10	11/14
Quickstand	1	n	9.7	8.9	8.8	7.1	5.6	3.0	1.8	2.0	1.0
	1	y	9.7	9.1	9.3	8.0	4.3	2.1	1.3	2.0	1.0
	2	n	9.6	8.6	8.8	7.1	6.0	6.1	7.0	5.0	4.0
	2	y	9.7	8.9	9.4	8.5	7.3	6.6	7.0	5.0	5.3
	3	n	9.6	8.6	8.6	7.1	7.1	6.8	7.1	6.0	5.0
	3	y	9.7	8.9	9.3	7.8	7.5	7.0	7.8	6.0	5.3
Riviera	1	n	9.8	9.6	9.6	9.0	8.3	6.5	7.0	7.0	6.0
	1	y	9.8	9.6	9.8	9.2	8.1	6.8	6.5	7.0	6.0
	2	n	9.8	9.6	9.7	9.3	8.8	9.0	8.0	8.5	7.3
	2	y	9.8	9.7	9.7	9.1	9.3	8.6	7.0	7.3	7.0
	3	n	9.8	9.6	9.7	9.0	8.9	9.5	8.6	8.8	7.6
	3	y	9.8	9.7	9.9	9.1	9.3	9.3	8.5	8.6	7.8

Table B1 (continued). Table of means for cultivar x trinexapac-ethyl x overseeding rates for simulated traffic tolerance in 2008. Trinexapac-ethyl te) treatments designated by (n) for non-treated and (y) for treated. Overseeding (os) treatments designated as (1) 0 kg/ha, (2) 612 kg/ha, and (3) 1225 kg/ha. Scale 1 – 10; 1=bare soil 10= 100% turf cover.

						Observation Dates					
Cultivar	os	te	9/12	9/19	9/26	10/3	10/10	10/17	10/27	11/10	11/14
Tifway 419	1	n	9.8	9.6	9.7	9.1	8.5	7.8	8.3	8.6	8.5
	1	y	9.8	9.6	9.8	9.3	8.8	8.5	7.6	7.8	8.0
	2	n	9.7	9.2	9.2	8.3	8.0	8.1	7.5	7.3	6.8
	2	y	9.0	8.6	8.0	6.8	7.1	6.8	6.6	6.5	6.1
	3	n	9.7	9.3	9.2	8.3	8.1	8.6	8.3	8.3	8.0
	3	y	9.8	9.6	9.7	9.2	9.0	9.1	8.8	9.0	9.1
Yukon	1	n	9.6	8.7	8.6	7.0	3.8	2.6	1.8	2.3	1.3
	1	y	9.7	9.1	9.2	8.6	5.1	3.3	2.6	2.3	1.3
	2	n	9.7	8.8	8.5	7.5	6.8	6.3	6.1	4.6	3.6
	2	y	9.7	9.1	9.3	8.0	7.3	7.5	7.3	5.6	4.0
	3	n	9.7	9.1	9.2	7.8	7.3	7.8	8.0	7.0	5.8
	3	y	9.7	9.2	9.5	8.5	7.1	8.0	7.6	6.6	5.3

APPENDIX C.

Table C1. Table of means for cultivar x trinexapac-ethyl x overseeding rate for shear strength in 2007. Trinexapac-ethyl (te) treatments designated by (n) for non-treated and (y) for treated. Overseeding (os) treatments designated as (1) 0 kg/ha, (2) 612 kg/ha, and (3) 1225 kg/ha. Measurements are in kg-Force.

			Observation Dates									
Cultivar	Trinexapac-ethyl	Overseeding Rate	9/10	9/17	9 /24	10/1	10/9	10/15	10/22	10/29	11/12	11/19
Quickstand	n	1	81.6	70.0	71.4	77.8	87.3	63.2	68.8	76.5	68.8	76.5
	n	2	72.3	77.0	73.2	72.2	105.0	63.9	70.7	78.4	70.7	78.4
	n	3	97.3	68.0	73.7	78.3	85.6	69.8	83.7	77.1	83.7	77.1
	y	1	87.3	75.0	91.7	81.5	96.0	62.9	74.3	85.7	74.3	85.7
	y	2	90.0	74.6	62.5	86.6	90.3	69.6	79.9	78.6	79.9	78.6
	y	3	78.6	78.3	66.7	70.7	78.6	74.9	80.6	81.7	80.6	81.7
Riviera	n	1	65.0	76.6	66.2	64.4	84.3	68.1	65.4	71.2	65.4	71.2
	n	2	76.3	82.6	69.8	76.3	87.3	68.4	73.2	84.4	73.2	84.4
	n	3	80.0	83.3	74.2	66.5	97.0	83.7	83.3	78.8	83.3	78.8
	y	1	86.3	82.3	84.3	67.8	94.6	83.8	77.2	76.3	77.2	76.3
	y	2	81.3	83.3	79.6	77.1	93.3	80.2	75.5	75.4	75.5	75.4
	y	3	83.0	84.3	78.5	81.7	93.3	73.9	76.3	75.0	76.3	75.0

Table C1(continued). Table of means for cultivar x trinexapac-ethyl x overseeding rate for shear strength in 2007. Trinexapac-ethyl (te) treatments designated by (n) for non-treated and (y) for treated. Overseeding (os) treatments designated as (1) 0 kg/ha, (2) 612 kg/ha, and (3) 1225 kg/ha. Measurements are in kg-Force.

			Observation Dates									
Cultivar	Trinexapac-ethyl	Overseeding Rate	9/10	9/17	9/24	10/1	10/9	10/15	10/22	10/29	11/12	11/19
Tifway 419	n	1	67.0	62.0	62.5	54.5	65.6	65.7	57.1	58.1	57.1	58.1
	n	2	74.6	69.3	66.9	62.9	75.3	60.9	58.3	53.8	58.6	53.8
	n	3	64.3	61.0	64.1	57.6	79.0	61.7	63.0	59.4	63.0	59.4
	y	1	65.6	74.3	56.9	56.3	86.3	64.8	74.4	73.4	74.4	73.4
	y	2	65.3	62.6	69.0	58.7	77.3	67.4	70.3	66.1	70.5	66.1
	y	3	74.6	60.6	67.6	66.5	84.3	74.3	85.5	72.4	85.5	72.4
Yukon	n	1	70.0	61.6	55.1	60.7	72.0	52.2	69.1	58.3	69.1	58.3
	n	2	68.0	64.3	59.4	53.1	69.3	61.5	64.3	66.9	64.3	66.9
	n	3	66.6	65.3	63.7	69.2	76.3	64.7	74.9	64.6	74.9	64.6
	y	1	73.0	74.0	66.4	53.9	80.6	68.1	71.9	69.4	71.9	69.4
	y	2	72.3	67.0	69.5	59.4	78.6	61.4	73.1	62.0	73.1	62.0
	y	3	74.0	63.0	65.4	53.4	74.6	63.9	68.8	74.2	68.8	74.2

Table C2. Table of means for cultivar x trinexapac-ethyl x overseeding rate for shear strength in 2008. Trinexapac-ethyl (te) treatments designated by (n) for non-treated and (y) for treated. Overseeding (os) treatments designated as (1) 0 kg/ha, (2) 612 kg/ha, and (3) 1225 kg/ha. Measurements are in kg-Force.

			Observation Dates									
Cultivar	Trinexapac-ethyl	Overseeding Rate	8/13	9/08	9/15	9/22	9/29	10/06	10/20	10/27	11/03	11/10
Quickstand	n	1	60.0	63.1	64.7	56.2	56.2	64.2	58.6	58.4	61.3	58.1
	n	2	56.3	57.8	60.3	51.9	72.5	64.9	56.5	62.5	64.7	61.1
	n	3	60.1	56.4	56.4	43.4	60.3	67.4	52.3	51.5	59.6	55.2
	y	1	62.4	60.6	45.7	49.4	59.2	63.9	45.3	51.2	66.4	54.1
	y	2	53.3	49.2	52.7	33.5	56.6	55.4	43.9	52.0	46.1	40.2
	y	3	48.0	50.3	54.1	36.6	54.9	51.2	45.9	48.0	48.0	39.3
Riviera	n	1	63.3	62.5	59.3	50.1	55.8	67.2	56.2	66.0	70.8	61.5
	n	2	58.2	55.6	54.7	56.8	77.6	78.2	68.1	74.4	76.5	65.1
	n	3	70.6	71.7	73.8	50.4	63.5	86.1	63.2	65.2	72.3	52.5
	y	1	64.6	68.3	67.9	42.7	68.2	59.7	59.2	67.3	76.4	78.5
	y	2	51.7	56.5	63.0	47.3	69.2	55.7	49.7	58.1	66.5	63.8
	y	3	57.7	52.3	59.2	37.9	50.5	51.8	43.3	55.6	49.0	45.2

Table C2(continued). Table of means for cultivar x trinexapac-ethyl x overseeding rate for shear strength in 2008. Trinexapac-ethyl (te) treatments designated by (n) for non-treated and (y) for treated. Overseeding (os) treatments designated as (1) 0 kg/ha, (2) 612 kg/ha, and (3) 1225 kg/ha. Measurements are in kg-Force.

			Observation Dates									
Cultivar	Trinexapac-ethyl	Overseeding Rate	8/13	9/08	9/15	9/22	9/29	10/06	10/20	10/27	11/03	11/10
Tifway 419	n	1	53.6	53.0	49.6	40.5	53.3	63.6	44.3	57.6	52.1	56.0
	n	2	49.1	58.7	54.7	43.7	48.3	61.5	48.4	53.7	55.8	54.5
	n	3	52.6	48.3	51.3	42.7	55.1	59.1	43.9	57.0	48.1	54.0
	y	1	64.5	54.4	54.9	46.6	64.9	62.5	51.8	64.2	64.8	56.3
	y	2	41.1	42.3	48.2	34.2	51.2	59.0	48.4	52.2	49.8	57.8
	y	3	50.4	52.8	51.3	42.8	55.6	58.4	46.1	58.2	53.5	61.4
Yukon	n	1	52.7	52.1	47.3	40.1	50.6	58.4	50.1	58.6	64.7	56.3
	n	2	56.0	50.6	53.9	42.6	55.6	59.9	50.2	62.1	60.5	52.0
	n	3	52.8	51.8	57.2	46.4	50.5	60.3	46.8	50.7	48.5	53.8
	y	1	61.1	67.1	59.4	50.8	61.3	67.7	56.2	66.2	73.8	57.0
	y	2	47.8	54.4	53.1	51.6	53.8	62.9	52.7	53.5	54.0	63.1
	y	3	51.1	50.5	49.6	46.4	58.1	59.6	42.2	49.6	52.0	51.7

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VITA

The author, Michael Todd Deaton was born on March 26, 1968 in Lexington, Kentucky to the parents of Ernie and Beulah Deaton. He was raised in Laurel County in southeastern Kentucky where he graduated from Laurel County High School in 1986. He attended the University of Kentucky and received a BS in agronomy with an emphasis in turf in 1992 and returned home to operate a family owned lawn care company. In May of 2007 he returned to the University of Kentucky to pursue a graduate degree in crop science and has future plans to enter the doctorate program in turf science.