5-2008

The Influence of Perennial Ryegrass Overseeding and Grooming on Bermudagrass Varietal Performance under Continual Traffic

Adam W. Thoms

To the Graduate Council:

I am submitting herewith a thesis written by Adam W. Thoms entitled "The Influence of Perennial Ryegrass Overseeding and Grooming on Bermudagrass Varietal Performance under Continual Traffic." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Plant Sciences.

John C. Sorochan, Major Professor

We have read this thesis and recommend its acceptance:

Thomas J. Samples, Dean A. Kopsell

Accepted for the Council:
Dixie L. Thompson

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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The Influence of Perennial Ryegrass Overseeding and Grooming on Bermudagrass Varietal Performance under Continual Traffic.

A Thesis

Presented for the Master of Science

Degree.

The University of Tennessee,

Knoxville.

Adam William Thoms

May 2008

DEDICATION

I dedicate this thesis to my parents, Bill and Kathy, and my family and friends. They have provided me with support through the years and taught me the importance of learning along with a strong work ethic. Equally important, these people have made life fun.

"There are never enough hours in the day if you enjoy doing what you do."

Roger Traetow (2004)

"Life's a dance."

John Michael Montgomery (1992)

ACKNOWLEDGMENTS

For their support and guidance at the University of Tennessee, I wish to express my sincere appreciation to my graduate committee members: Dr. J. Scott McElroy, Dr. Thomas J. Samples, and Dr. Dean A. Kopsell. Also, I give a special thanks to my advisor, Dr. John C. Sorochan, for his daily guidance, and support, his friendship and allowing me, the opportunity to attend the University of Tennessee.

I also give special thanks to Johnny Parham, Tyler Mittlesteatd, Will Jellicorse, Sam Oliver, and Josh Weigel as well as all the graduate students for their assistance and friendship. They helped make this research project possible, and their friendship has made my time in Tennessee pleasant.

I would also like to thank Lee Ellis, Bobby McKee, and the staff at the East Tennessee Research and Education Center. Their dedication to helping students in research is much appreciated.

ABSTRACT

Athletic field managers often make decisions regarding what turfgrass species and varieties to use from past experiences, or from non-sports turf related research such as the National Turfgrass Evaluation Program results. The wear tolerance of turfgrass varieties varies among species and varieties, which can greatly affect the performance of an athletic field. Mowing can also influence athletic field turf. Therefore advancements in mowing technology were tested to determine the impact of mowing, and mowing plus grooming on wear tolerance.

A two-year study was conducted at the University of Tennessee East Tennessee Research and Education Center in Alcoa to test four popular bermudagrass varieties (*Cynodon dactylon* [L.] Pers. x *Cynodon transvaalensis* Burt-Davy) commonly used as athletic field turfs in the transition zone. The performance of 'Tifway', 'Patriot', 'Mississippi Choice', and 'Riviera' bermudagrass were compared after being subjected to either mowing or mowing plus grooming three times a week, as well as fall overseeding with perennial ryegrass (*Lolium perenne* L.) .Simulated athletic traffic was applied twice a week to mimic high school football schedules using a Cady traffic simulator. Digital image analysis for each traffic event was used to measure changes in percent green cover, color, and turfgrass quality. Surface hardness values were determined using a Clegg Impact Hammer and total turf cover was measured visually once bermudagrass dormancy occurred.

Variety performance differed for each year of the study due to weather conditions. Overseeded and non-overseeded 'Tifway' and 'Riviera' bermudagrass consistently provided the highest percent green cover, color and quality ratings. However, overseeding bermudagrass improved wear tolerance of all varieties tested. Mowing plus grooming three times a week reduced percent turf cover in 2006 but not 2007, and had no effect on color or quality. Mowing plus grooming increased perennial ryegrass stand density following overseeding by providing better seed to soil contact. ‘Tifway’ and ‘Riviera’ bermudagrass provided the best color.

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Introduction

Thousands of athletic events take place around the world every day. Many of these events are held on turfgrass. Athletes also appreciate the quality of a high-quality field. Quality is measure by field safety and playability (traction and hardness) (Guise, 1996). Media also capture how well an athletic field handles stress from foot traffic through television replays and sporting event photographs that show parts of the turfgrass flying through the air or bare spots (Puhalla *et al*., 1999). Athletic field managers are constantly challenged to provide a playing surface that is aesthetically pleasing to spectators. A safe field is uniform, stable, not too hard, and able to withstand excessive wear (Guise, 1996). In Pennsylvania, Harper *et al*. (1984) determined that 21% of injuries could be classified as definitely, or possibly related to the playing surface.

The goal of this research was to find ways to improve athletic field quality thus creating a safe, aesthetically appealing playing surface which may limit incidences of player injury.

Transition Zone

Much of the research conducted in the past has focused on matching the correct species of turfgrass to the correct climate, for example establishing cool-season turfgrasses in the northernmost parts of the transition zone (Keen, 1969). In general, this area breaks up the temperate and subtropical climatic zones in the eastern U. S. and is centered at 37° N latitude and is 200 miles wide (Turgeon, 1980). Tennessee is located in the middle of the transition zone, a geographical area where high temperatures in the summer stress cool-season turfgrasses, which become less tolerant of disease. Also transition zone winter conditions are severe enough to injure most warm-season turfgrasses (Keen, 1969).

Bermudagrass (*Cynodon* spp. Rich.) is best suited for athletic fields in the transition zone due to its heat tolerance and its ability to spread by both rhizomes and stolons. This sod-forming growth habit allows bermudagrass to recover from injury quickly (Christians, 2004). Compared with other turfgrass species, bermudagrass has great wear tolerance (Turgeon, 1980). Hybrid bermudagrass (C. dactylon L. × C. transvaalensis Burtt-Davy) is often used on sports fields that are not overseeded because of its vigor and color (Gibeault *et al*., 1992).

Bermudagrass Research

Historically, much of the research conducted on bermudagrass has focused on its use as a golf course turf. Specifically, research has concentrated on improving quality of bermudagrass putting greens, because of the value they contribute to a golf course. Putting green research has focused on bermudagrass varieties (Hollingsworth, 2005), controlling thatch (Meinhold, 1973), and relieving compaction (Canaway, 1980). Recovery of bermudagrass and *Zoysia* (*Zoysia spp.* Willd.) from divots has also been studied (Karcher *et al*., 2005). Although knowledge gained from bermudagrass research for golf course use can be applied to athletic fields; however, turfgrass wear from sporting events warrants specific investigation.

Most traffic on athletic fields takes place in concentrated areas. Surveys of college and professional football games revealed that 78% of the traffic occurs on just 7% of the field (playing surface) (Cockerham 1989). An extreme amount of traffic in one area often results in plant loss and exposed soil.

Some turfgrasses, have great wear tolerance, while others recover faster from injury (Canaway, 1975). Variability in wear tolerance among species is due, in part to anatomical and morphological characteristics such as total cell wall content of schlerenchyma fibers, shoot density, leaf tensile strength, and leaf width (Shearman and Beard, 1975). For best performance and to facilitate plant growth and recovery from injury, a key is choosing an appropriate species and variety for the climatic conditions the turfgrasses will encounter. Maintaining the wrong species of grass, such as annual bluegrass (*Poa annua* L.) which has poor wear tolerance and shallow roots, can result in more anterior cruciate ligament injuries from non-uniform surfaces (Chivers et al., 2005).

Warm-season turfgrasses are typically more wear-tolerant than cool-season turfgrasses (Beard, 1973). Wear-tolerant bermudagrass varieties have higher stem moisture, less stem cellulose, and higher concentrations of potassium (K), manganese (Mn), and magnesium (Mg) (Trenholm *et al.*, 2000). However, exogenous application of these elements does not seem to increase wear tolerance. Specifically, 'Tifway' bermudagrass did not increase shoot and root growth when high levels of K were applied (Sartain, 2002). Bermudagrass varieties recover differently from simulated golf divot injuries. 'Tifsport' bermudagrass recovered the slowest of 48 varieties tested (Karcher *et al.*, 2005).

As turf cover decreases, the soil often becomes compacted and leads to potential injuries from the hard surface (Rogers and Waddington, 1988). Bermudagrass absorbed more energy than tall fescue (*Festuca arundinacea* Schreb.) or Kentucky bluegrass (*Poa pratensis* L.) (Rogers and Waddington, 1988). Newer varieties of bermudagrass 'Tifton 10' and 'Quickstand', had higher G_{max} (gravitational deceleration values) and less root mass than other bermudagrass varieties tested (Rutledge *et al*., 2005). Brosnan *et al.* (2005) evaluated genotypes of Kentucky bluegrass and concluded that leaf angle and shoot density contribute to wear tolerance.

Sports Turf Research

In many cases, athletic field managers have little research that is specific to sports turf management. When selecting a specific variety, decisions are often based on National Turfgrass Evaluation Program (NTEP) results which, in most cases, do not include traffic tolerance.

Sports turf research often helps athletic field managers develop a best management plan (BMP). A BMP involves fertilization, irrigation, mowing, pest control, and soil management. Sports turf managers are committed to implementing a BMP (Klein, 2002). Using local resources, such as extension services, helps athletic field managers implement improvements based on research, including selection of proper species, conducting soil tests, and identifying pests (Christians, 2004).

Many factors influence sports turf quality, particularly budget, intensity of field use, climate, fertilization, cultivation, irrigation, and species/variety selection. Each factor influences the field's eventual success/playability. Lundberg (2002) determined how many simulated football and soccer games could be played until cool-season turf cover was unacceptable. Goddard (2006) compared the wear tolerance of three bermudagrass varieties and a hybrid Kentucky bluegrass variety topdressed with crumb rubber. Regardless of species or variety, crumb rubber topdressing increased turfgrass wear tolerance. In the fall, hybrid Kentucky bluegrass provided the same percent turf cover as both 'Riviera' and 'Tifway' bermudagrass. However, hybrid Kentucky bluegrass initially did not resist wear as well as ‘Riviera’ and ‘Tifway’ bermudagrasses until temperatures became more favorable in the fall.

Further research investigating the acceptability of bermudagrass varieties for athletic fields in the transition zone is warranted. In Arkansas in 2003, seeded varieties generally recovered to 50 percent cover one day earlier than vegetatively propagated varieties after divots were removed. Plants generally recovered faster following divot removal during the second year of growth compared with the first year (Karcher *et. al.*, 2005).

Grooming

One way to improve the wear tolerance of athletic turf is to increase stand density**.** Bermudagrass spreads above ground by stolons and below ground by rhizomes. Shoots and roots emerge from nodes on both stolons and rhizomes. Divots occur and soil is exposed as sports turf is trafficked. Areas of bare ground are often visible after several events.

Slicing stolons prior to trafficking may reduce divoting. Vertical mowing is one way to slice bermudagrass stolons. Carrow *et al*. (1987) found that vertical mowing twice per year decreased thatch by eight percent, and increased aerial shoot density. Conversely, research conducted at the University of Florida, determined that vertical mowing a ‘TifEagle’ bermudagrass putting green had no effect on thatch accumulation and decreased turf quality (Unruh *et al*., 2005).

Vertical mowing ‘DeAnza’ and ‘Victoria’ *Zoysia* several times a year increased firmness and lessened thatch accumulation (Cockerham, 1997). Similarly, vertical mowing and core aerifying on ‘Meyer’ *Zoysia* provided excellent thatch control but stressed the turf (Weston and Dunn, 1985).

Grooming bermudagrass putting greens at the proper height (to avoid scalping) should be done two to three times a week when growth is vigorous (Isaac, 1993). Recently, Jacobsen (Textron Co., Charlotte, NC) introduced a groomer with a reel that directs stolons to vertical grooming blades causing less damage to the turf than traditional groomers that can puncture turf and penetrate the soil surface. When a lift kit is attached to the reel mower, turf can be mowed and groomed at typical sports field heights. However, the effects of frequent vertical mowing for bermudagrass wear tolerance is unknown.

Overseeding Rates

In the transition zone, athletic fields are often used year round. However, bermudagrass stops growing and loses color after the first hard frost and stays dormant until soil temperatures reach 15 °C (Bruneau, 2004). In many cases, athletic field managers overseed bermudagrass with perennial ryegrass (*Lolium perenne* L.) at much higher seeding rates than golf course fairways. This is due to the short amount of time before a major traffic event. Mazur (1999) found that increasing the seeding rate of perennial ryegrass from 90 to 180 g/m^{-2} helped with quicker establishment. At the higher seeding rate, the perennial ryegrass was more prevalent in May than at the lower rate (Mazur, 1999).

Simulated Athletic Traffic

Simulated athletic traffic has three components: wear due to friction or scuffing, compaction from weight of the player and distribution of that weight, and shear injury to the grass plant as a cleat twists (Cockerham, 1994). Until recently, in studies focusing on turfgrass wear tolerance the Brinkman traffic simulator has been the standard used to administer traffic treatments. However, the Cady Traffic Simulator (CTS) best mimics football game traffic by tearing tissue and compacting soil with repeated impacts (Henderson. *et al*., 2005). The CTS is a modified Jacobsen™ Vaerator VA-24 (Textron Co., Charlotte, NC) with artificial feet creating a traffic pass 2.19 m wide and 667 cleat marks m^{-2} (Goddard *et al.*, 2008).

The CTS produces a much larger force per area than the Brinkman traffic simulator due to the small contact area (Vanini *et al.*, 2007). Ten passes of the Brinkman traffic simulator were required to create the same traffic stress as the CTS accomplished in two passes (Vanini *et al*., 2007). The CTS produced a higher compressive stress and net shear strength. When the CTS was run forward, the stress was 30 times higher than the combined stresses of the drums of the Brinkman traffic simulator, and net shear stress was 15 times higher (Henderson *et al*., 2005).

Quantitative Athletic Turf Measurements

Several traffic experiments have visually measured simulated athletic traffic (Steir and Rogers, 2001; Bayrer, 2006; Park *et al*., 2007), however visual estimates may result in observational bias. Digital image analysis (DIA) provides a quantitative measurement of turfgrass qualities while removing observational bias (Karcher *et al.*, 2007; Karcher and Richardson, 2003; Richardson *et al.*, 2001). Goddard (2006) used DIA to rate percent green cover after individual simulated athletic traffic events. DIA evaluates turfgrass color, cover, and quality by scanning pixels. Turfgrass cover is rated by scanning for pixels selected in a set range and dividing by total pixels present, ranging from 0 to 100 percent. Turfgrass color is perceived by humans as a correlation of hue, brightness, and saturation (Lewis *et al*., 2007). Karcher and Richardson (2003) found that hue and saturation provide the best color indicators in turf. As an added benefit, DIA can allow untrained people to collect data regarding turfgrass color, quality, and percent cover.

Objectives

The objectives of this research project were to determine the:

1. Differences in wear tolerance among ‘Tifway’, ‘Riviera’, ‘Patriot’, and ‘Mississippi Choice’ bermudagrasses.
2. Effects of frequent grooming (3 times a week) with a Jacobsen (Textron) mower for heavily trafficked bermudagrass varieties.
3. Influence of perennial ryegrass overseeding effectiveness on ‘Tifway’, ‘Riviera’, ‘Patriot’, and ‘Mississippi Choice’ bermudagrass when trafficked.

Materials and Methods

A two-year experiment was conducted from June 2006 to May 2008 at the East Tennessee Research and Education Center in Alcoa, TN. Plots were established from sod on 16 June 2006. The root zone consisted of Sequatchie silt loam soil (fine-loamy, siliceous, semiactive, thermic Humic Hapludult).

The experimental design was a randomized complete block in a four-way factorial arrangement replicated three times. All experimental factors were randomized with ARM 7 software (Gylling Data Management Inc., 2003). Each experimental factor was present in every replication, resulting in 16 plots per replication. Four plots of each variety (‘Tifway’, ‘Patriot’, ‘Mississippi Choice’, and ‘Riviera’) were established from sod in each replication. Two plots of each variety were mown plus groomed three times a week, and two plots of each variety were mown three times a week. One mown plus groomed plot and one mown plot for each variety were overseeded with perennial ryegrass in each replication. Repeated measures was done prior to each traffic event, and two days after the last traffic event for percent green cover, color, and turfgrass quality ratings. A total of 48 plots were established. Each plot was 1.1 m^2 in area.

In 2007 after spring green-up ratings, plots were sprayed with the systemic, broad-spectrum herbicide, (Round-up® Monsanto Co., St. Louis, MO) and were removed using a Ryan Junior® sod cutter (Ryan Co., Johnson Creek, WI) on 7 June 2007. The study was re-established on 15 June 2007. Bermudagrass varieties were established on the same plots as the previous year to eliminate possible contamination.

Starter fertilizer 0-20-20 (Tennessee Cooperative, LeVergne, TN) was applied at 24 kg fertilizer/ha to the soil on 16 June 2006, and again on 15 June 2007. The sod was fertilized 16 June 2006 and 15 June 2007 with 24 kg N/ha of 34-0-0 (Ammonium Nitrate, Tennessee Cooperative, LeVergne, TN) and irrigated.

During establishment, the sod was mowed with a Honda (Honda Power Equip., Alpharetta, GA) push mower at 5.08 cm until rooting occurred. Rooting was tested by tugging on the sod in random plots. For two weeks the entire study was mowed with a Toro Groundmaster (Toro Co., Minneapolis, MN) rotary mower at 2.54 cm. Grooming treatments began 10 July 2006 and 2007 and were stopped 25 August 2006 and 28 August 2007. The plots were mowed as needed with a Toro Groundmaster (Toro Co., Minneapolis, MN) rotary mower at 2.54 cm.

A Jacobsen (Textron Co., Charlotte, NC) reel mower set at 2.2 cm was used to mow and groom appropriate plots three times each week. Vertical blades on the mowing plus grooming treatments were 2.5 mm below the 2.2 cm height of cut.

In the second week of August of both years, plots were hollow-tine aerified with a Jacobsen Greensaire 24-OPC (Textron Co., Charlotte, NC), and sand topdressing was applied.

Beginning 1 July 2006 and 2007, based on soil test reports, nitrogen fertilization consisted of 24 kg N/ha of 34-0-0 (Ammonium Nitrate, Tennessee Cooperative, LeVergne, TN) applied once a week for 10 weeks and irrigated immediately after application.

Plots were delineated by spraying a narrow band of Finale (Glufosinate Ammonium, Bayer CropScience, Raleigh, NC) at label rate between each plot. Plots were irrigated four times a week for 10 minutes at night to prevent drought stress.

Chipco Ronstar G (Oxadiazon, Bayer CropScience, Raleigh, NC) was applied to prevent germination of weeds, and Manage (Halosulfuron-methyl, Monsanto, St. Louis, MO) was applied in the summer to control nutsedge. Both herbicides were applied at label rate. Perennial ryegrass was removed 1 June 2007 with the herbicide Revolver® **(**Foramsulfuron, Bayer CropScience, Raleigh, NC). Revolver® also was sprayed at label rate on the non-overseeded plots in the fall to eliminate volunteer perennial ryegrass and annual bluegrass.

Plots were irrigated as needed to prevent wilt.

Bermudagrass was overseeded with 673 kg perennial ryegrass/ha on 20 September 2006 and 1 October 2007 (after the fifth simulated traffic event in 2006 and the seventh simulated traffic event in 2007, respectively). Traffic was withheld for one week after overseeding.

Traffic simulation treatments began 25 August and ended 27 November in 2006 and started 28 August ended 29 November in 2007. All plots were trafficked with a CTS twice each week in an effort to mimic traffic on high school football fields.

A location was randomly selected on each plot for digital imaging. In order to monitor changes in the stand, the same area was subjected to DIA before each traffic event.

Digital images were captured using a 0.28 m^2 light box equipped with four TCP 40w Spring Lamps® (Lighthouse Supply Co., Bristol, VA) and powered by a Xantrex 600 HD Power Pack® (Xantrex Technology, Vancouver, British Columbia). Digital images were taken with a Canon G5 (Canon Inc., Japan) camera with 5 million mega pixels and transferred to the computer as JPEG images. Digital image analysis was accomplished by scanning pixels using SigmaScan Pro© software (v. 5.0, SPSS Inc., Chicago, IL) for turfgrass color, quality, and percent green cover on every experimental plot (Karcher *et al.*, 2007; Karcher and Richardson, 2003; Richardson *et al.*, 2001).

Total picture size was 307,200 pixels. Pixels defined as green turf by the customized macro had a hue range of 45-120° and saturation between 0 and 100 percent. Color scale ranged from 1 to 9 with 1 being brown or yellow turf and 9 being deep dark green color. Turfgrass quality scale was 1 to 9 with 1 being dead or bare turf and 9 being excellent quality. Six was considered acceptable for both color and quality ratings.

Total turfgrass cover ratings were collected visually for dormant and actively growing turf on 10, 17, 20, and 28 November 2006 and 9, 16, 19, and 29 November 2007. Cover was rated on a 0 to 100 percent scale.

Three random drops per plot with a 2.5 kg Clegg Impact Hammer (Lafayette Instruments, Lafayette, IN) provided a measure of surface hardness by tracking deceleration values in G_{max} (harder surface gives higher values). On 24 October 2006 and 2007, a Shear Clegg Tester (Dr Baden Clegg Pty Ltd, Jolimont, Australia) was used to determine the force (Newton meters, Nm) required to tear turfgrass from three random locations per plot.

Three random 5 cm^2 area x 5 cm deep soil cores were taken from each plot to test physical properties [bulk density (BD), air-filled macro-porosity (AP), and micro-porosity or capillary porosity (CP), and saturated hydraulic conductivity (K_{sat}), percent soil organic matter (OM), and surface organic matter]. Cores were pulled; the surface organic matter consisting of verdure and thatch was removed and placed in a labeled bag. Surface organic matter was placed in a drying oven and dried at 75 °C for 48 hours before weighing, with the difference being the total surface organic matter. Then the surface organic matter was placed into the ashing oven for 24 hours at 300 °C to remove all organic matter, and a final weight was measured.

Soil cores were processed for saturated hydraulic conductivity according to Ferguson *et al.* (1960) to determine K_{sat}, BD, and total porosity. Soil cores were placed in a drying oven for 48 hours at 86 °C. After drying, soil cores were ground, massed, and placed into an ashing oven for 24 hours at 300 °C to remove organic matter.

Statistics were developed for treatments and treatment interactions using Proc MMAOV from the SAS system for Microsoft Windows, version 9.1 (Statistical Analysis Software, Cary, N.C.) (*P*=0.05, *P*=0.01, *P*=0.001) for color values, quality ratings, percent green cover values, visual turf cover, Clegg Impact Hammer readings, shear Clegg tester readings, and soil physical values. Data were pooled over digital image dates and separated using mean separation. Sod was new in both years, so statistics for each year were run separately

Results and Discussion

Bermudagrass variety, mowing type, overseeding, and date influenced turfgrass cover, color, quality, surface hardness, and soil physical properties when subjected to simulated athletic field traffic (Tables 1.1-1.7).

Percent Green Cover

Light vertical mowing with reel mower three times a week reduced turf cover by three percent in 2006, but no differences were observed in 2007 (Table 2.1). Since the difference in 2006 was only three percent, and the trend in 2007 was reversed by two percent, and not significant, results suggest that the mowing treatments tested do not influence turf cover when trafficked.

Also, in 2007 the August, September, and October temperatures remained optimal for bermudagrass growth. Therefore, the mowing treatments may not have had any effect after they stopped 31 August. In 2006, average temperatures collected on site for August, September, and October were 1.5 °C above average, 1.9 °C below normal, and 1.4 °C below normal temperatures, respectively. In contrast, August, September, and October 2007 average temperatures collected on site were 2.6 °C, 1.4 °C, and 2.8 °C above average, respectively**.** These elevated temperatures kept the bermudagrass active in 2007 and contributed to increased green cover after the grooming treatments were discontinued.

In 2006 and 2007, overseeding bermudagrass with perennial ryegrass improved the percent green cover on all four varieties tested (Figure 1.1 and 1.2). As the fall progressed in both years, air temperatures and soil temperatures did eventually decline. Bermudagrass begins to lose color and chlorophyll, becoming dormant when air temperatures fall below 25 °C. Conversely, perennial ryegrass thrives in air temperatures around 18 °C and has great growth and color (Beard, 1973). The loss of color in bermudagrass, and the strong color and growth of perennial ryegrass, combined with lower temperatures, allowed for overseeding to improve percent green cover on all plots in the study over time. In 2006, no differences between varieties and traffic events occurred until after 8 September (five traffic events) for the non-overseeded plots and 3 November (15 traffic events) for the overseeded plots.

After 20 October (10 traffic events), non-overseeded ‘Patriot’ bermudagrass had the least percent green cover followed by non-overseeded ‘Mississippi Choice’, ‘Riviera’ and ‘Tifway’ bermudagrasses. However, the non-overseeded ‘Tifway’ and ‘Riviera’ bermudagrasses were not significantly different from the overseeded ‘Patriot’ plot.

Shearman and Beard (1975) found wear tolerance variability among turfgrass species. More recently, both Rutledge (2005) and Goddard (2006) found variability among bermudagrass varieties over time and with traffic events.

After 27 November (20 traffic events), ‘Tifway’ and ‘Riviera’ had greater percent green cover than ‘Patriot’ and ‘Mississippi Choice’ when not overseeded (21, 20, 7, and 6.8 percent, respectively).

Goddard (2006) found non-overseeded ‘Tifway’ and non-overseeded ‘Riviera’ bermudagrass varieties to have the same amount of percent green cover in Arkansas after 42 traffic passes, and more than non-overseeded ‘Quickstand’ bermudagrass and ‘Heat Tolerant Bluegrass’ (‘HTBG’). In Tennessee, non-overseeded ‘Riviera’ bermudagrass and ‘HTBG’ had greater cover than non-overseeded ‘Tifway’ and non-overseeded ‘Quickstand’. Meanwhile, Bayrer (2006) found ‘Riviera’ to consistently have the highest percent turfgrass cover of varieties tested under one, two and three simulated athletic events a week in Kentucky.

Overseeded plots had a greater percent green cover after 27 November (20 traffic events) than all non-overseeded varieties. ‘Tifway’ bermudagrass had greater turf percent green cover than ‘Riviera’, ‘Mississippi Choice’, which were greater than ‘Patriot’ bermudagrass (77, 63, 60, and 53 percent, respectively). Similar to non-overseeded bermudagrass plots, overseeded ‘Tifway’ had the highest percent green cover after 20 traffic events on 27 November. High percent green cover in overseeded ‘Tifway’ bermudagrass can be attributed to the superior wear tolerance of ‘Tifway’ bermudagrass as also shown in Goddard’s (2006) simulated traffic study.

In 2007, differences between varieties occurred over time and with traffic events (Figure 1.2). For all varieties, percent green cover declined between 21 September and 26 October (five and 10 traffic events) compared with 2006. This occurred because of rainfall on 21 September, resulting in traffic events six and seven taking place under abnormally wet conditions.

Traffic events were simulated in these high moisture conditions to mimic what would happen on an athletic field. The result was a large amount of mud coating the turfgrass present. It took a couple of weeks for this mud to get cleaned off, and the DIA to detect the turfgrass present. Regardless of overseeding, all varieties recovered as traffic events increased. Unseasonably warm weather in September and on into October, as mentioned previously, provided conditions favorable for bermudagrass growth and recovery. As in 2006, at season end on 29 November 2007 (after 20 traffic events) when not overseeded ‘Patriot’, ‘Tifway’, and ‘Riviera’ provided greater turf cover than ‘Mississippi Choice’ (64, 63, 59, and 50 percent green cover, respectively). The high percent green cover on 29 November in the non-overseeded plots can been seen as a direct result of the more favorable bermudagrass growing conditions.

Overseeded ‘Tifway’ and ‘Mississippi Choice’ had the greatest percent green cover followed by overseeded ‘Riviera’ and ‘Patriot’ bermudagrass (87, 86, 79, and 76 percent, respectively). However, only the ‘Tifway’ and ‘Mississippi Choice’ were significantly greater than ‘Patriot’. All overseeded varieties benefited from the warmer fall much like the non-overseeded varieties, with higher percent green cover in 2007 compared with 2006 after 20 games. The warmer temperatures allowed the perennial ryegrass and bermudagrass to repair the wear caused from each simulated traffic event.

Early in the fall, when temperatures are still elevated, bermudagrass recovery is needed to repair a field’s cover from traffic events. If conditions are not favorable for repair, the traffic stress will be more noticeable, and more emphasis will be placed on the bermudagrasses wear tolerance.

Reynolds (2002) found 'Tifway' to be one of the tested varieties slowest to recover from traffic two and four weeks after injury. Similarly, Karcher *et al.* (2005) found that of 42 varieties in the 2002 bermudagrass NTEP trial, 'Tifway' was one of the slowest varieties to recover from divot injuries during the summer months. The four varieties used in this experiment ranked 'Riviera' 19th, 'Patriot' 31st, 'Mississippi Choice' 35th and 'Tifway' 38th out of 42 total varieties in 2003 and 2004 in a divot recovery experiment within the bermudagrass NTEP. This meant that with the continual trafficking, there would be no chance for these varieties to recover.

Many transition zone athletic field managers must select a turfgrass variety that has high wear tolerance. Often this is due to the timing of most sports seasons, which either finish after the growing season or start before bermudagrass breaks dormancy. Although 'Patriot' has consistently received high marks in cold hardiness, color, and quality ratings in the NTEP trials from 1997 to 2001 (Martin *et al*., 2007), it does not have the wear tolerance for athletic fields of other varieties tested here.

'Tifway' bermudagrass consistently scores low in studies evaluating recovery, but it handles athletic field wear very well. Sun and Liddle (1993) found that wider leaves were more prone to trampling than other finer leaves on plants. Bermudagrass leaf textures vary by variety. 'Tifway' is a fine-textured bermudagrass; 'Patriot' is a medium-fine variety; and 'Riviera' and 'Mississippi Choice' are medium-textured bermudagrasses (Morris 2006).

Bermudagrass varieties that tend to be denser have a finer leaf texture. Density of bermudagrass is mostly due to rhizome and stolon internode length. The smaller the internode length the more growing points (Karcher *et al*., 2005). Similarly, Trenholm *et al* (2000) found a dense turf canopy can increase turf wear tolerance along with adequate stem moisture. Shorter internode lengths generally have lower lateral growth rates (Cattani *et al*., 1996).

This explained why the plots with ‘Patriot’ filled in the fastest and looked the best early, but was not as dense as ‘Tifway’ plots. Once simulated traffic was applied and temperatures were not warm enough for recovery, the less dense plots wore out more quickly. Rutledge (2005) found that when traffic was simulated in July to August, ‘Patriot’ had more lateral re-growth than ‘Tifway’.

The warmer fall of 2007 kept the bermudagrass active longer and able to repair itself, as was evidenced by at least 50 percent green cover on 29 November 2007. For this reason differences in wear tolerance were not demonstrated as in 2006. ‘Patriot’ had the largest decreases in percent green cover after traffic events in both years but was able to quickly re-grow with the warmer weather in 2007. ‘Tifway’ and ‘Riviera’ both showed wear tolerance, with slow decreases in percent green cover after traffic events in both years of the study. Both varieties also showed slower re-growth, recovering less than the faster growing ‘Patriot’ variety.

In 2007, mowing treatments and overseeding over time provided significant differences (Figure 1.3). Regardless of overseeding, mown and mown plus groomed plots had a reduction in percent green cover from 27 August (0 traffic events) to 26 October (10 traffic events). Percent green cover on these dates went from 95 to 22 on non-overseeded mown plots, 95 to 17 on non-overseeded mown plus groomed plots, 95 to 34 on overseeded mown plots, and 94 to 43 on overseeded mown plus groomed plots. This loss in percent green cover was from two games being simulated in high moisture conditions. All mown and mown plus groomed plots increased in percent green cover through 29 November (20 traffic events).

On 29 November percent green cover was greater on overseeded mown (80) plots and overseeded mown plus groomed (84) than on non-overseeded mown (61) plots and non-overseeded mown plus groomed (57). Differences in percent green cover occurred between non-overseeded mowing treatments and overseeded mowing treatments after 26 October through the 29 November. Overseeding helped increase the percent green cover for both mowing treatments.

On 12 November overseeded mown plus groomed plots (71) had a higher percent green cover than overseeded mown plots (61). This was due to a better stand of ryegrass in the mown plus groomed plots from improved seed to soil contact.

Total Percent Turf Cover Rated Visually

In 2006, overseeding significantly increased percent turfgrass cover for ‘Patriot’ (71 vs. 88), ‘Mississippi Choice’ (79 vs. 89), and ‘Riviera’ (82 vs. 89) bermudagrass, but not ‘Tifway’ (90 vs. 93) bermudagrass (Table 2.2). Overall, ‘Tifway’ bermudagrass (90) had the greatest turfgrass cover but was not significantly different from the other varieties when overseeded. Non-overseeded ‘Riviera’ and ‘Mississippi Choice’ had greater turf cover than ‘Patriot’ bermudagrass (82, 79, and 71 percent, respectively).

In 2007, no significant interactions for variety and overseeding were observed for total turf cover rated visually (Table 2.2). Large portions of bermudagrass were still actively growing as was evident by the 50 percent and greater green cover on 29 November for all of the non-overseeded bermudagrass plots. With the bermudagrass still active, it was able to repair itself and lessen the detrimental effects of the simulated traffic, thus helping add to the total turf cover.

Visual ratings for total turf cover were significant for mowing and overseeding treatment interactions for 2006, but not 2007 (Table 2.3). Mowing and overseeding provided the greatest turf cover. However, results were not significantly different than those in mown plus groomed plots that were overseeded; results were better than plots mown and not overseeded, which in turn were better than plots mown plus groomed and not overseeded (91, 88, 86, and 75 percent, respectively). Adding a plant that thrives in cooler weather, such as perennial ryegrass, will increase percent cover as was evidenced in the overseeded plots.

Cockerham *et al*. (1997) found that repeated vertical mowing could reduce thatch by 11 percent on zoysiagrass. Thatch can also be removed on bermudagrass by vertical mowing. Perennial ryegrass benefited from having thatch removed by grooming three times a week, providing better seed to soil contact when overseeding occurred on 22 September. In 2007, the increased bermudagrass growth influenced by the warmer temperatures did not allow for the effects of grooming to be seen when overseeding was applied. Non-overseeded plots that were mown plus groomed had lower DIA percent green cover, as well as lower turf cover than plots with mowing treatments. This may suggest that grooming three times a week may reduce turf cover.

In 2006, total turf cover visual ratings were significant for the mowing over time (10, 17, 20 and 28, November, respectively) interaction (Figure 1.4). In 2007, significant differences occurred only over time and traffic events (Table 2.4). In 2006, differences in mown (86 percent) and mown plus groomed (78 percent) treatments did not occur until 20 November (19 traffic events). Mowing plus grooming reduced percent green cover, compared with mowing, on two of the four visual rating dates. No differences occurred between mown plots over time except 17 November (17 traffic events) and 28 November (20 traffic events). In this comparison, 17 November had 93 percent total turf cover versus only 84 percent turf cover on 28 November. The additional four traffic events in the poor environmental conditions caused the decrease in total turf coverage. Mown plus groomed plots on 10 November and 17 November (17 and 18 traffic events, respectively) had significantly greater turf cover (88, 87, 78, and 75 percent, respectively) than mown plus groomed plots on 20 November and 28 November (19 and 20 traffic events, respectively). The addition of traffic in cooler weather will decrease turfgrass cover because of the inability of the bermudagrass turf to repair the damage.

Contrary to what was expected, turf cover in 2007 increased with time and traffic (Table 2.4). Bermudagrass was still able to recover from traffic, and growing conditions continued to be favorable for some additional bermudagrass growth, causing total turf cover to increase with each rating date (74, 75, 80, and 86 percent total turf cover, respectively). This is evident by the high percent green cover ratings (at least 50 percent green cover on all plots) from DIA for traffic events 15 and 20 in 2007.

Significant interactions occurred in 2006 for perennial ryegrass overseeding over time (Figure 1.5). Overseeding effects on total turf cover were evidenced 20 and 28 November (19 and 20 traffic events, respectively). In addition, differences in total turf cover occurred beginning 20 November for non-overseeded plots; however, no differences occurred for overseeded plots over time. Overseeded plots were able to repair after traffic events, and did not have the decline in total turf cover compared with the plots that were not overseeded. Bermudagrass was mostly dormant by 21 November, and with the continued simulated traffic, those plots could not recover like the overseeded plots.

Total turf cover ratings are more important than color and quality ratings because many athletic field managers are simply just trying to battle excessive traffic (Gaussoin *et al.*, 2001). Many managers do not have the budget for overseeding; this is why total turf cover is so important. For these fields, selecting a species that is wear tolerant is especially important.

Color Ratings

In 2006 and 2007, interactions for color ratings occurred for mowing treatments over time (Figures 1.6 and 1.7). In 2006, the color ratings for mown and mown plus groomed treatments steadily declined from 18 August (7.5 and 7.3) to 20 October (5.2 and 4.9); however, there were no differences between mowing treatment on these two dates. Color ratings decreased over time with the lower temperatures of the later months. Significant differences between mowing treatments occurred once on 8 September when mown plots had a lower color rating (5.8) than the mown plus groomed plots (6.4).

Five traffic events by the 8 September rating date opened up the canopy for DIA to detect thatch. Carrow *et al.* (1987) found that grooming removed thatch, which can have a yellow -brown color. Color ratings taken only eight days after the discontinuation of grooming showed lack of thatch, which could influence color ratings. Without thatch, DIA would only have green tissue to analyze.

By 20 October, the effects of mowing plus grooming along with five more traffic events resulted in turf color that was consistent between mowing treatments. From 20 October to 27 November, no differences in color occurred for mown plots, but mown plus groomed plots had greater turf color on 3 November (5.3) compared with color on 20 October (4.9). This may have resulted from a combination of factors, including increased traffic, lack of cushioning as a result of grooming, and the decrease in bermudagrass color because of dormancy.

The initial decrease in color that occurred in 2006 for mowing by date treatment interactions were anticipated because traffic was being applied and environmental conditions for bermudagrass growth were becoming unfavorable. Over time color ratings leveled off, probably because of the perennial ryegrass, which compensated for the decrease in bermudagrass color caused by the traffic and bermudagrass dormancy. Mowing plus grooming kept the thatch down; however, the effects on color were perhaps lost because of traffic events which continued to wear the plot and tear the tissue and the continued mowing activity.

Color ratings for mowing treatments in 2007 differed by date (Figure 1.7). Mowing and grooming treatments showed no difference in color from mowing treatments except 12 November (15 traffic events) when mown plots had a lower color rating (5.5) than mown plus groomed plots (5.9). The 12 November color rating was higher for mown plus groomed plots, most likely due to a better stand of perennial ryegrass. The removal of thatch throughout the summer allowed for better seed to soil contact. By 12 November, the perennial ryegrass was able to mature and improve these color ratings.

On 21 September, 26 October, and 12 November (5, 10, and 15 traffic events) color ratings for mown plots were better than mown plots analyzed on 27 August and 29 November as well as mown plus groomed plots analyzed 27 August, 26 October, and 29 November. The lower color ratings on 27 August compared with other treatments was not surprising due to the extreme heat stress of that time period as well as the continued drought conditions. In September, drought relief and cooler temperatures reduced some of the stress on plants. On the 29 November, rating date temperatures were low and 20 traffic events had taken place; reduced plant material to lowered turfgrass color ratings compared with the other rating dates. Color ratings on 21 September, 26 October, and 12 November for mown plots benefited from less extreme environmental stress and at least five fewer traffic events than on 29 November. The lower color rating for the mown plus groomed plot compared with the mown plot on 26 October could be explained by a higher number of young perennial ryegrass plants becoming established. On 12 November mowing plus groomed plots had a higher color rating, most likely due to perennial ryegrass. It can be assumed that during the establishment of overseeding (26 October), colors lighter due to young plants present. As in 2006, overseeding maintained the turfgrass color over time as traffic events increased and bermudagrass dormancy occurred.

In 2006 and 2007, interactions occurred over time for variety and overseeding (Figures 1.8 and 1.9). In 2006, color ratings for all bermudagrass varieties that were not overseeded declined significantly from 18 August to 27 November 2006 (Figure 1.8). As in the 2002 bermudagrass NTEP trial, color ratings decreased from September to November (Morris 2007). Non-overseeded ‘Tifway’ bermudagrass gradually decreased in color over time, with significant differences occurring between 18 August and 20 October (7.5 and 6.0) and 20 October and 27 November (6.0 and 4.3). During the two time periods, there were 0 versus 10 and 10 versus 20 traffic events.

In the 2002 bermudagrass NTEP trial, ‘Tifway’ bermudagrass that was not trafficked had an August color rating of 6.8, which declined to 6.0 in November. Traffic also added to the decrease in color ratings by tearing the bermudagrass, which left the tissue to die on the plot’s surfaces and created more yellow tissue. Between 8 September, 20 October, and 3 November (5, 10, and 15 traffic events, respectively), ‘Patriot’ color ratings decreased (7.5, 6.1, and 3.5, respectively). Results for the 2002 bermudagrass NETP trial for ‘Patriot’ bermudagrass showed similar loss in color from September (6.0) to November (4.6) in non-trafficked plots (Morris, 2006).

Significant color loss occurred between 18 August and 8 September 2006 (0 vs. 5 traffic events) in the non-overseeded ‘Mississippi Choice’ (7.9 vs. 5.5) and ‘Riviera’ (6.8 vs. 4.6) bermudagrass varieties. An additional decrease in color occurred between 20 October (5.8) and 3 November (4.1) in the non-overseeded ‘Mississippi Choice’, but not for ‘Riviera’ (10 and 15 traffic events). Steady color decline of non-overseeded ‘Mississippi Choice’ bermudagrass mirrored NTEP color results for September (7.3), October (6.2)**,** and November (5.1). Non-overseeded ‘Riviera’ did not have a significant decline in color after 8 September 2006. Color ratings for non-overseeded ‘Riviera’ declined from September (6.7) to October (5.8) to November (4.8); the same was true for bermudagrass in the NTEP as well (Morris, 2007). The decline in color over time is expected with the environmental conditions that forced the bermudagrass into dormancy.

Also in 2006, overseeded ‘Tifway’ and ‘Patriot’ bermudagrass declined in color from 8 September to 20 October (7.0 to 4.4 and 7.7 to 4.8, respectively). ‘Tifway’ and ‘Patriot’ bermudagrass plots were overseeded on 22 September. As the ryegrass emerged, it was lighter in color and took a couple of weeks to mature and become darker. The color deterioration could be expected considering the effects of overseeding during this time period plus the traffic of 10 simulated athletic events. Unlike the non-overseeded plots, significant improvement in color occurred for the ‘Patriot’ bermudagrass between 20 October (4.8) and 27 November (5.8). Between 20 October (10 traffic events) and 27 November (20 traffic events), the perennial ryegrass became mature enough to increase the color in the ‘Patriot’ plots. In addition, plots covered with ‘Patriot’ bermudagrass had the earliest loss in percent green cover. Without bermudagrass present, perennial ryegrass did not have to compete for favorable growing conditions, allowing a better stand of ryegrass to establish. Initially, from 18 August to 8 September (0 and 5 traffic events), overseeded ‘Mississippi Choice’ (7.2 and 5.1) and ‘Riviera’ (7.1 and 5.0) declined in color; ‘Mississippi Choice’ again showed a significant decline in color (4.0) on 20 October (10 traffic events). As with ‘Tifway’ and ‘Patriot’ plots, the color declined with the first 5 traffic events; then ‘Mississippi Choice’ saw an additional decline in color as overseeding was established. Similar to overseeded ‘Tifway’ bermudagrass, both ‘Patriot’ and ‘Mississippi Choice’ showed an improvement in turf color between 20 October and 3 November (10 and 15 traffic events, respectively).

Comparing plots of the same bermudagrass varieties, little difference occurred in color between non-overseeded and overseeded plots until 20 October (10 traffic events) when overseeded plots had lower color ratings. The lower color ratings were likely a result of the germinating ryegrass seedlings influencing the color ratings, by having a lighter green color.

Perennial ryegrass did not influence color ratings until 3 November 2006 (15 traffic events), when overseeded bermudagrass plots had higher color ratings compared with non-overseeded bermudagrass plots. A significant improvement in turfgrass color also occurred on overseeded plots of ‘Tifway’ (5.6 to 8.0), ‘Patriot’ (3.5 to 5.4), ‘Mississippi Choice’ (4.1 to 6.3), and ‘Riviera’ (4.5 to 6.2) between 20 October and 3 November 2006 (10 and 15 traffic events, respectively).

‘Tifway’ overseeded had significantly higher color ratings on 3 November 2006 (15 traffic events) compared with all other varieties on this date. Rutledge (2005) also found ‘Tifway’ to have highest color later in the fall among varieties tested. The greater turfgrass color in the overseeded ‘Tifway’ bermudagrass was a response from both the perennial ryegrass and the limited ‘Tifway’ bermudagrass dormancy. However, even with overseeding ‘Tifway’ demonstrated the highest DIA percent green cover compared with the other varieties tested. On 27 November (20 traffic events), all overseeded bermudagrass plots had significantly higher color ratings than the non-overseeded plots.

Unlike 2006, the 2007 initial color ratings for all non-overseeded varieties (‘Tifway’, ‘Patriot’, ‘Mississippi Choice’, and ‘Riviera’ bermudagrasses) prior to traffic events were very low, particularly on the non-overseeded ‘Riviera’ bermudagrass (6.3, 5.6, 5.8, and 4.3, respectively). All varieties except ‘Tifway’ would be considered unacceptable because of color ratings below six.

By 21 September (5 traffic events) color ratings for all varieties regardless of overseeding, improved to acceptable levels above six. Even though the plots were irrigated, high temperatures and drought conditions in August may have contributed to the lower initial color ratings. Color ratings for non-overseeded ‘Patriot’ (7.3 and 8.3) and non-overseeded ‘Mississippi Choice’ (6.6 and 7.7) bermudagrass continued to increase from 21 September (5 traffic events) and 26 October (10 traffic events). During the same period, non-overseeded ‘Tifway’ (6.7 and 6.8) and ‘Riviera’ (7.3 and 7.4) bermudagrasses’ color ratings remained constant. The color improvements by 21 September can perhaps be associated with improving environmental conditions. Between 26 October (10 traffic events) and 12 November (15 traffic events), color ratings dropped to unacceptable levels, below six on all four non-overseeded varieties, with ‘Patriot’ showing the greatest color decrease (8.3 to 4.3).

Overseeding bermudagrass in 2007 improved the color ratings after 26 October (10 traffic events) through 29 November (20 traffic events), compared with non-overseeded bermudagrass plots for the same time period (Figure 1.10). As in 2006, the initial color ratings for all four varieties were lower on the plots overseeded with perennial ryegrass 26 October (6.2, 6.2, 6.3, and 6.5) than the non-overseeded plots (6.8, 8.3, 7.7, and 7.4). This is likely a result of the light green color of the perennial ryegrass seedlings. By 12 November (15 traffic events), overseeded plots of all varieties had greater turfgrass color than non-overseeded plots. This is likely a result of the perennial ryegrass having time to establish fully, providing a darker green color.

Overseeding bermudagrass with perennial ryegrass kept color ratings from declining due to the deep green color of the perennial ryegrass. Not all athletic field budgets are large enough to cover overseeding. Managers of these fields must choose a turfgrass variety that retains color longer into the fall. Reynolds (2002) found non-overseeded 'Tifway' retained color as well as five other varieties ('TifSport', 'GN-1', 'Quickstand', 'Navy Blue', and 'Tifton 10') tested in North Carolina during October. The non-overseeded 'Tifway' also maintained a higher color rating during November than the other varieties.

With the presence of color late into the fall, a limited amount of re-growth occurred in non-overseeded 'Tifway' bermudagrass to offset some of the loss of turf tissue from traffic. In both years of the study, non-overseeded 'Tifway' bermudagrass had higher color ratings on 3 November 2006 and 12 November 2007 (15 traffic events) than all other varieties tested on the same dates. Therefore it should be considered for use when budgets are not large enough to allow for overseeding.

Quality Ratings

Turfgrass quality ratings differed over time for variety and overseeding interactions over time in 2006 and 2007 (Figures 1.10 and 1.11). In 2006, quality ratings were unchanged for all non-overseeded bermudagrass varieties through 20 October (10 traffic events), except 'Patriot' bermudagrass, which decreased from 6.4 to 5.3 over time from 8 September to 20 October (0 to 10 traffic events). In addition, on 20 October (10 traffic events), non-overseeded 'Patriot' bermudagrass (5.3) had lower quality ratings than non-overseeded 'Tifway', 'Mississippi Choice', and 'Riviera' bermudagrasses (5.9, 5.9, and 6.0, respectively). Additional reductions in turfgrass quality occurred between 20 October and 3 November (10 and 15 traffic events) for non-overseeded 'Patriot' (5.3 to 3.6), 'Mississippi Choice' (5.9 to 4.0), and 'Riviera' (5.9 to 4.5).

The sudden decrease in quality ratings can be correlated to the sudden loss of percent green cover of non-overseeded 'Patriot' bermudagrass, emphasizing its lack of wear tolerance. Decreases in turfgrass quality occurred between 8 September and 3 November (0 and 15 traffic events) on non-overseeded 'Tifway' (6.4 and 5.5) and again between 3 November and 27 November (5.5 to 4.2 after 15 and 20 traffic events, respectively). The addition of traffic and the continued deterioration of bermudagrass growing conditions contributed to the decline in bermudagrass quality after 20 October (10 traffic events). However, non-overseeded 'Tifway' bermudagrass had the highest percent green cover in November compared with non-overseeded varieties tested, and did not experience a drop in turfgrass quality until November indicating 'Tifway's wear tolerance.

From 1997 to 2001 non-overseeded 'Tifway', 'Patriot', and 'Riviera' bermudagrass varieties were entries in the bermudagrass NTEP trials. Visual quality ratings were taken on all varieties in the NTEP on a 1 to 9 scale, with 1 being poor and 9 an excellent variety. 'Riviera' and 'Tifway' had equal turfgrass quality of 6.4. Meanwhile 'Patriot' had a lower turfgrass quality of 6.1, when managed with a lower fertility schedule (Martin *et al*., 2007). 'Patriot' exhibited higher turfgrass quality than 'Tifway' and 'Riviera' in the NTEP trials when fertilized with the higher rate of fertilizer (Martin *et al*., 2007). Rutledge (2005) found that 'Tifway' and 'Patriot' consistently had similar turfgrass quality during traffic stress periods in July and August.

Overseeding with perennial ryegrass in 2006 helped to maintain quality ratings for all overseeded plots compared with non-overseeded plots (Figure 1.10). Specifically, turfgrass quality increased in overseeded 'Tifway' bermudagrass plots (6.5, 7.8, and 7.3, respectively) for 20 October, 3 November, and 27 November (10, 15, and 20 traffic events). The late-season turfgrass quality increase can be attributed to directly to overseeding. Turfgrass quality for overseeded ‘Tifway’ bermudagrass was higher on 3 November and 27 November (15 and 20 traffic events) than all other overseeded plots. Higher turfgrass quality in November for overseeded ‘Tifway’ reflects the superior wear tolerance of ‘Tifway’ bermudagrass.

Overseeded ‘Patriot’ bermudagrass was the only variety to have lower quality ratings on 27 November (5.6, after 20 traffic events) when compared with 18 August (6.4 after 0 traffic events). This was likely due to the lack of wear tolerance of ‘Patriot’ bermudagrass observed during this study. No change occurred over time (20 October 3 November, and 27 November at 10, 15, and 20 traffic events, respectively) for overseeded ‘Mississippi Choice’ (6.2, 6.4, and 6.4) and overseeded ‘Riviera’ (6.8, 6.4, and 6.5) bermudagrass. The overseeding of ‘Mississippi Choice’ and ‘Riviera’ bermudagrass did stop the decline in turfgrass quality that occurred with the non-overseeded plots of the same varieties. In summary, overseeding perennial ryegrass into ‘Tifway’ bermudagrass was most beneficial in terms of turfgrass quality. ‘Mississippi Choice’ and ‘Riviera’ benefited to a lesser degree, while ‘Patriot’ did not benefit.

A decline in turfgrass quality in 2007 for non-overseeded ‘Tifway’ bermudagrass occurred between 27 August and 12 November (6.3 and 5.4 for 0 and 15 traffic events). A similar decline occurred in turfgrass quality for non-overseeded ‘Patriot’ bermudagrass between 26 October and 12 November (6.2 and 4.8 for 10 and 15 traffic events). Decreases in turfgrass quality of non-overseeded bermudagrass should be expected as a result of growing conditions becoming less favorable, the continuation of traffic, and bermudagrass going into dormancy.

Between 27 August and 21 September (0 and 5 traffic events), turfgrass quality increased for non-overseeded ‘Mississippi Choice’ (4.8 and 5.8) and ‘Riviera’ (4.8 and 7.0) bermudagrass. However, quality decreased over time from 26 October to 12 November (10 and 15 traffic events, respectively) for both non-overseeded ‘Mississippi Choice’ (6.1 and 4.6) and ‘Riviera’ (6.4 and 5.0) bermudagrass. Turfgrass quality likely remained higher than the year before for all varieties, particularly for non-overseeded ‘Patriot’, ‘Mississippi Choice’, and ‘Riviera’ bermudagrasses, because of unseasonably warm fall temperatures, which supported some bermudagrass growth.

In 2007, although traffic events continued, unseasonably warm fall temperatures provided optimal growing conditions for both bermudagrass and the overseeded perennial ryegrass throughout the study. Specifically, overseeded ‘Tifway’ bermudagrass increased in quality between 26 October and 12 November (6.4 and 7.2 for 10 and 15 traffic events). Overseeded ‘Patriot’ bermudagrass quality remained constant throughout the study (5.9, 5.9, 5.9, 6.3, and 6.3). Turfgrass quality continued to increase on overseeded ‘Mississippi Choice’ bermudagrass from 27 August (4.8, 5.6, and 6.4 for 0, 5, and 10 traffic events) until 12 November (7.3 for 15 traffic events) and 29 November (7.1 for 20 traffic events). Quality increased for overseeded ‘Riviera’ bermudagrass between 27 August and 21 September (4.6 and 7.5 for 0 and 5 traffic events), then decreased by 26 October (6.1 for 10 traffic events) and remained unchanged throughout the remainder of the study.

The initial increases in quality for the ‘Mississippi Choice’ and ‘Riviera’ bermudagrasses regardless of overseeding may be a result of the favorable weather from mid-August to September. Although traffic was applied over time on all plots, turfgrass quality was sustained by unseasonably warm fall temperatures that contributed to optimal conditions for turfgrass recovery. By the end of the study (29 November), turfgrass quality was greatest on all overseeded plots regardless of variety. Overseeded ‘Tifway’ and ‘Mississippi Choice’ demonstrated higher quality than ‘Patriot’ and ‘Riviera’ bermudagrass (7.2, 7.1, 6.3, and 6.0, respectively).

In 2006, interactions for mowing treatments and overseeding treatments over time occurred for turfgrass quality (Figure 1.12). By 20 October (10 traffic events), no differences were observed in non-overseeded plots that were mown versus plots that were mown plus groomed. However, overseeded plots that were mown (6.7) had better turfgrass quality than the non-overseeded mown plots (5.9) and the mown plus groomed plots (5.6) but not the mown plus groomed plots that were overseeded (6.3). As the non-overseeded plots began to move into dormancy, the quality ratings declined and continued to do so throughout the study. In addition, no difference in quality occurred on 20 October (10 traffic events) for mown plus groomed plots that were overseeded (6.3) compared with overseeded mown plots (6.7). By 3 November (15 traffic events), regardless of mowing treatments, the overseeded plots had higher turfgrass quality (6.8 and 6.3) than non-overseeded plots (4.5 and 4.3). The same results occurred at the end of the study on 27 November (20 traffic events), with overseeding plots having higher turfgrass quality (6.7 and 6.2) than non-overseeded (4.0 and 3.9), again without regard to mowing treatment.

In 2007, mowing treatments over time were different (Figure 1.13). Mown plus groomed plots had higher turfgrass quality (6.0) than mown plots (5.6) on 12 November (15 traffic events). Grooming treatments throughout the summer were effective in removing thatch so that when overseeding was done, there was better seed to soil contact than in the mown plots. A better stand of ryegrass would result in improved quality and color, thus enhancing overall turfgrass in these plots. Drought conditions caused lower initial (27 August, 0 traffic events) turfgrass quality ratings for both mowing treatments (5.3 and 5.4 for 0 traffic events) compared with the ensuing study ratings. Environmental stresses declined between 27 August and 26 October, and quality ratings improved even with the continued trafficking. Mown treatments had higher turfgrass quality from 21 September (6.1 for 5 traffic events) to 26 October (6.1 for 10 traffic events) compared with all other quality readings. Turfgrass quality increased on mown plus groomed plots after the initial quality rating (5.4 for 0 traffic events) and remained the same for the rest of the study (6.4, 6.2, 6.0, and 6.0). Turfgrass quality declined for mown treatments from 6.2 on 26 October to 5.6 on 12 November (15 traffic events) and remained lower as traffic continued.

Surface Hardness Readings

In 2006 and 2007, differences were observed for G_{max} values using a Clegg Impact Hammer on varieties and mowing treatments (Table 2.5). G_{max} values in 2006 were lowest for 'Rivera' bermudagrass (61), but was statistically similar to 'Tifway' (66); in turn, 'Tifway' was not different from 'Patriot' (68) and 'Mississippi Choice' (72).

Goddard (2006) found in Tennessee that when subjected to fall traffic, ’Tifway' had lower G_{max} values than 'Riviera' and 'Heat Tolerant Bluegrass' but not lower than 'Quickstand'. In Arkansas, Goddard (2006) found 'Tifway' and 'Riviera' bermudagrasses to have the same G_{max} value when subjected to fall traffic. In contrast, Reynolds (2002) and Rutledge (2005) found 'Tifway' to be consistently one of the highest rated for G_{max} values when measured in June, July, and August and when compared with ‘Quickstand’, ‘Navy Blue’, ‘TifSport’, ‘Tifton 10’, and ‘GN-1’.

Again in 2007, ‘Riviera’ (60) had lower G_{max} values than ‘Tifway’ (68) and ‘Mississippi Choice’ (70): however, its values were similar to ‘Patriot’ (65). There were no statistical differences in G_{max} values for ‘Patriot’, ‘Tifway’, and ‘Mississippi Choice’. These results suggest ‘Riviera’ bermudagrass would provide the softest surface of the varieties tested in both years.

G_{max} values also varied with mowing treatments (Table 2.5). In 2006, G_{max} values were lower for plots that were mown (63) compared with mown plus groomed plots (70). Similarly, in 2007 mown plots (63) rated lower than mown plus groomed plots (69).

Cockerham *et al*. (1997) and Carrow *et al*. (1987) both found regular vertical mowing would reduce thatch. Mowing and grooming three times a week kept thatch reduced, even though grooming was discontinued 31 August. When the G_{max} values were taken 24 October, less thatch was present to cushion the blow.

Tinsel Strength

Tinsel strength of the plots was tested with a shear tester on 24 October 2006 and 2007. No differences were found among any treatments (Table 1.5).

Soil Physical Properties

Soil physical properties were examined after each simulated playing season to look for treatment effects on soil physical properties. In 2006, overseeded (4.8 cm/hr) plots had slower K_{sat} than plots which were not overseeded (5.7 cm/hr) (Table 2.6).

In 2007, an interaction occurred for variety, mowing, and overseeding treatments for soil infiltration rates (Figure 1.14). The three of the four highest rates of soil infiltration were for mown plots. Non-overseeded ’Riviera’ mown plus groomed plots had the higher soil infiltration rates but not more than non-overseeded ‘Mississippi Choice’ mown plots, non-overseeded ‘Patriot’ mown plots, and overseeded ‘Riviera’ mown plots. Canaway (1980) found no differences for soil infiltration rates when hollow tine aerification and scarification treatments where applied with trafficking events. In 2006, there were no differences in K_{sat} values due to mowing treatments, supporting the claim that soil infiltration does not benefit from different mowing treatments.

Interactions between variety and overseeding occurred in 2006 for total porosity (Figure 1.15). Overseeded ‘Patriot’ (61) had greater total porosity than non-overseeded ‘Patriot’ (57). In contrast, non-overseeded ‘Mississippi Choice’ (60) had greater total porosity than overseeded ‘Mississippi Choice’ (54). No differences were observed between overseeded ‘Tifway’ (58) and non-overseeded ‘Tifway’ (60) or overseeded ‘Riviera’ (57) and non-overseeded ‘Riviera’ (57). Overseeded ‘Mississippi Choice’ (54) had less total porosity than overseeded ‘Tifway’ (60), non-overseeded ‘Tifway’ (58), and overseeded ‘Patriot’ (60) bermudagrasses. Variety and overseeding also had a significant interaction for total porosity in 2007 (Figure 16.). Overseeded ‘Mississippi Choice’ (65) and overseeded ‘Riviera’ (63) had greater total porosity than overseeded ‘Tifway’ (58) and non-overseeded ‘Mississippi Choice’ (58). No significant differences existed between any other treatments.

In 2007, differences also existed for mowing and overseeding treatments for total porosity (Figure 1.17). Mown and overseeded plots (64) had a greater porosity than mown and not overseeded plots (59), mown plus groomed and not overseeded plots (61), and mown plus groomed and overseed plots (59). Allowing thatch to accumulate on the surface, and the addition of perennial ryegrass overseeding protected the positive effects of aerification done in the summer of 2007.

Air-filled porosity interactions occurred for variety and overseeding treatments in 2006 (Figure 1.18). Overseeded Patriot' had a greater percent of macro-pores than non-overseeded 'Patriot' (20 vs. 16 percent). All other varieties had the same percent macro-pores regardless of overseeding treatment. Overseeded 'Patriot' bermudagrass also had a greater percent of macro-pores than all other treatments except overseeded 'Tifway' bermudagrass (19.7 vs. 17.4 percent). Overseeding allowed an increase in turfgrass cover, and protected the macro-pores in the soil.

Capillary porosity did not differ under any treatments in 2006. Two interactions occurred in 2007 for capillary porosity. First, variety by overseeding interaction, and second was mowing by overseeding interaction (Figures 1.19 and 1.20). The only variety to have differences between overseeding and non-overseeding was 'Mississippi Choice'; non-overseeded 'Mississippi Choice' plots (37) had a lower percentage of capillary pore space than overseeded 'Mississippi Choice' plots (42). Overseeded 'Mississippi Choice' plots (42) had greater capillary pore space than all treatments except overseeded 'Riviera' plots (39), non-overseeded 'Riviera' plots (39), and overseeded 'Tifway' plots (41). Overseeded 'Tifway' plots (41) had a greater capillary pore space than non-overseeded 'Mississippi Choice' plots (37), non-overseed 'Patriot' plots (37) and overseeded 'Patriot' plots (35).

Capillary pore space was greatest under mown and overseeded plots (41) compared with mown and not overseeded (37), mown plus groomed and not overseeded (38), and mown plus groomed and overseeded (38), which were similar (Figure 1.20).

In 2006, soil bulk densities differed by variety (Table 2.7). ‘Tifway’ (1.54 g/cm^3) bermudagrass had a lower bulk density than ‘Patriot’ (1.60 g/cm^3), ‘Mississippi Choice’ (1.62 g/cm^3), and ‘Riviera’ (1.60 g/cm^3) bermudagrasses (Table 2.7). Less compaction occurred on the variety with the most vegetative cover from DIA. Similarly, Goddard (2006) found trafficked ‘Tifway’ plots had a lower soil bulk density (1.68 g/cm^3) than trafficked ‘Riviera plots (1.79 g/cm^3).

In 2007, bulk density varied under overseeding treatments (Table 2.8). Plots which were not overseeded had a higher bulk density (1.60 g/cm^3) compared to overseeded plots (1.56 g/cm^3). Overseeding potentially limited the amount of compaction by adsorbing some of the impact from the simulated traffic events.

Soil organic matter in 2007 for overseeded plots (0.96 grams) was less than non-overseed plots (0.97 grams) (Table 2.9). There were no differences in soil organic matter for any treatment in 2006.

Surface organic matter varied for variety by mowing treatments in 2007 (Figure 1.21). More organic material was on the surface of ‘Patriot’ mown plus groomed plots (4.11 g), ‘Mississippi Choice’ mown plots (4.30 g) than ‘Patriot’ mown (2.91 g), ‘Tifway’ mown (2.80 g), and ‘Tifway’ mown plus groomed (2.43 g). No differences in surface organic material existed for ‘Riviera’ mown (3.56 g), ‘Riviera’ mown plus groomed (3.24 g), and ‘Mississippi Choice’ mown plus groomed plots existed with any variety in this experiment. There were no differences in surface organic matter for any treatments in 2006.

Conclusions

Athletic field managers need to select a variety that is wear tolerant and not one with high recuperative abilities for fields that host fall sports (football and fall soccer). Fall weather conditions limit bermudagrass growth, limiting recovery ability. Traffic continues at a pace faster than bermudagrass can recover due to poor weather conditions, for this reason it is imperative to have a variety that can withstand the effects of athletic traffic

Differences between varieties occurred, with ‘Tifway’ bermudagrass consistently yielding the greatest wear tolerance followed by ‘Riviera’ bermudagrass. Less wear tolerance was exhibited by ‘Mississippi Choice’ and ‘Patriot’ exhibiting a lower wear tolerance than ‘Tifway’ and ‘Riviera’ bermudagrass. A high level of wear tolerance is essential for bermudagrass athletic fields that are not overseeded.

Mowing plus grooming three times a week lowered turfgrass wear tolerance in 2006, but not in 2007. Mowing plus grooming did improve overseeding stands by providing better seed to soil contact for the overseeding.

Overseeding benefited all bermudagrass varieties wear tolerance. Initial readings immediately after overseeding were lower due to young plants in rating areas. Overseeding improved late fall color, percent green cover and turfgrass quality. Wear tolerance again was highest in ‘Tifway’ and ‘Riviera’ bermudagrass varieties. Fields can be improved if budgets for overseeding.

‘Tifway’ bermudagrass also provided some of the lowest surface hardness conditions, along with protecting the soil from compaction the best. ‘Mississippi Choice’ provided the hardest playing surface. None of the four varieties had differences in shear strength of the sod.

Warmer conditions provided a longer bermudagrass growing season in 2007, but still not at an adequate level to allow for the bermudagrass varieties to be considered successful on most athletic fields (Figure 2.1). As the growing days shortened, more turfgrass injury was apparent on the plots. Extreme heat and drought can be attributed to making all varieties have an unacceptable turfgrass quality level at points throughout the 2007 season.

Rainfall can also influence the success for failure of an athletic field. Athletic events taking place during or immediately following large rainfalls can cause significant injury to turfgrass stands. If growing conditions are still adequate the turfgrass can recover from the extreme damage caused from traffic.

More research is needed for how these varieties will over-winter and come out of dormancy in the spring. Research also needs to be done seeing how the trafficked plots will heal from injury.

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Appendices

Appendix A

Tables

Table 1.1. ANOVA table for bermudagrass variety†, mowing‡ and overseeding§ treatments and interactions for percent green cover and visual ratings¶, Knoxville, TN.

	2006				2007			
Treatments	D.F.	D.I.A.#	D.F.	Visual	D.F.	D.I.A.#	D.F.	Visual
Variety (V)	3	***	3	***	3††	***	3	**
Mowing (M)	1	***	1	***	1††	NS	1	NS
V x M	3	NS	3	NS	3††	NS	3	NS
Overseeding (O)	1	***	1	***	1††	***	1	NS
V x O	3	NS	3	**	3††	*	3	NS
M x O	1	NS	1	**	1††	NS	1	NS
V x M x O	3	NS	3	NS	3††	NS	3	NS
Date (D)	19	***	3	***	16††	***	3	***
D x V	57	***	9	NS	48††	***	9	NS
D x M	19	NS	3	**	16††	NS	3	NS
D x V X M	57	NS	9	NS	48††	NS	9	NS
D x O	19	***	3	***	16††	***	3	NS
D x V x O	57	***	9	NS	48††	***	9	NS
D x M x O	19	NS	3	NS	16††	**	3	NS
D x V x M X O	57	NS	9	NS	48††	NS	9	NS

*, **, ***, significant at the 0.05, 0.01, and 0.001 probability levels, respectively.

† Varieties consisted of: ‘Tifway’, ‘Patriot’, ‘Mississippi Choice’, and ‘Riviera’ bermudagrass varieties.

‡ Mowing treatments were completed with a reel mower three times a week from 10 July to 16 November; grooming treatments consisted of light vertical mowing with a reel mower three times a week from 10 July to 31 August.

§ Overseeding treatments were applied at 67 g/m^2 on 22 September 2006 and 1 October 2007, (after 5 and 7 traffic events, respectively).

¶ Percent green cover determined using digital image analysis; visual ratings were based on 1 to 100 scale of dormant and actively growing turf taken on 10, 17, 20, 28 November 2006 and 9, 16, 19, 29 November 2007.

D.I.A. = digital image analysis.

†† 2007 had fewer degrees of freedom due to three fewer sampling dates.

Table 1.2. ANOVA table for bermudagrass variety†, mowing‡ and overseeding§ treatments and interactions for color ratings¶, Knoxville, TN.

Treatments	df	2006	df	2007
Variety (V)	3	***	3	NS
Mowing (M)	1	NS	1	*
V x M	3	NS	3	NS
Overseeding (O)	1	***	1	***
V x O	3	NS	3	**
M x O	1	NS	1	NS
V x M x O	3	NS	3	NS
Date (D)	19	***	16#	***
D x V	57	***	48#	***
D x M	19	***	16#	**
D x V X M	57	NS	48#	NS
D x O	19	***	16#	***
D x V x O	57	*	48#	***
D x M x O	19	NS	16#	NS
D x V x M X O	57	NS	48#	NS

*, **, ***, significant at the 0.05, 0.01, and 0.001 probability levels, respectively.

† Varieties consisted of: ‘Tifway’, ‘Patriot’, ‘Mississippi Choice’, and ‘Riviera’ bermudagrass varieties.

‡ Mowing treatments were completed with a reel mower three times a week from 10 July to 16 November; grooming treatments consisted of light vertical mowing with a reel mower three times a week from 10 July to 31 August.

§ Overseeding treatments were applied at 67 g/m^2 on 22 September 2006 and 1 October 2007, (after 5 and 7 traffic events, respectively).

¶ Color ratings were determined by digital image analysis.

2007 had fewer degrees of freedom due to three fewer sampling dates.

Table 1.3. ANOVA table for bermudagrass variety†, mowing‡ and overseeding§ treatments and interactions for quality ratings¶, Knoxville, TN.

Treatments	df	2006	df	2007
Variety (V)	3	***	3	***
Mowing (M)	1	***	1	*
V x M	3	NS	3	NS
Overseeding (O)	1	***	1	***
V x O	3	NS	3	*
M x O	1	NS	1	NS
V x M x O	3	NS	3	NS
Date (D)	19	***	16#	***
D x V	57	***	48#	***
D x M	19	***	16#	*
D x V X M	57	NS	48#	NS
D x O	19	***	16#	***
D x V x O	57	***	48#	*
D x M x O	19	*	16#	NS
D x V x M X O	57	NS	48#	NS

* and ***, significant at the 0.05 and 0.001 probability levels.

† Varieties consisted of: ‘Tifway’, ‘Patriot’, ‘Mississippi Choice’, and ‘Riviera’ bermudagrass varieties.

‡ Mowing treatments were completed with a reel mower three times a week from 10 July to 16 November; grooming treatments consisted of light vertical mowing with a reel mower three times a week from 10 July to 31 August.

§ Overseeding treatments were applied at 67 g/m^2 on 22 September 2006 and 1 October 2007, (after 5 and 7 traffic events, respectively).

¶ Quality ratings were determined by digital image analysis.

2007 had fewer degrees of freedom due to three fewer sampling dates.

Table 1.4. ANOVA table for bermudagrass variety†, mowing‡ and overseeding§ treatments and interactions for Clegg Impact Hammer ¶, Knoxville, TN. 2006 and 2007.

Treatments	df	2006	2007
Variety (V)	3	**	*
Mowing (M)	1	**	**
V x M	3	NS	NS
Overseeding (O)	1	NS	NS
V x O	3	NS	NS
M x O	1	NS	NS
V x M x O	3	NS	NS

* and ** significant at the 0.05 and 0.01 probability levels.

† Varieties consisted of: ‘Tifway’, ‘Patriot’, ‘Mississippi Choice’, and ‘Riviera’ bermudagrass varieties.

‡ Mowing treatments were completed with a reel mower three times a week from 10 July to 16 November; grooming treatments consisted of light vertical mowing with a reel mower three times a week from 10 July to 31 August.

§ Overseeding treatments were applied at 67 g/m^2 on 22 September 2006 and 1 October 2007, (after 5 and 7 traffic events, respectively).

¶ Clegg Impact Hammer Readings were taken once each fall 24 October 2006 and 2007.

Table 1.5. ANOVA table for bermudagrass variety†, mowing‡ and overseeding§ treatments and interactions for Shear Clegg readings¶, Knoxville, TN. 2006 and 2007.

Treatments	df	2006	2007
Variety (V)	3	NS	NS
Mowing (M)	1	NS	NS
V x M	3	NS	NS
Overseeding (O)	1	NS	NS
V x O	3	NS	NS
M x O	1	NS	NS
V x M x O	3	NS	NS

† Varieties consisted of: 'Tifway', 'Patriot', 'Mississippi Choice', and 'Riviera' bermudagrass varieties.

‡ Mowing treatments were completed with a reel mower three times a week from 10 July to 16 November; grooming treatments consisted of light vertical mowing with a reel mower three times a week from 10 July to 31 August.

§ Overseeding treatments were applied at 67 g/m^2 on 22 September 2006 and 1 October 2007, (after 5 and 7 traffic events, respectively).

¶ Shear Clegg readings were taken once each fall 24 October 2006 and 2007.

Table 1.6. ANOVA table for bermudagrass variety†, mowing‡ and overseeding§ treatments and interactions for soil physical characteristics ¶, Knoxville, TN.. 2006.

Treatments	df	K_{sat}	Organic Matter	Total Porosity	Capilary Porosity	Air Filled Porosity	Bulk Density	Surface OM
Variety (V)	3	NS	NS	NS	NS	NS	*	NS
Mowing (M)	1	NS	NS	NS	NS	NS	NS	NS
V x M	3	NS	NS	NS	NS	NS	NS	NS
Overseeding (O)	1	*	NS	NS	NS	NS	NS	NS
V x O	3	NS	NS	**	NS	**	NS	NS
M x O	1	NS	NS	NS	NS	NS	NS	NS
V x M x O	3	NS	NS	NS	NS	NS	NS	NS

* and ** significant at the 0.05 and 0.01 probability levels.

† Varieties consisted of: 'Tifway', 'Patriot', 'Mississippi Choice', and 'Riveria' bermudagrass varieties.

‡ Mowing treatments were completed with a reel mower three times a week from 10 July to 16 November; grooming treatments consisted of light vertical mowing with a reel mower three times a week from 10 July to 31 August.

§ Overseeding treatments were applied at 67 g/m^2 on 22 September 2006, (after 5 traffic events, respectively).

¶ Soil cores were taken 6 December 2006.

Table 1.7. ANOVA table for bermudagrass variety†, mowing‡ and overseeding§ treatments and interactions for soil physical characteristics ¶, Knoxville, TN. 2007.

Treatments	df	K_{sat}	Organic Matter	Total Porosity	Capillary Porosity	Air Filled Porosity	Bulk Density	Surface OM
Variety (V)	3	NS	NS	NS	*	NS	NS	NS
Mowing (M)	1	NS	NS	NS	NS	NS	NS	NS
V x M	3	NS	NS	NS	NS	NS	NS	*
Overseeding (O)	1	NS	***	NS	NS	NS	*	NS
V x O	3	**	NS	*	*	NS	NS	NS
M x O	1	NS	NS	**	**	NS	NS	NS
V x M x O	3	**	NS	NS	NS	NS	NS	NS

*, **, ***, significant at the 0.05, 0.01, and 0.001 probability levels, respectively.

† Varieties consisted of: ‘Tifway’, ‘Patriot’, ‘Mississippi Choice’, and ‘Riviera’ bermudagrass varieties.

‡Mowing treatments were completed with a reel mower three times a week from 10 July to 16 November; grooming treatments consisted of light vertical mowing with a reel mower three times a week from 10 July to 31 August.

§ Overseeding treatments were applied at 67 g/m^2 on 1 October 2007, (after 7 traffic events, respectively).

¶ Soil cores were taken 24 January 2008.

Table 2.1. Main effects for mowing† treatments for percent green cover‡, Knoxville, TN.

Treatment (M)	2006	2007
Mowing	74	66
Grooming and Mowing	71	68
LSD (0.05)	***	NS

*** significant at the 0.001 probability level.

† Mowing treatments were completed with a reel mower three times a week from 10 July to 16 November; grooming treatments consisted of light vertical mowing with a reel mower three times a week from 10 July to 31 August.

‡ Percent green cover was determined by digital image analysis.

Table 2.2. Treatment interaction effects for variety and overseeding† for visual turf cover‡, Knoxville, TN.

Interactions V x O	2006	2007
'Tifway'	90	83
'Tifway' overseeded	93	83
'Patriot'	71	76
'Patriot' overseeded	88	80
'Mississippi Choice'	79	79
'Mississippi Choice' overseeded	89	79
'Riviera'	82	75
'Riviera' overseeded	89	77
LSD (0.05)	5.9	NS

† Overseeding treatments were applied at 67.38 g/m^2 on 22 September 2006 and 1 October 2007, respectively.

‡ Visual ratings were based on 1 to 100 scale of dormant and actively growing turf taken on 10, 17, 20, 28 November 2006 and 9, 16, 19, 29 November 2007.

Table 2.3. Treatment interactions effects for mowing† and overseeding‡ for visual turf cover§, Knoxville, TN.

Interactions		
M x O	2006	2007
Mowing	86	78
Groomed	75	79
Mowing and Overseeding	91	78
Groomed and Overseeding	88	80
LSD (0.05)	4	NS

† Mowing treatments were completed with a reel mower three times a week from 10 July to 16 November; grooming treatments consisted of light vertical mowing with a reel mower three times a week from 10 July to 31 August.

‡ Overseeding treatments were applied at 67 g/m^2 on 22 September 2006 and 1 October 2007, respectively.

§ Visual ratings were based on 1 to 100 scale of dormant and actively growing turf taken on 10, 17, 20, 28 November 2006 and 9, 16, 19, 29 November 2007.

Table 2.4. Date† interaction for total turf cover‡, Knoxville, TN. 2007

Interactions	
Date	Visual Total Turf Cover
9, Nov. (17 traffic events)	74
16, Nov. (18 traffic events)	75
19, Nov. (19 traffic events)	80
29, Nov. (20 traffic events)	86
LSD (0.05)	3.5

† Rating dates were 9, 16, 19, and 29 November 2007.

‡ Visual total turf cover was rated on a 1 to 100 percent cover scale.

Table 2.5. Main effects for variety and mowing† treatments for Clegg Impact Hammer values‡, Knoxville, TN. 2006 and 2007.

Treatments		
Variety (V)	**2006**	**2007**
'Tifway'	66	68
'Patriot'	68	65
'Mississippi Choice'	72	70
'Riviera'	61	60
LSD (0.05)	6.0	5.9
Mowing/Grooming (M)		
Mown	63	63
Mown plus groomed	70	69
LSD (0.05)	***	*

* and ***, significant at the 0.05 and 0.001 probability levels.

†Mowing treatments were completed with a reel mower three times a week from 10 July to 16 November; grooming treatments consisted of light vertical mowing with a reel mower three times a week from 10 July to 31 August.

‡Clegg Impact Hammer Values were taken on 24 October 2006 and 2007 in G_{max} values.

Table 2.6. Main effect of overseeding† treatments on soil infiltration rates‡. Knoxville, TN. 2006.

Treatments Overseeding (O)	2006
Overseeded	4.8
Not Overseeded	5.7
LSD (0.05)	*

* significant at the 0.05 probability levels.

† Overseeding treatments were applied at 67 g/m^2 on 22 September 2006 (after 5 traffic events, respectively).

‡ Infiltration rates (amount of water passing through a point in a set amount of time) are represented in cm/hr.

Table 2.7. Main effect of variety treatments on bulk density†. Knoxville, TN. 2006.

Treatment Variety (V)	2006
'Tifway'	1.54
'Patriot'	1.61
'Mississippi Choice'	1.62
'Riviera'	1.60
LSD (0.05)	0.55

†Bulk density (a measurement of compaction) was measured in g/cm3.

Table 2.8. Main effect of overseeding† treatments on soil bulk density‡. Knoxville, TN. 2007.

Interactions	
Overseeding (O)	**2007**
Overseeded	1.56
Not Overseeded	1.6
LSD (0.05)	*

* significant at the 0.05 probability level.

†Bulk density (a measurement of compaction) was measured in g/cm^3.

Table 2.9. Main effect of overseeding† treatment on soil organic matter‡. Knoxville, TN. 2007.

Interactions	
Overseeding (O)	**2007**
Overseeded	0.96
Not Overseeded	0.97
LSD (0.05)	***

*** significant at the 0.001 probability level.

† Overseeding treatments were applied at 67 g/m^2 on 1 October 2007 (after 7 traffic events, respectively).

‡ Soil organic matter was measured in grams (g)

Appendix B

Figures

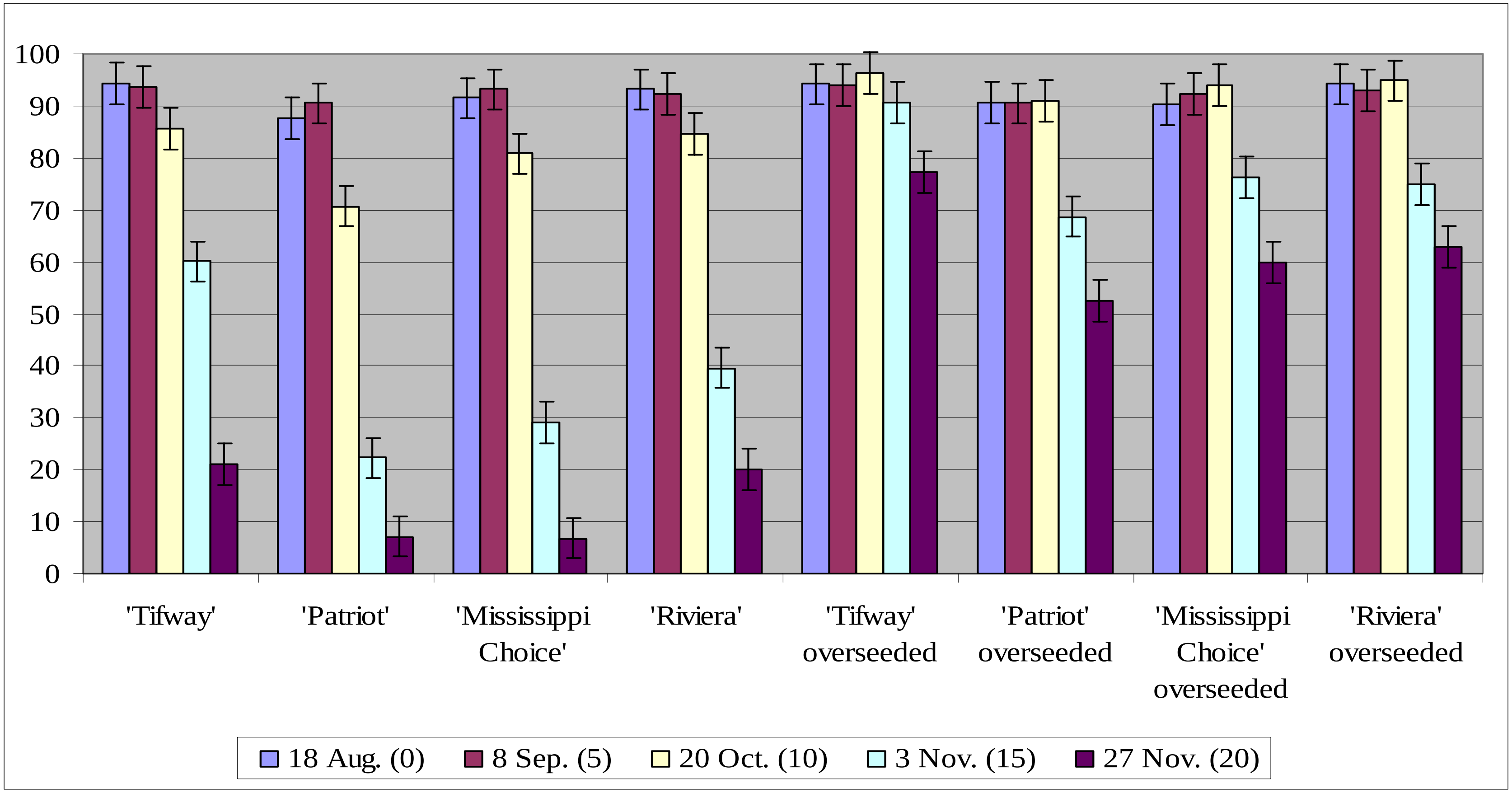

Figure 1.1. Variety and overseeding† treatment interactions over time for percent green cover‡. Knoxville, TN. Fall 2006.
† Overseeding treatments were applied at 67 g/m^2 on 22 September 2006 (after traffic event 5).
‡ Percent green cover was determined by digital image analysis.
§ (#) Indicates number of traffic events applied with the Cady Traffic Simulator.

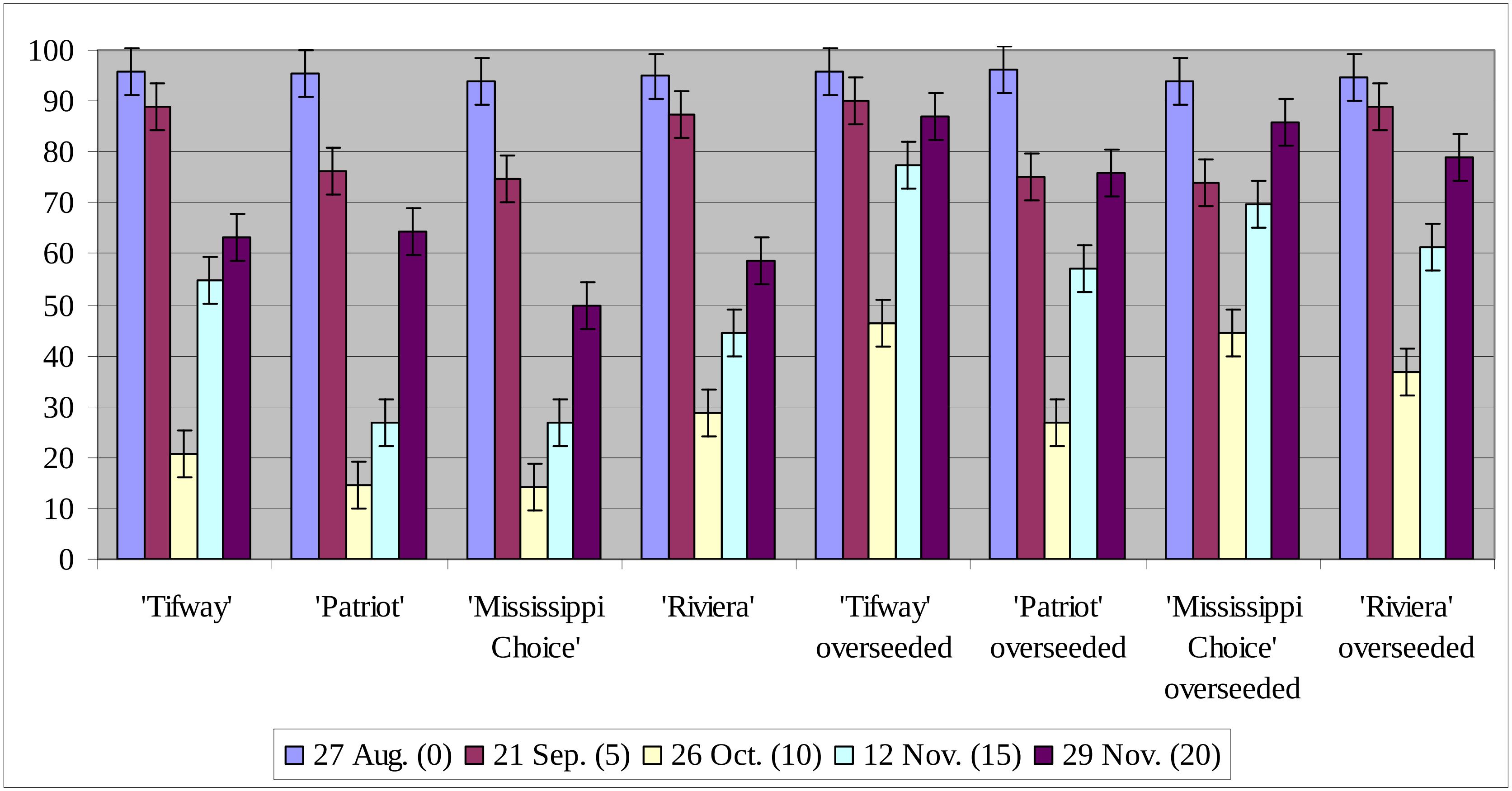

Figure 1.2. Variety and overseeding† treatment interactions over time for percent green cover‡. Knoxville, TN. Fall 2007.
† Overseeding treatments were applied at 67 g/m^2 on 1 October 2007 (after traffic event 7).
‡ Percent green cover was determined using digital image analysis.
§ (#) Indicates number of traffic events applied with the Cady Traffic Simulator.

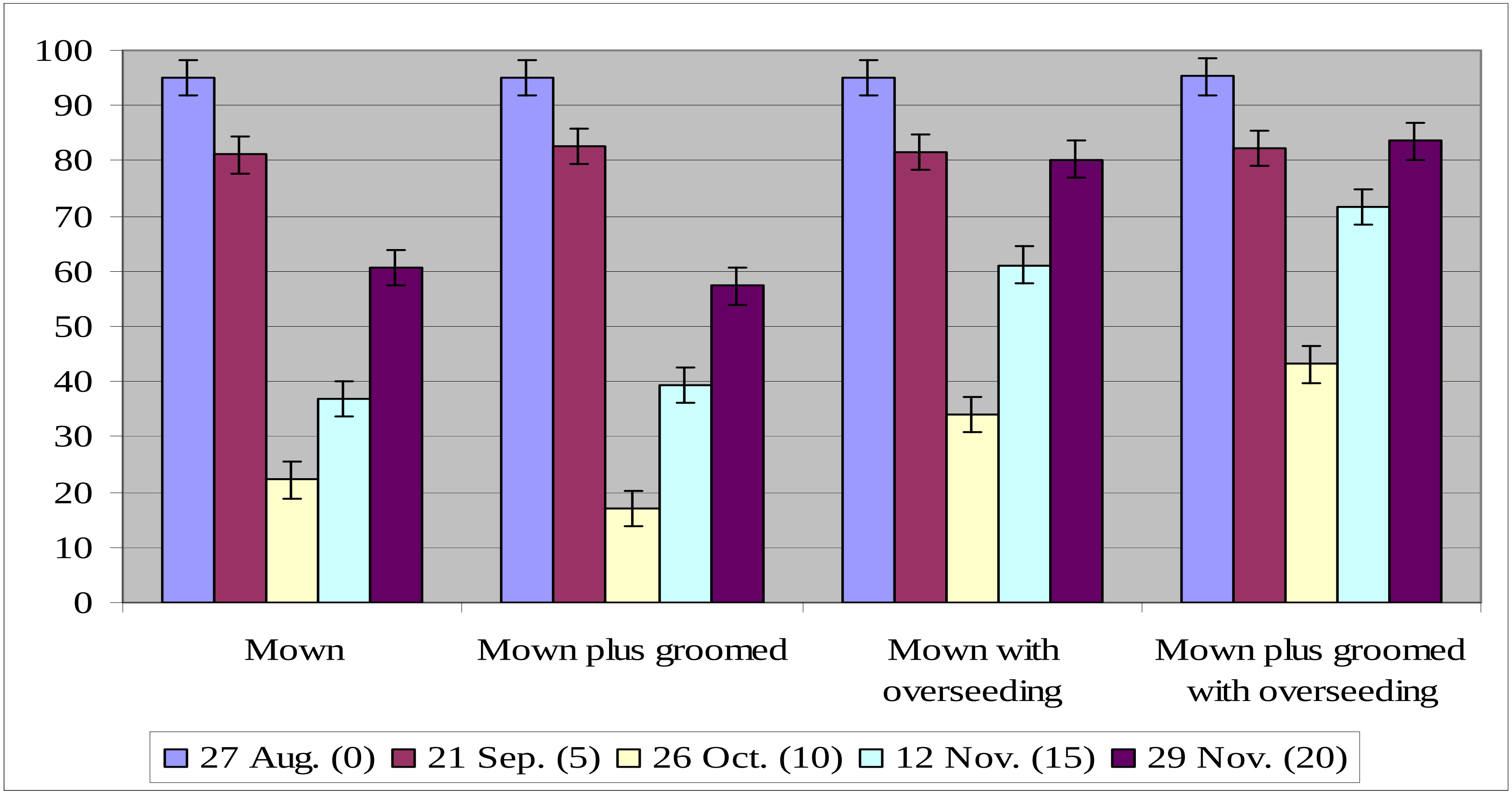

Figure 1.3. Mowing† and overseeding‡ treatment interactions over time for percent green cover§. Knoxville, TN. Fall 2007.
† Mowing treatments were completed with a reel mower three times a week from 10 July to 16 November; grooming treatments consisted of light vertical mowing with a reel mower three times a week from 10 July to 31 August.
‡ Overseeding treatments were applied at 67 g/m^2 on 1 October 2007 (after traffic event 7).
§ Percent green cover was determined using digital image analysis.
¶ (#) Indicates number of traffic events applied with the Cady Traffic Simulator.

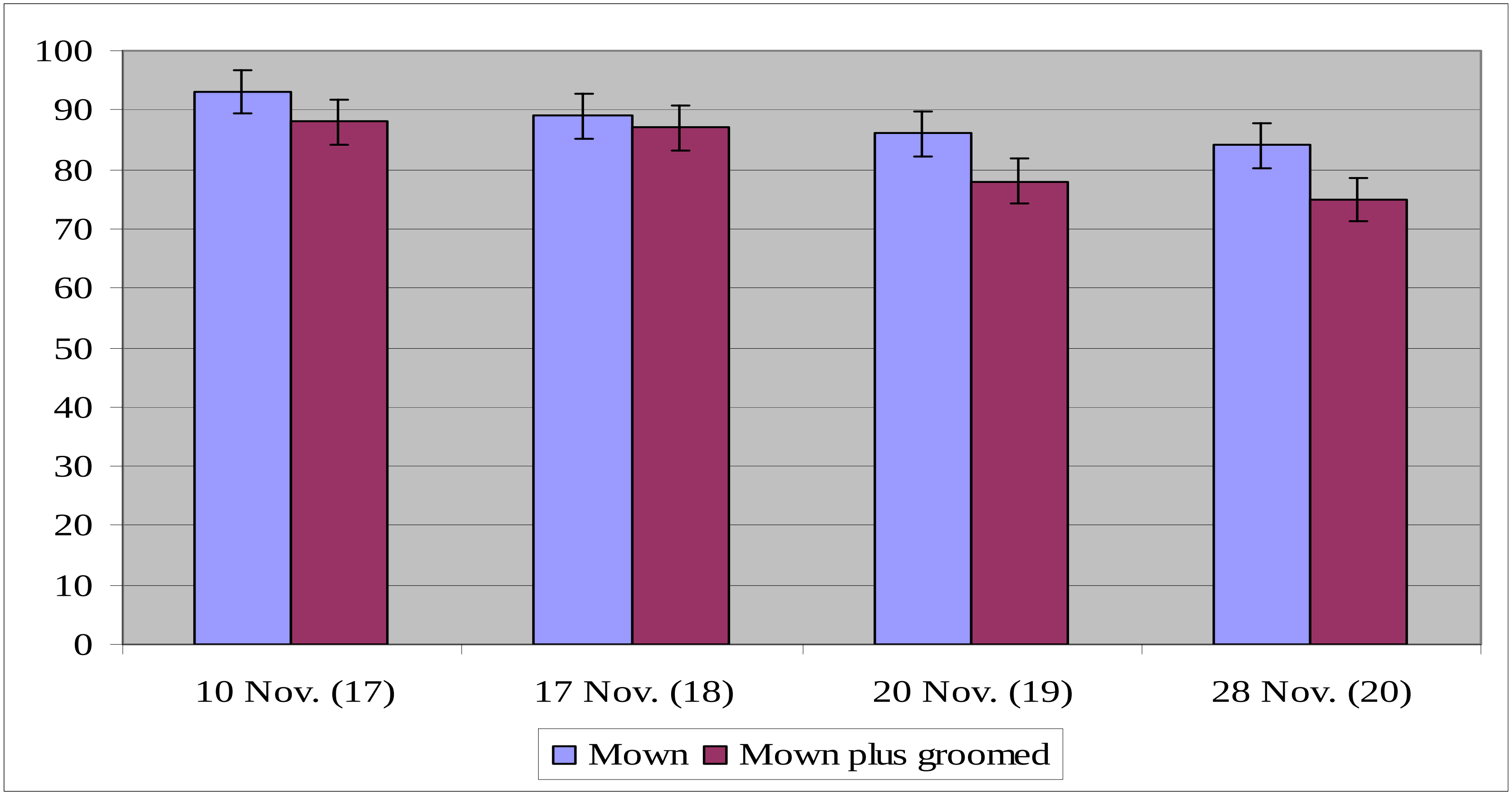

Figure 1.4. Mowing treatment† interactions over time for visual turf cover‡. Knoxville, TN. Fall 2006.
† Mowing treatments were completed with a reel mower three times a week from 10 July to 16 November; grooming treatments consisted of light vertical mowing with a reel mower three times a week from 10 July to 31 August.
‡Visual turf cover was based on 1 to 100 scale of dormant and actively growing turf taken after 10, 17, 20 and 28 November 2006 (17, 18, 19, and 20 traffic events, respectively).
§ (#) Indicates number of traffic events applied with the Cady Traffic Simulator.

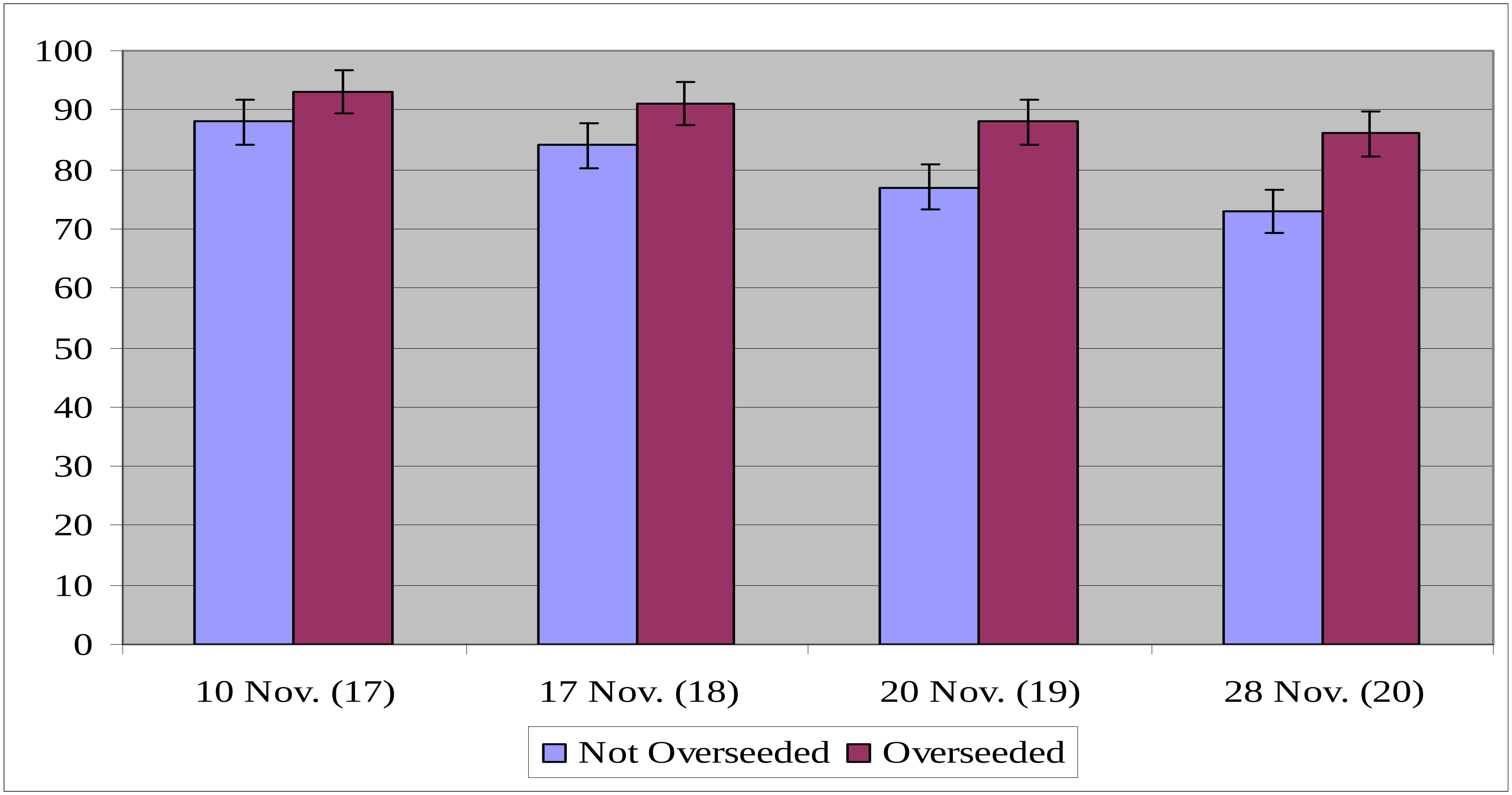

Figure 1.5. Overseeding treatment† interactions over time for visual turf cover‡. Knoxville, TN. Fall 2006.
† Overseeding treatments were applied at 67 g/m^2 22 September 2006 (after traffic event 5).
‡Visual turf cover was based on 1 to 100 scale of dormant and actively growing turf taken after 10, 17, 20, and 28 November 2006 (17, 18, 19, and 20 traffic events, respectively).
§ (#) Indicates number of traffic events applied with the Cady Traffic Simulator.

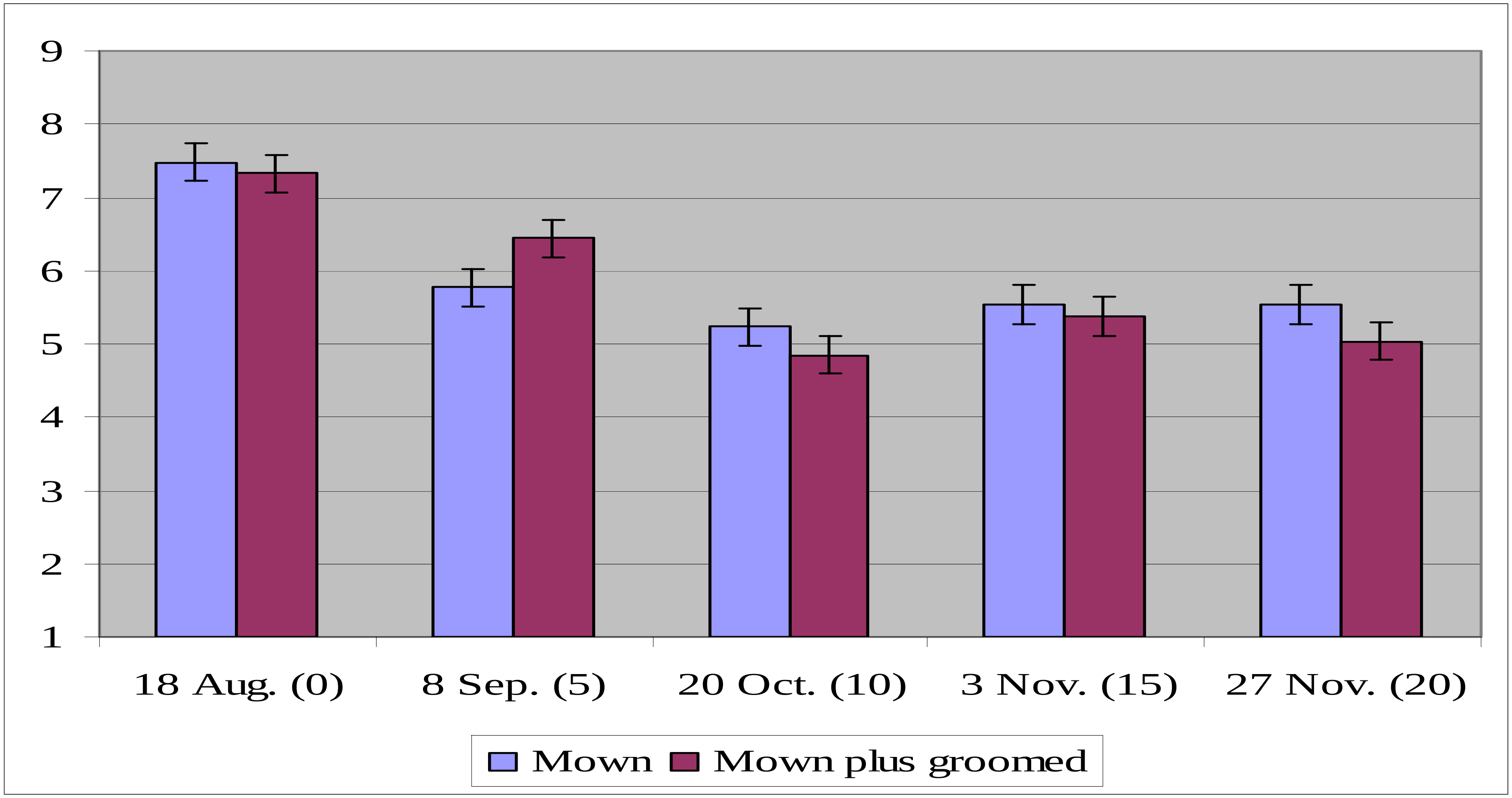

Figure 1.6. Mowing treatment† interactions over time for color ratings‡. Knoxville, TN. Fall 2006.
† Mowing treatments were completed with a reel mower three times a week from 10 July to 16 November; grooming treatments consisted of light vertical mowing with a reel mower three times a week from 10 July to 31 August.
‡ Color ratings were determined using digital image analysis.
§ (#) Indicates number of traffic events applied with the Cady Traffic Simulator.

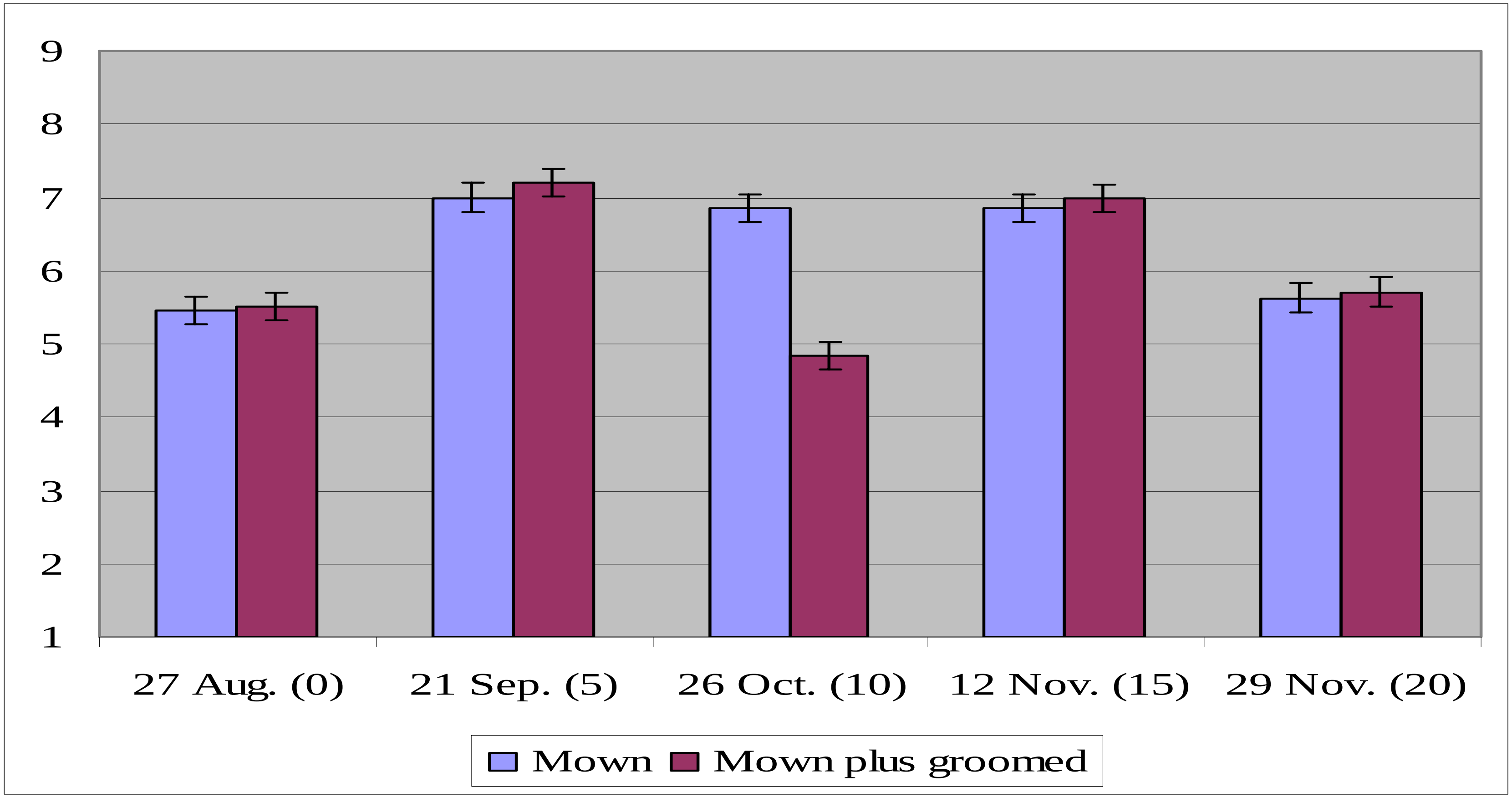

Figure 1.7. Mowing treatment interactions over time for color ratings. Knoxville, TN. Fall 2007.
† Mowing treatments were completed with a reel mower three times a week from 10 July to 16 November; grooming treatments consisted of light vertical mowing with a reel mower three times a week from 10 July to 31 August.
‡ Color ratings were determined using digital image analysis.
§ (#) Indicates number of traffic events applied with the Cady Traffic Simulator.

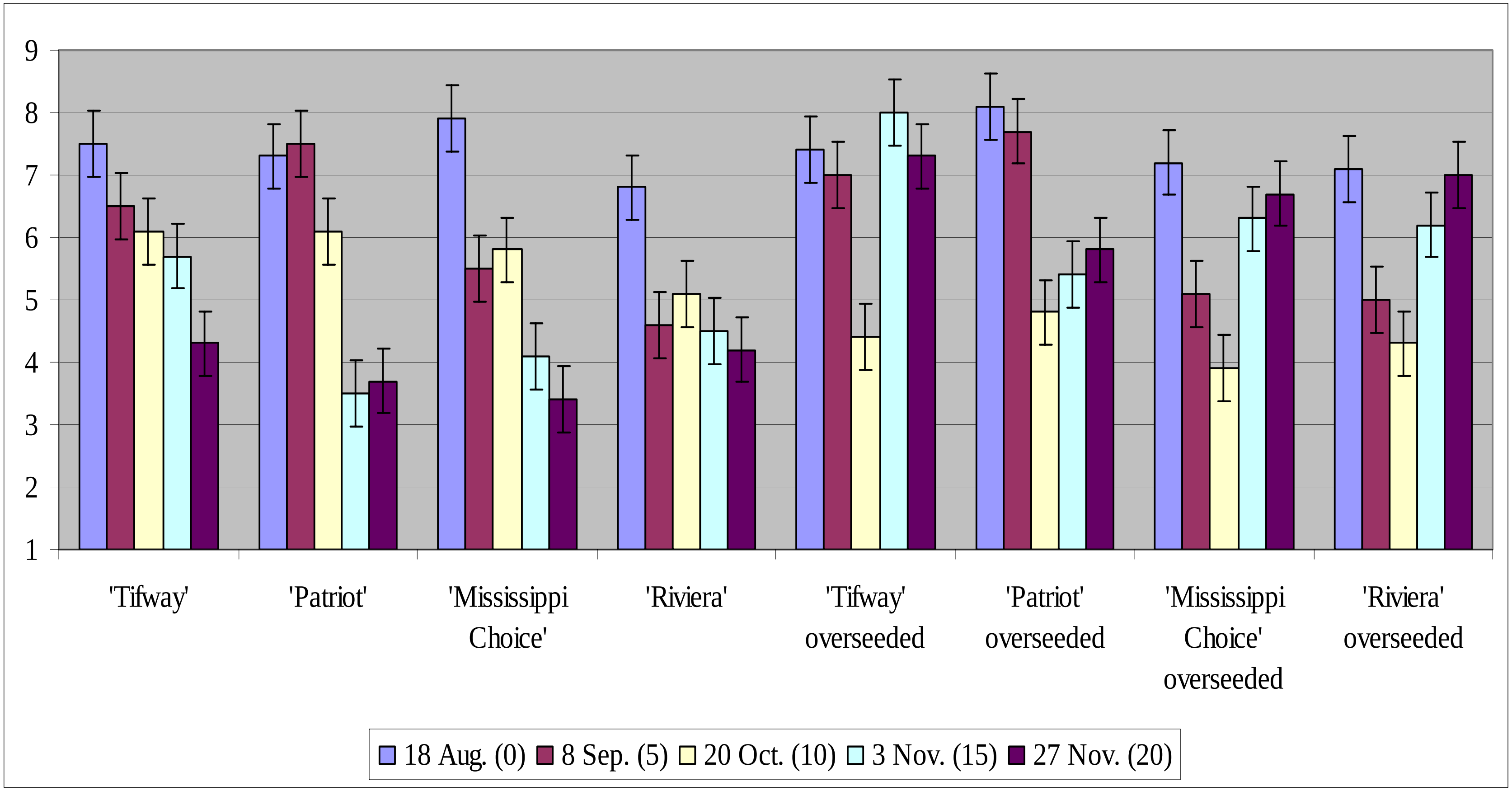

Figure 1.8. Variety and overseeding treatment† interactions over time for color ratings‡. Knoxville, TN. Fall 2006.
† Overseeding treatments were applied at 67 g/m^2 on 22 September (after traffic event 5).
‡ Color ratings were determined using digital image analysis.
§ (#) Indicates number of traffic events applied the Cady Traffic Simulator.

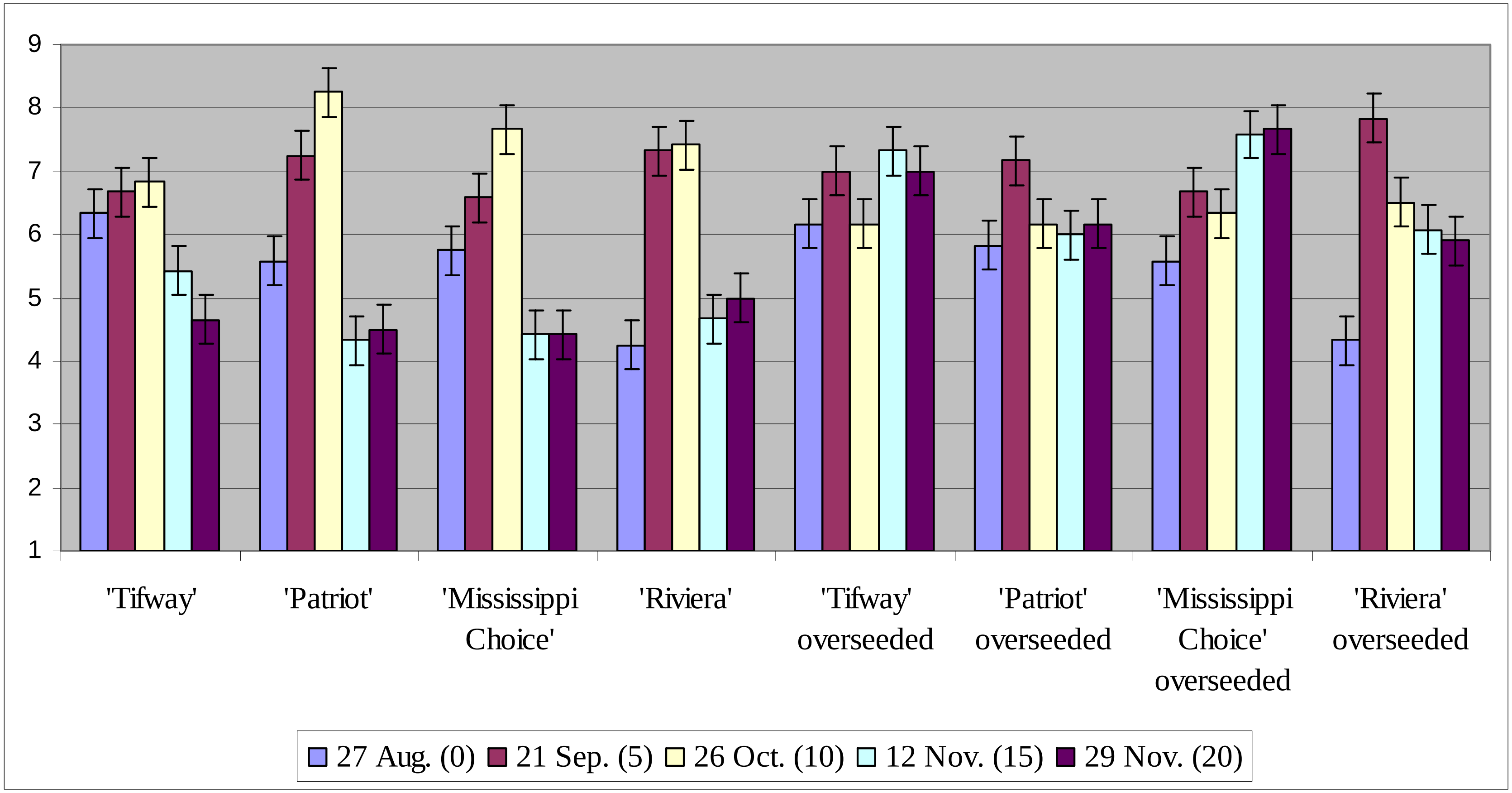

Figure 1.9. Variety and overseeding treatment† interactions over time for color ratings‡. Knoxville, TN. Fall 2007.
† Overseeding treatments were applied at 67g/m^2 on 1 October (after traffic event 7).
‡ Color ratings were determined using digital image analysis.
§ (#) Indicates number of traffic events applied with the Cady Traffic Simulator.

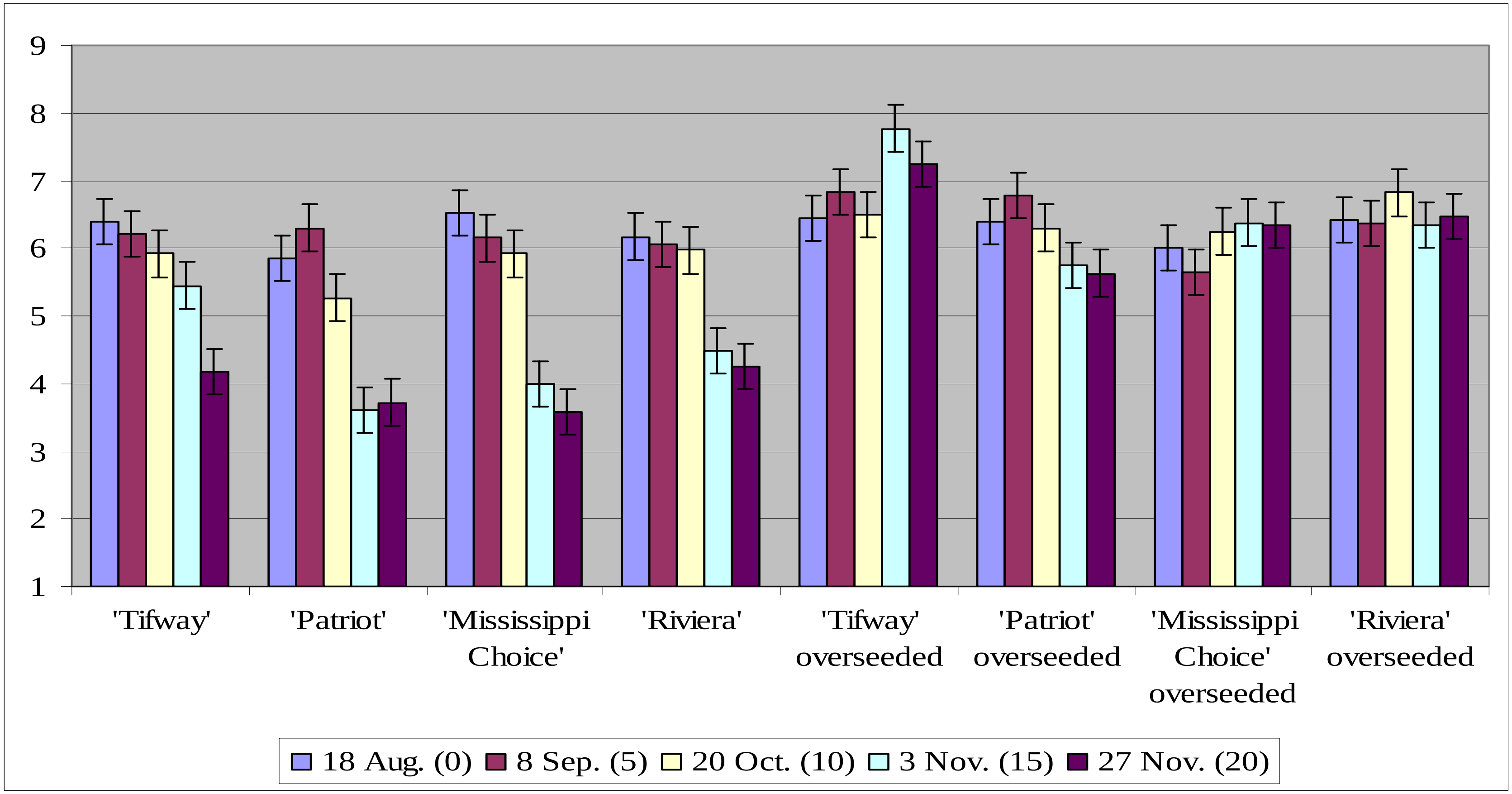

Figure 1.10. Variety and overseeding treatment† interactions over time for quality ratings‡. Knoxville, TN. Fall 2006.
† Overseeding treatments were applied at 67 g/m^2 on 22 September 2006 (after traffic event 5).
‡ Quality ratings were determined using digital image analysis.
§ (#) Indicates number of traffic events applied with the Cady Traffic Simulator.

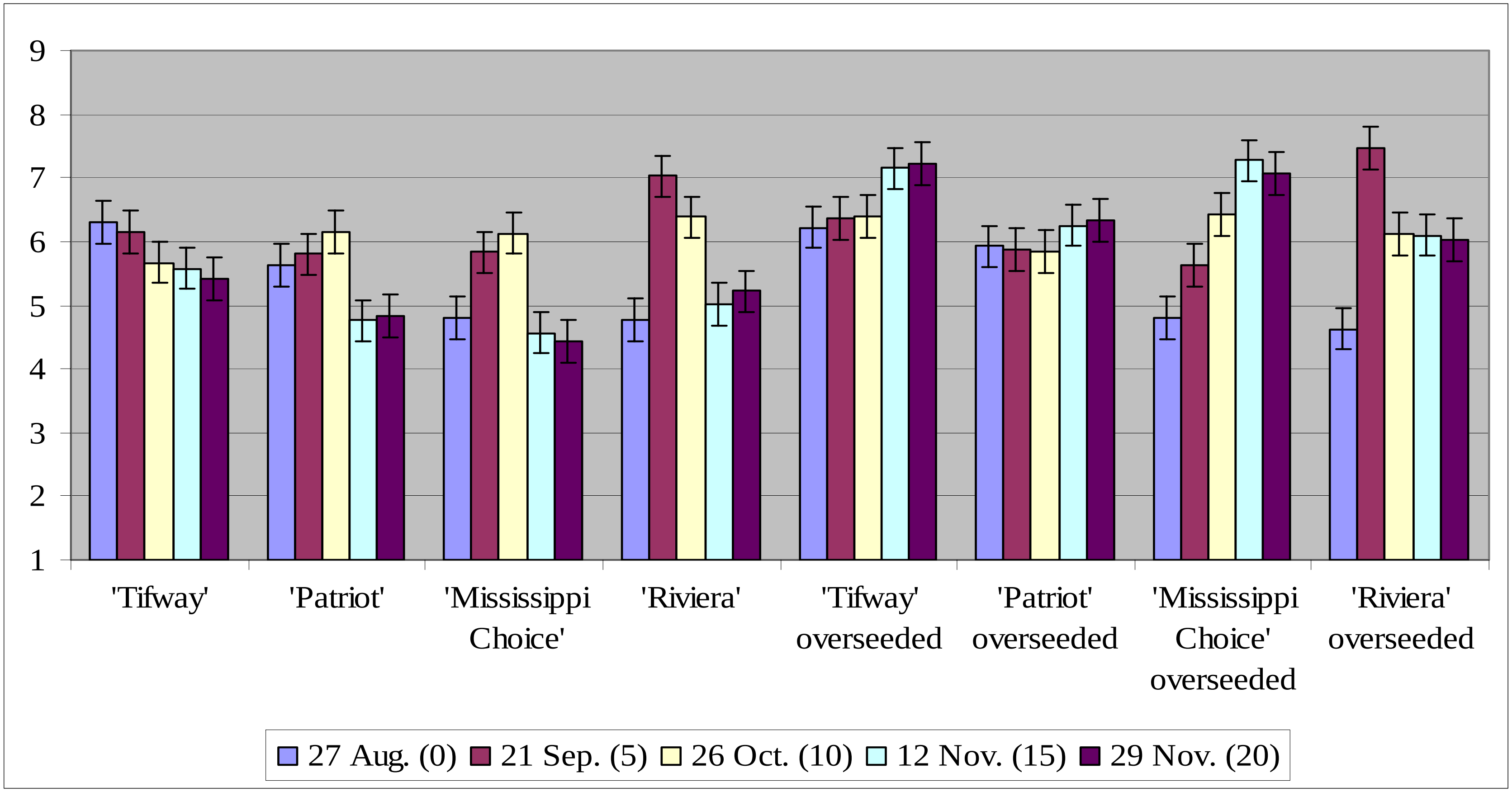

Figure 1.11. Variety and overseeding treatment† interactions over time for quality ratings‡. Knoxville, TN. Fall 2007.
† Overseeding treatments were applied at 67 g/m^2 on 1 October (after traffic event 7).
‡ Quality ratings were determined using digital image analysis.
§ (#) Indicates number of traffic events applied with the Cady Traffic Simulator.

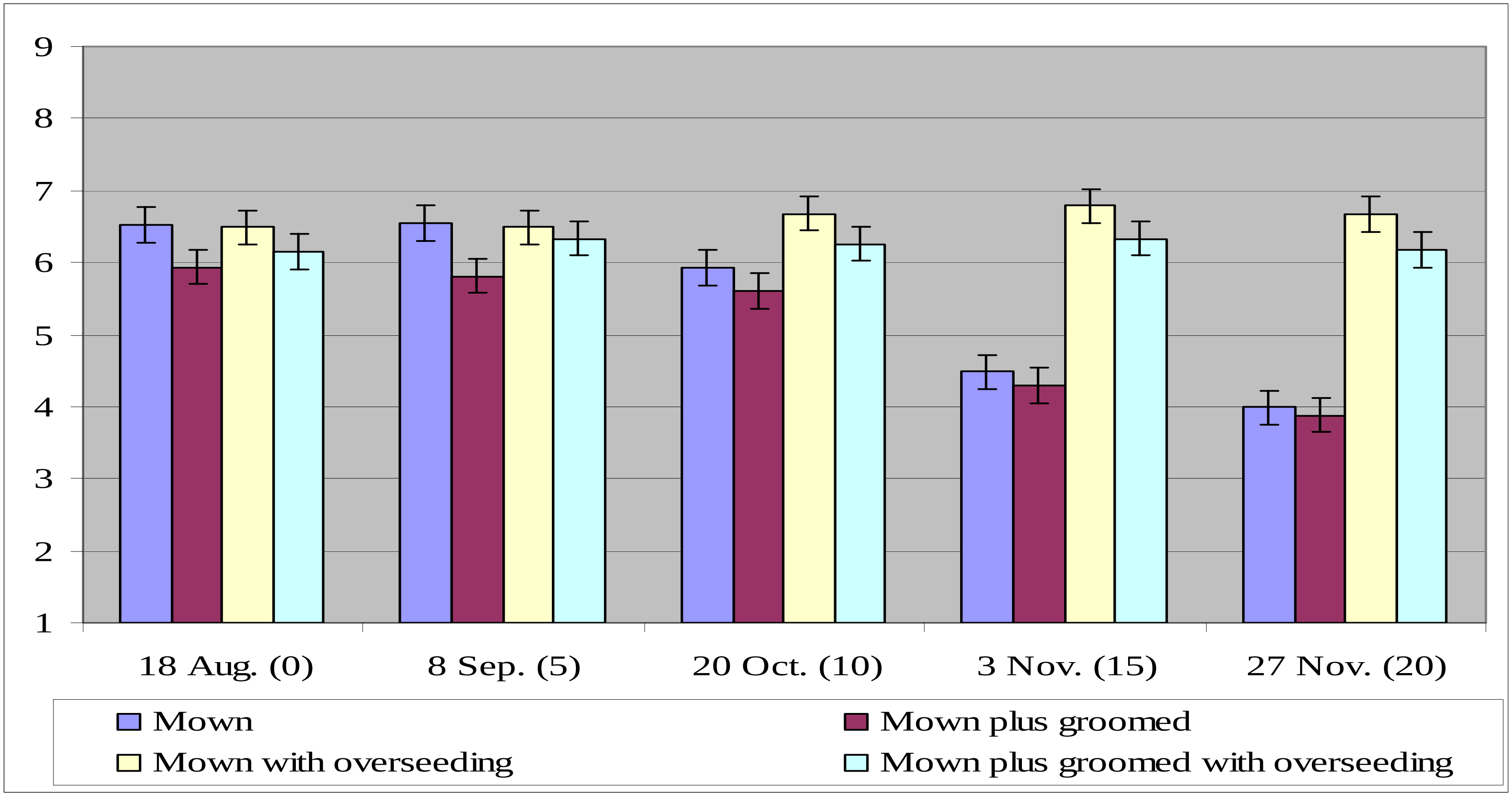

Figure 1.12. Mowing† and overseeding treatment‡ interactions over time for quality ratings§. Knoxville, TN. Fall 2006.

† Mowing treatments were completed with a reel mower three times a week from 10 July to 16 November; grooming treatments consisted of light vertical mowing with a reel mower three times a week from 10 July to 31 August.

‡ Overseeding treatments were applied at 67 g/m^2 on 22 September (after traffic event 5).

§ Quality ratings were determined using digital image analysis.

¶ (#) Indicates number of traffic events applied with the Cady Traffic Simulator.

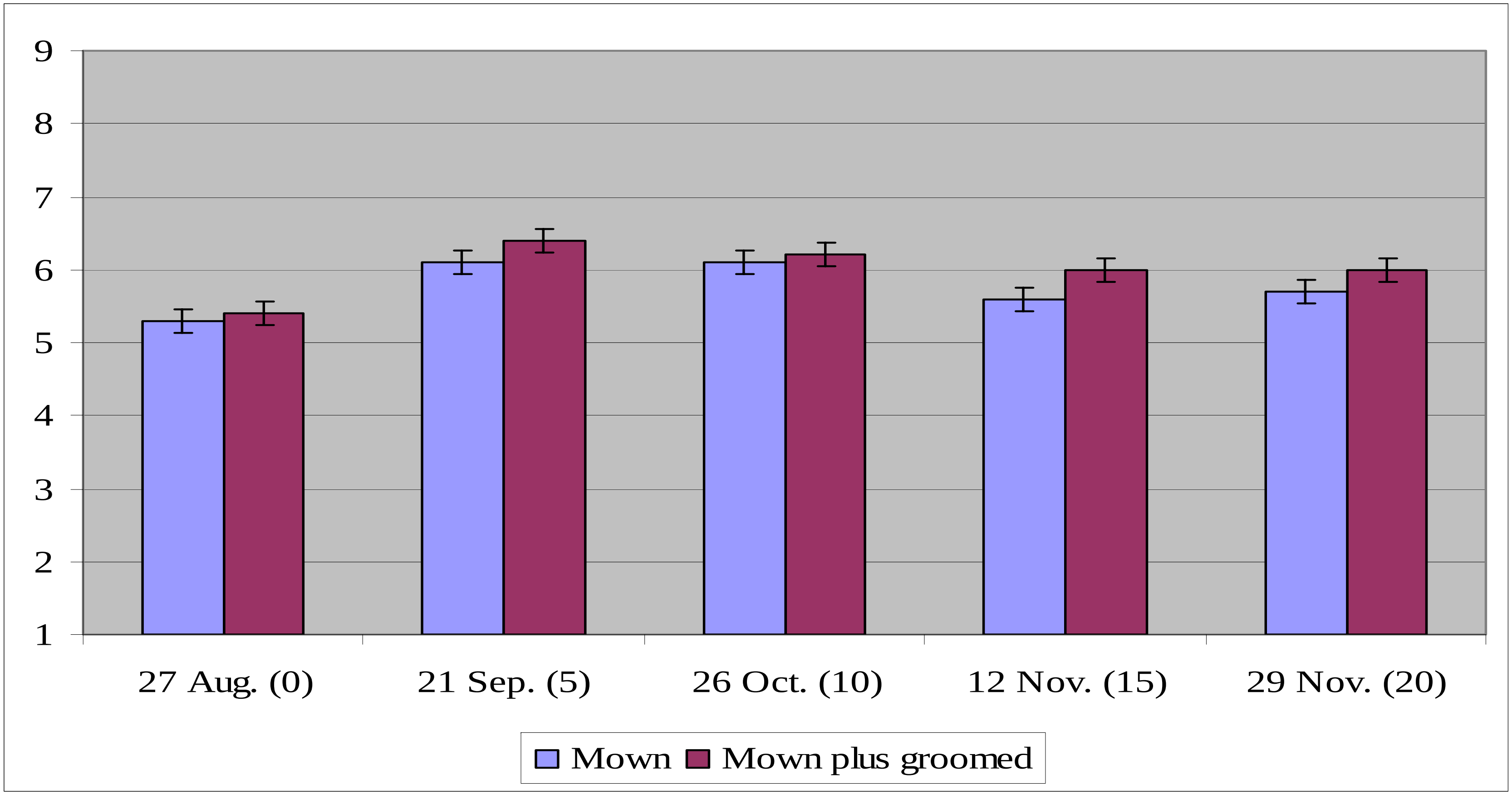

Figure 1.13. Mowing, treatment† interactions over time for quality ratings‡. Knoxville, TN. Fall 2007.
† Mowing treatments were completed with a reel mower three times a week from 10 July to 16 November; grooming treatments consisted of light vertical mowing with a reel mower three times a week from 10 July to 31 August.
‡ Quality ratings were determined using digital image analysis.
§ (#) Indicates number of traffic events applied with the Cady Traffic Simulator.

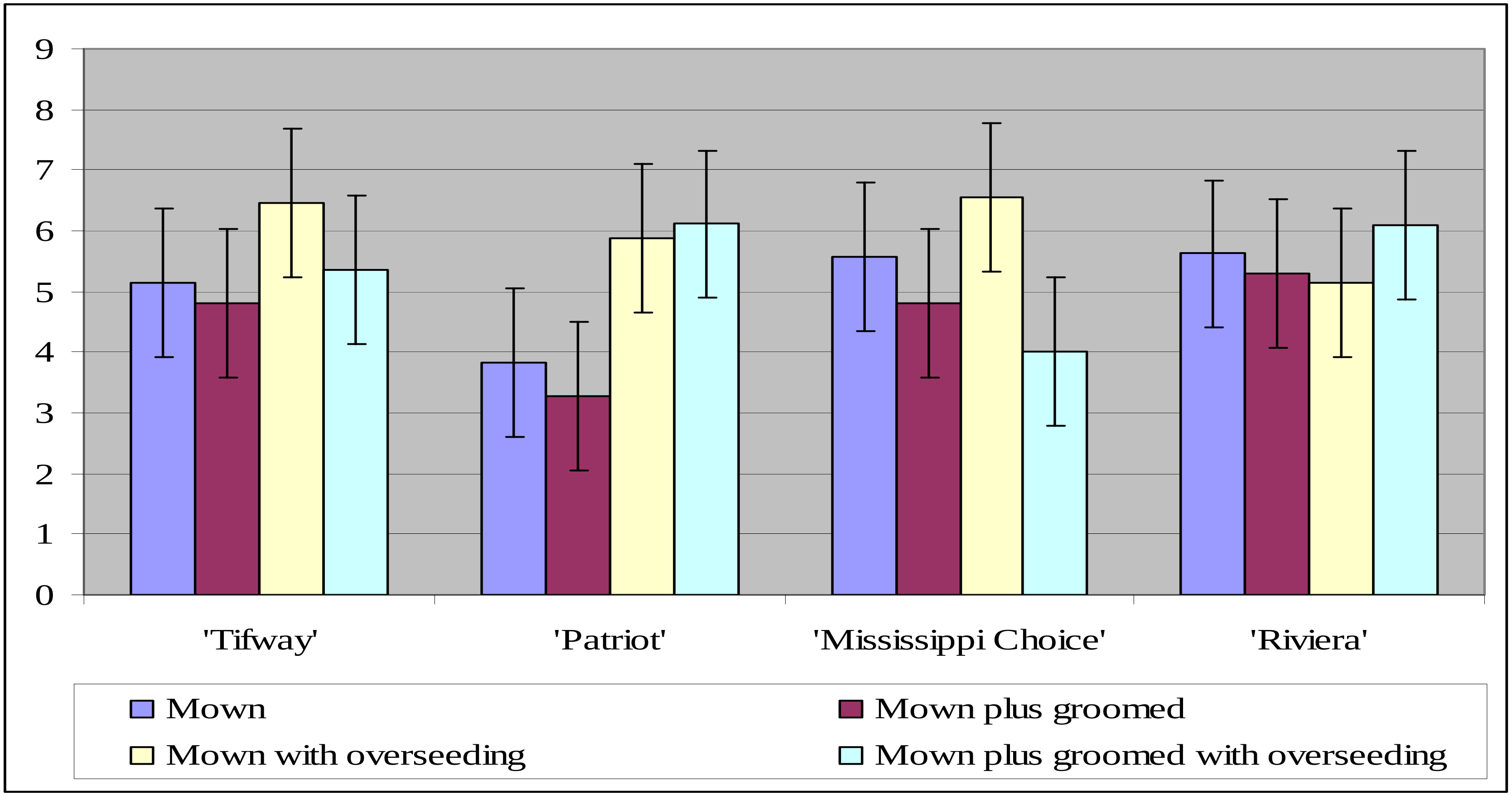

Figure 1.14. Variety, mowing†, and overseeding‡ treatment interactions on soil infiltration rates§. Knoxville, TN. Fall 2007.

† Mowing treatments were completed with a reel mower three times a week from 10 July to 16 November; grooming treatments consisted of light vertical mowing with a reel mower three times a week from 10 July to 31 August.

‡ Overseeding treatments were applied at 67 g/m^2 on 1 October (after traffic event 7).

§ Infiltration rates (amount of water passing through a point in a set amount of time) are represented in cm/hr.

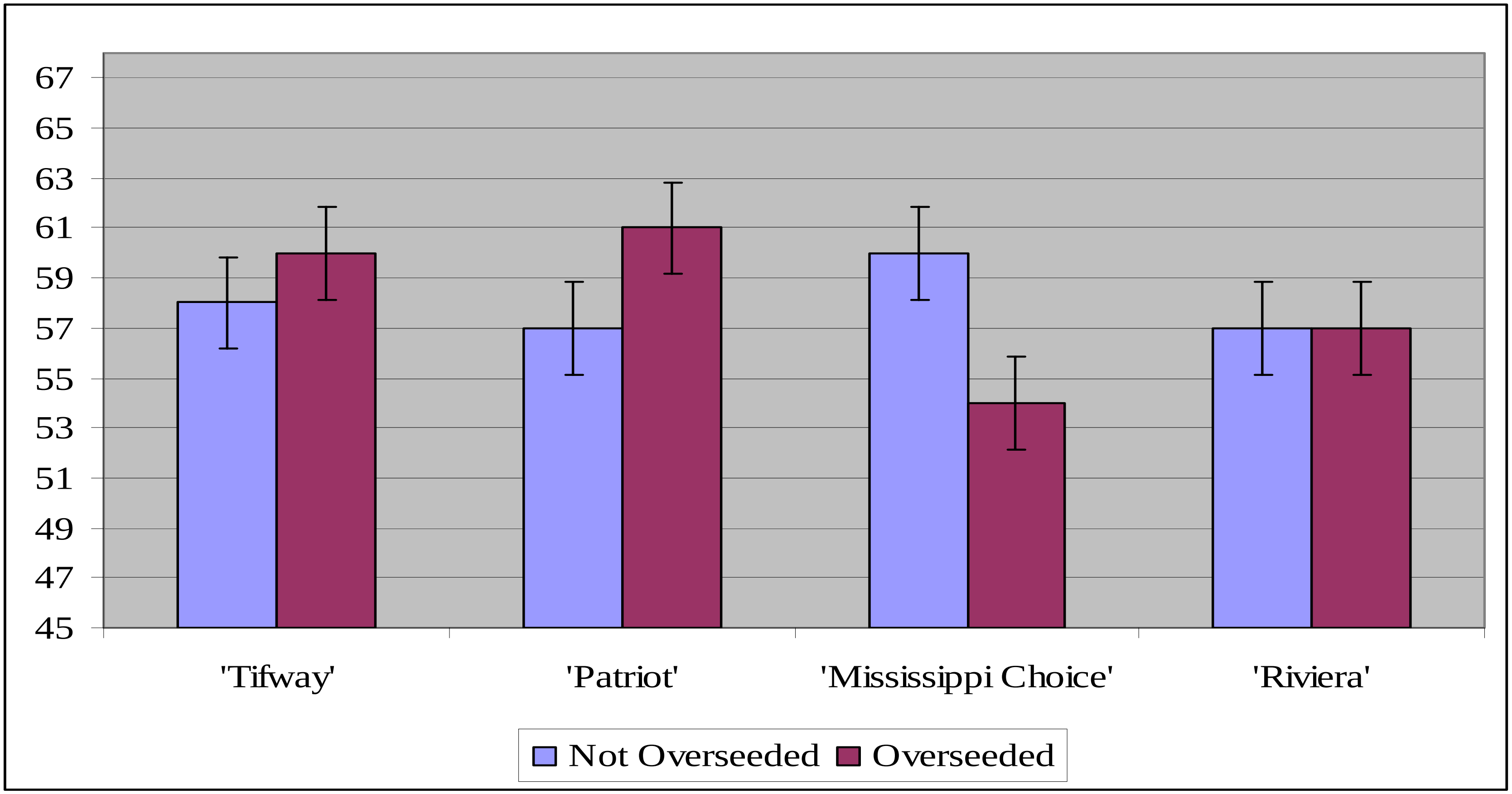

Figure 1.15. Variety and overseeding† treatment interactions on total soil porosity‡. Knoxville, TN. Fall 2006.
† Overseeding treatments were applied at 67 g/m^2 on 22 September (after traffic event 5).
‡ Total soil porosity is percent of the total weight of the soil core for capillary porosity and air-filled porosity.

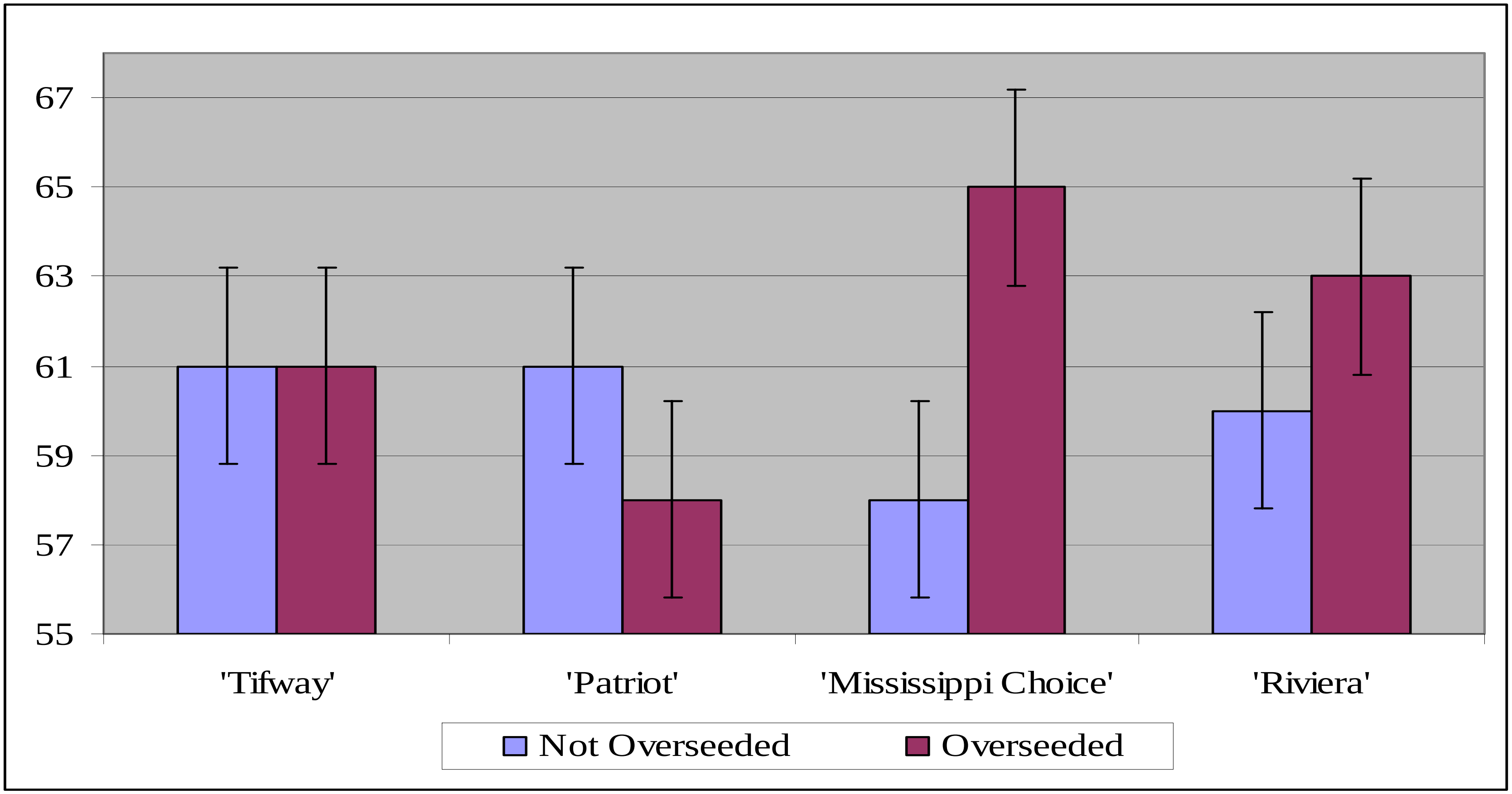

Figure 1.16. Variety and overseeding† treatment interactions on total soil porosity‡. Knoxville, TN. Fall 2007.
† Overseeding treatments were applied at 67 g/m^2 on 1 October (after traffic event 7).
‡ Total soil porosity is percent of the total weight of the soil core for capillary porosity and air-filled porosity.

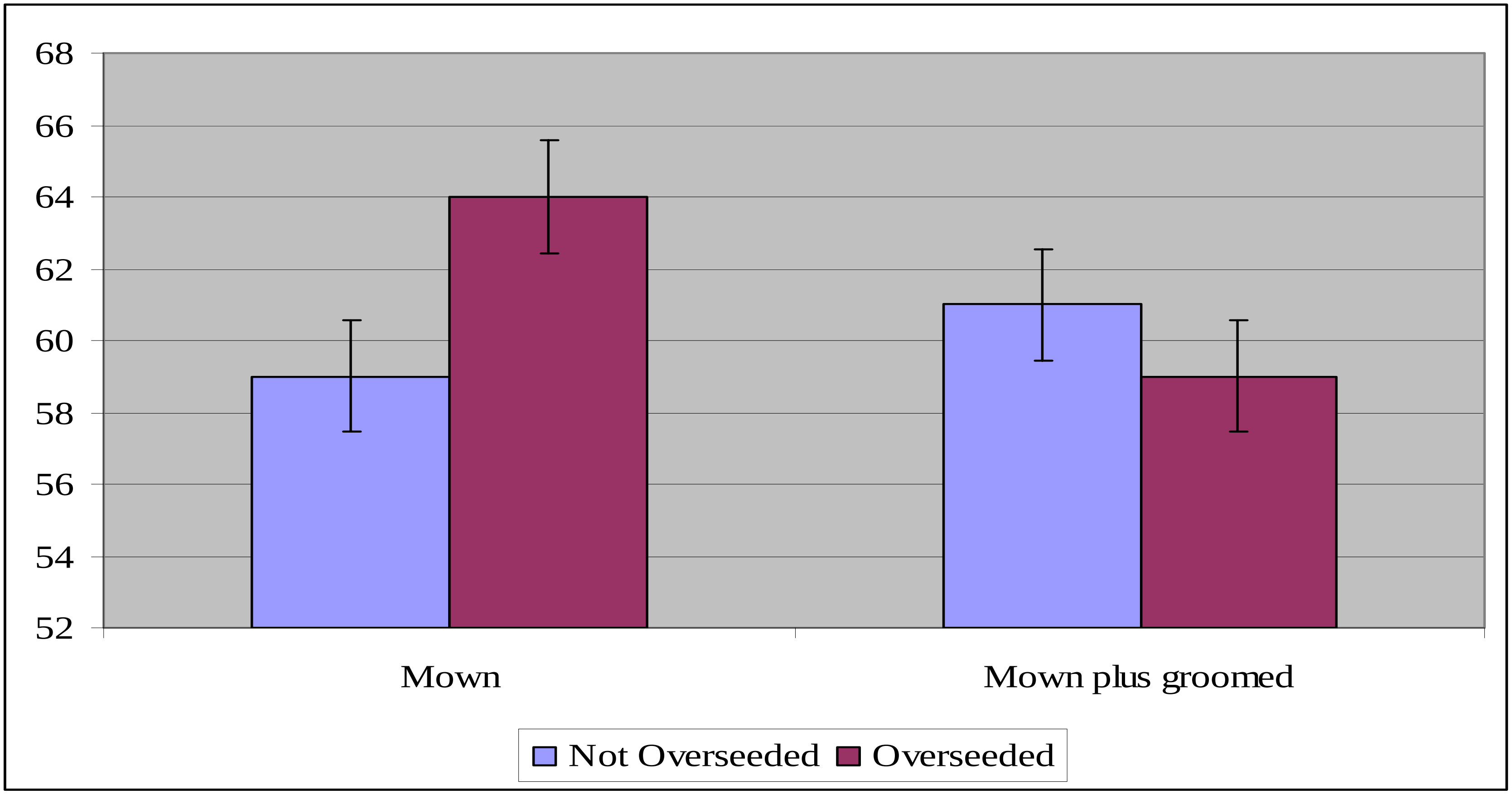

Figure 1.17. Mowing† and overseeding‡ treatment interactions on total soil porosity§. Knoxville, TN. Fall 2007.
† Mowing treatments were completed with a reel mower three times a week from 10 July to 16 November; grooming treatments consisted of light vertical mowing with a reel mower three times a week from 10 July to 31 August.
‡ Overseeding treatments were applied at 67 g/m^2 on 1 October (after traffic event 7).
§ Total soil porosity is percent of the total weight of the soil core for capillary porosity and air-filled porosity.

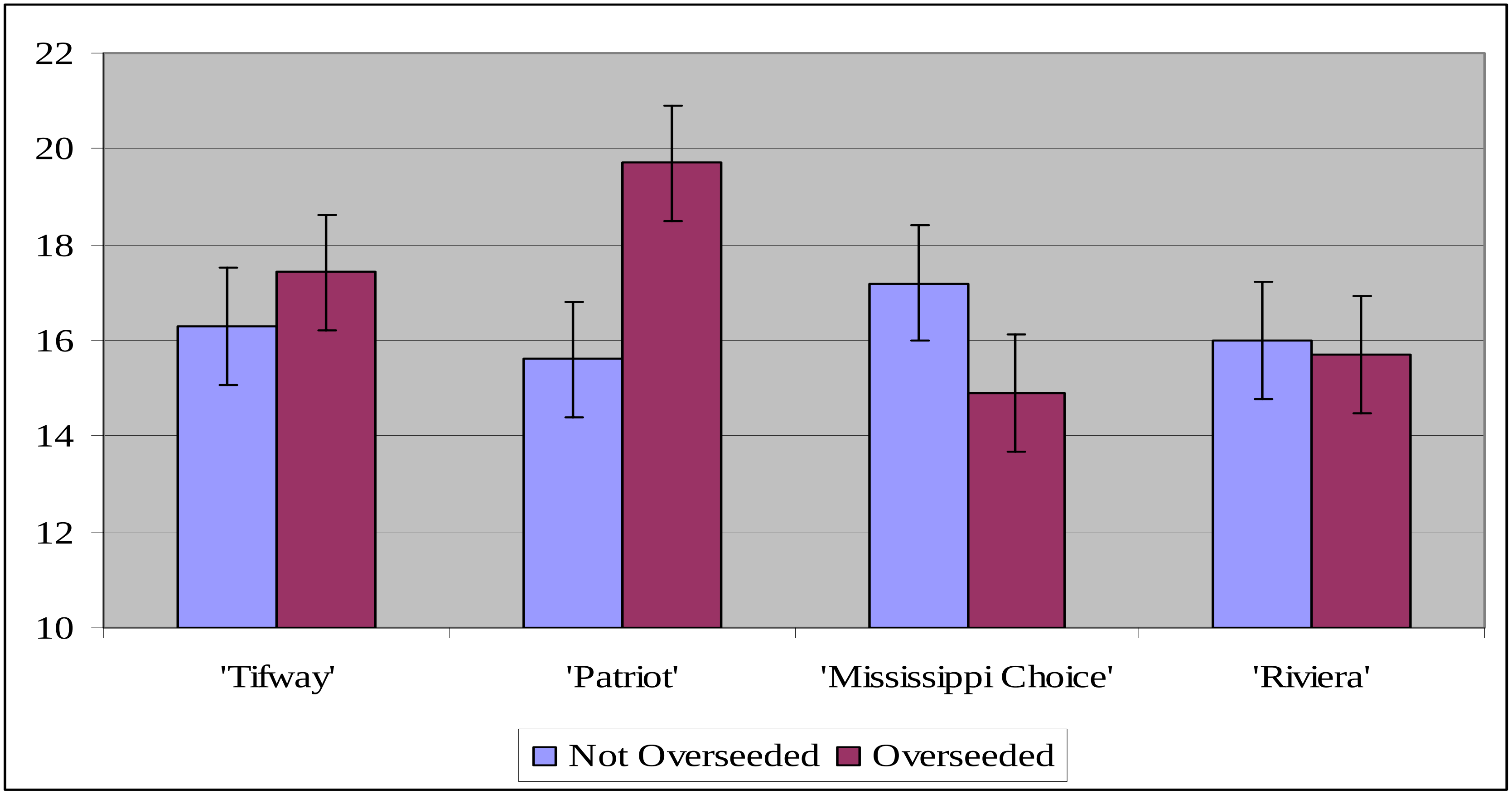

Figure 1.18. Variety and overseeding† treatment interactions on air-filled soil porosity‡. Knoxville, TN. Fall 2006.
† Overseeding treatments were applied at 67 g/m^2 on 22 September (after traffic event 5).
‡ Air-filled soil porosity is the percent of the total weight of the soil core at field capacity

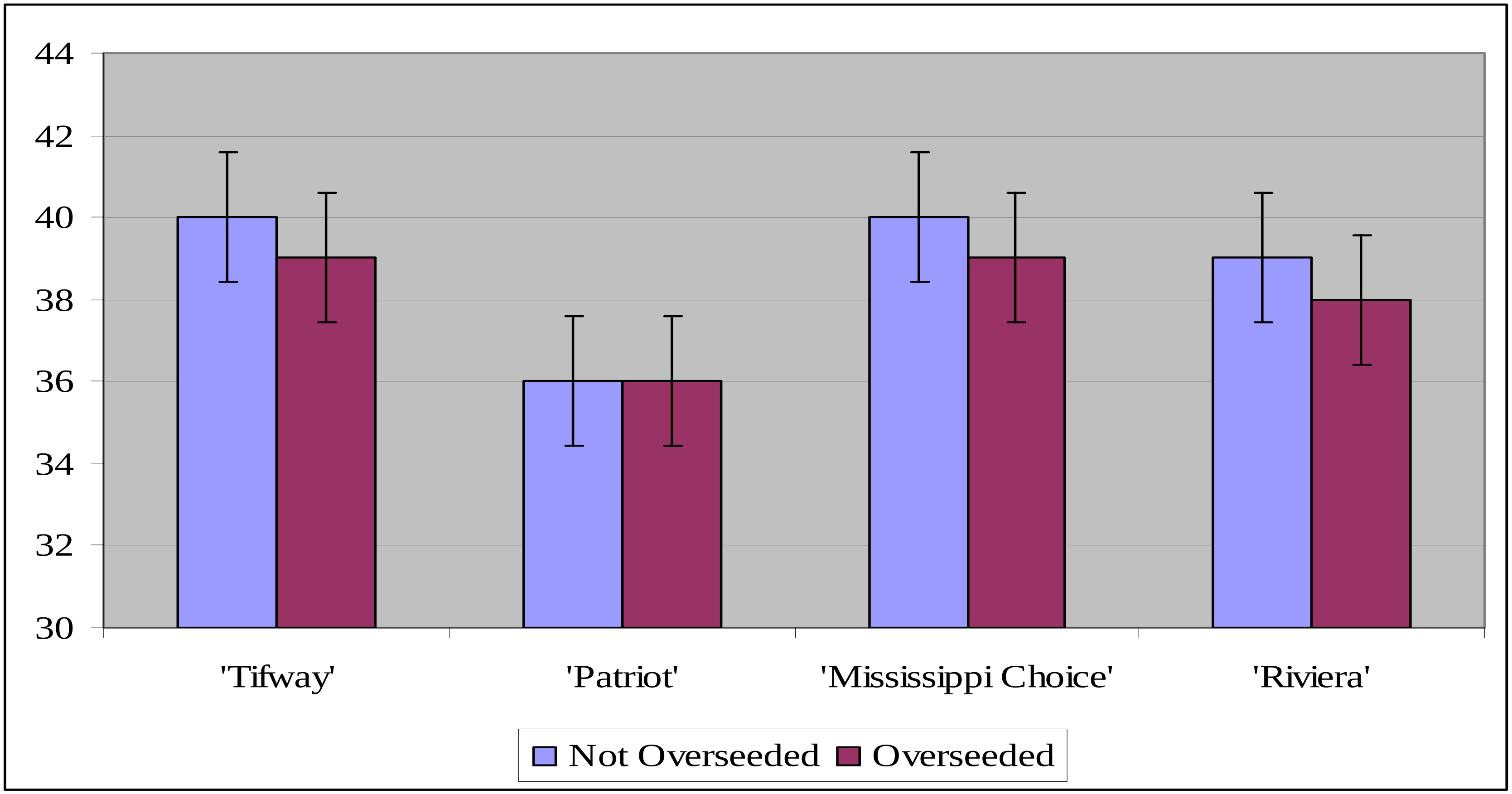

Figure 1.19. Variety and overseeding† treatment interactions on capillary porosity‡. Knoxville, TN. Fall 2007.
† Overseeding treatments were applied at 67 g/m^2 on 1 October (after traffic event 7).
‡ Capillary porosity is the percent of the total weight of the soil core at zero moisture.

Figure 1.20. Mowing† and overseeding‡ treatment interactions on capillary porosity§. Knoxville, TN. Fall 2007.

† Mowing treatments were completed with a reel mower three times a week from 10 July to 16 November; grooming treatments consisted of light vertical mowing with a reel mower three times a week from 10 July to 31 August.

‡ Overseeding treatments were applied at 67 g/m^2 on 1 October (after traffic event 7).

§ Capillary porosity is the percent of the total weight of the soil core at zero moisture.

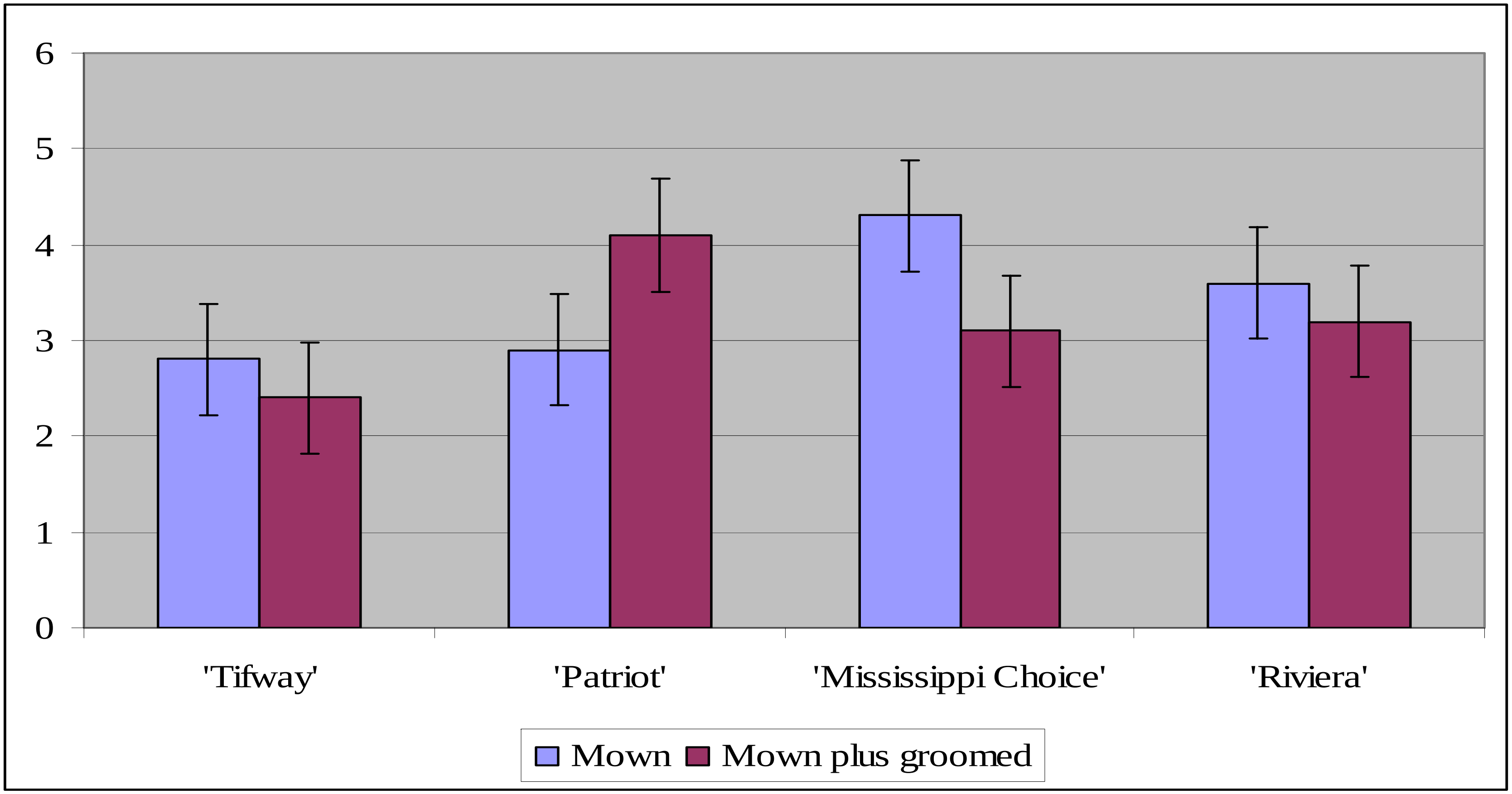

Figure 1.21. Variety and mowing† treatment interactions on surface organic matter‡. Knoxville, TN. Fall 2007.
† Mowing treatments were completed with a reel mower three times a week from 10 July to 16 November; grooming treatments consisted of light vertical mowing with a reel mower three times a week from 10 July to 31 August.
‡ Surface organic matter consisted of verdure and thatch.

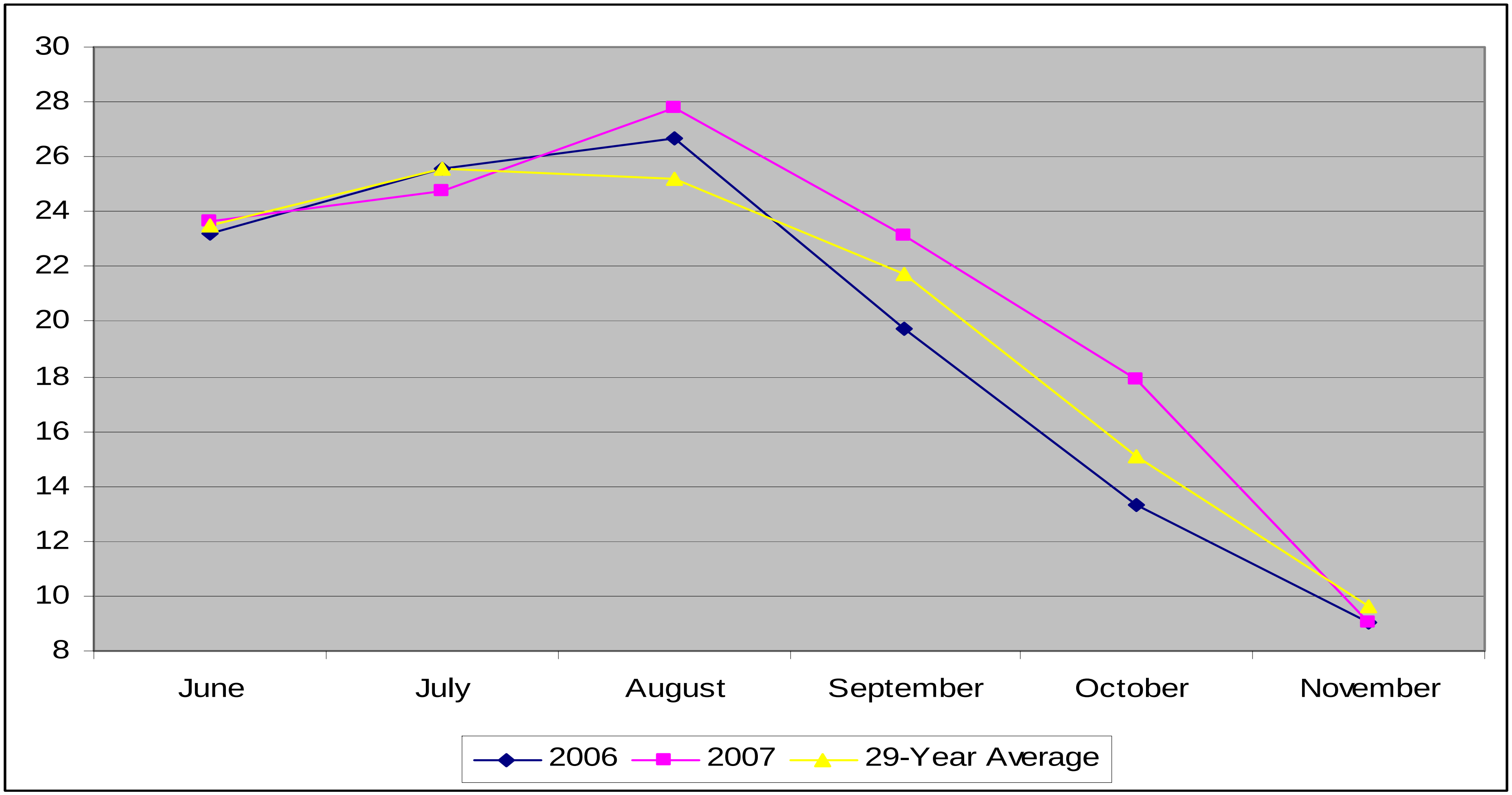

Figure 2.1. Average daily temperatures in degrees Celsius. Knoxville, TN. Fall 2006, 2007† and 29-year average‡.
† 2006 and 2007 average daily temperatures were taken at the East Tennessee Research and Education Center.
‡ 29-year average for Knoxville, TN was courtesy of N.O.A.A.

VITA

Adam William Thoms was born in Waverly, Iowa, on September 9, 1983. He graduated from Waverly-Shell Rock High School in 2002. He then attended Iowa State University where he received his Bachelor of Science degree in Horticulture in 2006, specializing in turfgrass management. He attended the University of Tennessee at Knoxville where he completed his Master of Science degree in Plant Science, specializing in turfgrass science. Upon finishing his thesis, Adam plans to pursue a Ph.D. at the University of Tennessee.