GROOMING FREQUENCY AND SPACING EFFECTS ON A TIFEAGLE

BERMUDAGRASS PUTTING GREEN

Except where reference is made to the work of others, the work described in this thesis is my own or was done in collaboration with my advisory committee. This thesis does not include proprietary or classified information.

William E. Dunnivant

Robert H. Walker
Professor
Agronomy and Soils

Elizabeth A. Guertal, Chair
Professor
Agronomy and Soils

David Y. Han
Extension Specialist &
Associate Professor
Agronomy and Soils

Amy N. Wright
Associate Professor
Horticulture

George T. Flowers
Interim Dean
Graduate School

GROOMING FREQUENCY AND SPACING EFFECTS ON A TIFEAGLE

BERMUDAGRASS PUTTING GREEN

William E. Dunnivant

A Thesis

Submitted to

the Graduate Faculty of

Auburn University

in Partial Fulfillment of the

Requirements for the

Degree of

Master of Sciences

Auburn, Alabama
August 9, 2008

GROOMING FREQUENCY AND SPACING EFFECTS ON A TIFEAGLE

BERMUDAGRASS PUTTING GREEN

William E. Dunnivant

Signature of Author

Date of Graduation

VITA

William Edwin Dunnivant, son of Jeff and Maryanne Dunnivant, was born May 31, 1983 in Decatur, Alabama. He graduated from Decatur High School in 2001. In the fall of 2001, he entered Auburn University and graduated cum laude in 2005 with a Bachelor of Science degree in Agronomy and Soils. In the spring of 2006 he was accepted into the Graduate School at Auburn University. He received a Master of Science degree in Agronomy and Soils in some month, 2008.

THESIS ABSTRACT

GROOMING FREQUENCY AND SPACING EFFECTS ON A TIFEAGLE

BERMUDAGRASS PUTTING GREEN

William E. Dunnivant

Master of Science, August 9, 2008
(B.S., Auburn University, 2005)

61 Typed Pages

Directed By Elizabeth A. Guertal

Cultivation methods for the ultradwarf hybrid bermudagrasses (*Cynodon dactylon* (L.) Pers. x *C. transvaalensis* Burtt Davy) are relatively unstudied. The ultradwarf bermudagrasses, with their slow recovery from cultivation for thatch control, may be well-suited for a less severe type of vertical mowing, commonly called grooming. The objective of this research study was to examine the effects of grooming frequency and groomer blade spacing on the quality and agronomic performance of a TifEagle hybrid bermudagrass putting green. The 2 yr experiment was a randomized complete block design with 3 replications, with factorial treatments of grooming frequency (1x/week, 3x/week and 6x/week) and groomer blade spacing (6.4 and 12.8 mm).

All treatments were applied with the groomers mounted in front of walking greens mowers, with all plots maintained at a 3.0 mm mowing height. In each year treatments were applied from May through Sept. Collected data included monthly quality, monthly shoot density, monthly clipping yield, and monthly dry mass of stolon and rhizomes. Yearly data collection included thatch depth, fall carbohydrate content, modified stimpmeter readings, and root mass. There was slight evidence that increased grooming frequency reduced dry weight of stolons and rhizomes. In general, grooming frequency and groomer spacing had little effect on shoot growth, clipping yield, color, quality or ball roll in this Tifeagle hybrid bermudagrass putting green.

ACKNOWLEDGEMENTS

I would like to thank Dr. Elizabeth Guertal and the members of my graduate committee for their guidance, support, and cooperation throughout the course of my masters research project. I am grateful for your patience and willingness to help me learn throughout this endeavor. To Jim Harris and Christy Hicks, Superintendent and Assistant Superintendent of the Auburn University Turfgrass Research Unit, I especially thank you for ensuring that my research was well taken care of on a daily basis. Special thanks also to our turfgrass research technician Bill Bryce, and to all of the student workers for their help with the field and lab work that made completion of this project possible. And to my fellow graduate students Brad Young and Ellen Knight, thank you for all of your help, friendship, and support. And last of all, I would like to thank both of my parents, Jeff and Maryanne Dunnivant, my brother Christopher Dunnivant, and the rest of my family for all their love, support, and encouragement throughout my years at Auburn University.

Style manual or journal used Publications Handbook and Style Manual of the American Society of Agronomy

Computer software used Microsoft Excel 2003, Microsoft Word 2003, and The SAS System for Windows v 9.1

TABLE OF CONTENTS

LIST OF TABLES x

LIST OF FIGURES xii

I. LITERATURE REVIEW 1

II. MATERIALS AND METHODS 12

III. RESULTS AND DISCUSSION 17

IV. CONCLUSIONS 27

LITERATURE CITED 28

APPENDIX 33

LIST OF TABLES

Table 1. Initial soil test results from the TifEagle hybrid bermudagrass putting green used as the research site, Auburn, AL..34

Table 2. Effect of grooming frequency on shoot density of TifEagle hybrid bermudagrass, Auburn, AL..35

Table 3. Effect of groomer blade spacing on shoot density of TifEagle hybrid bermudagrass, Auburn, AL..36

Table 4. Effect of grooming frequency and groomer blade spacing on thatch depth of a TifEagle hybrid bermudagrass putting green, Auburn, AL 37

Table 5. Effect of grooming frequency on the dry weight of stolon and rhizomes harvested from TifEagle hybrid bermudagrass, Auburn, AL 38

Table 6. Effect of groomer blade spacing on the dry weight of stolon and rhizomes harvested from TifEagle hybrid bermudagrass, Auburn, AL 39

Table 7. Effect of grooming frequency on clipping yield of TifEagle hybrid bermudagrass, Auburn, AL, 2006...40

Table 8. Effect of grooming frequency on clipping yield of TifEagle hybrid bermudagrass, Auburn, AL, 2007...41

Table 9. Effect of grooming on clipping yield of TifEagle hybrid bermudagrass, Auburn, AL, 2006. 42

Table 10. Effect of groomer blade spacing on clipping yield of TifEagle hybrid bermudagrass, Auburn, AL, 2007. 43

Table 11. Carbohydrate content (dry matter basis) of a TifEagle hybrid bermudagrass putting green, Auburn, AL. 44

Table 12. Effect of grooming frequency and groomer blade spacing on Stimpmeter speed of TifEagle hybrid bermudagrass, Auburn, AL. 45

Table 13. Overseed shoot density on a TifEagle hybrid bermudagrass putting green, Auburn, AL. 46

LIST OF FIGURES

Figure 1. Effect of grooming frequency on the shoot density of TifEagle hybrid bermudagrass, Auburn, AL. 47

Figure 2. Effect of grooming frequency on the dry weight of stolons and rhizomes harvested from TifEagle hybrid bermudagrass, Auburn, AL 48

Figure 3. Effect of grooming frequency on golf ball roll, Auburn, AL. 49

I. LITERATURE REVIEW

Introduction

The ever increasing demand for high quality putting greens, coupled with the high maintenance required to sustain bentgrass (*Agrostis palustris* Huds.) in the southeast has produced finer textured bermudagrasses that have the ability to be mowed closely, producing putting green speeds comparable to bentgrass. Hybrid bermudagrass (*Cynodon dactylon* x *Cynodon transvaalensis* L.) is a long-lived perennial with stolons and rhizomes that facilitate aggressive spread and tolerance to low mowing heights. Because it is a warm-season turf with excellent heat, drought, and wear tolerance, it is a commonly used turf on southern putting greens (Taliaferro et al., 2004).

Until the late 1940's and mid 1950's, common variants of seeded bermudagrass (*Cynodon dactylon* L.) were used on golf course putting greens. When maintained at low mowing heights, common bermudagrass produces thin, bumpy turf, and a poor putting surface. To combat this problem, 'Tifgreen' and 'Tifdwarf' were released as improved putting green-type bermudagrass cultivars. Tifgreen, an interspecific hybrid between *C. dactylon* and African bermudagrass (*C. transvaalensis*), was released in 1956 by Dr. Glen W. Burton of the USDA in Tifton, Georgia for its high shoot density, fine texture, and tolerance to low mowing heights (Hein, 1961).

Tifdwarf, a 1965 release by Dr. Burton, is believed to be a natural mutant from Tifgreen and is superior to Tifgreen, with shorter leaves and internodes (Burton, 1966).

Tifdwarf boasts a dark green color, low occurrence of seed heads, tolerance of mowing heights as low as 0.32 cm (1/8”) and late fall color retention. Tifdwarf doesn’t differ from Tifgreen in its tolerance of poor drainage, heavy traffic, or cold weather, but it does break dormancy 10 to 11 days earlier than Tifgreen, and it has better shade tolerance when compared with other bermudagrasses (Moncrief, 1967).

Since its release in 1965, Tifdwarf has become the standard for high-quality bermudagrass putting greens in the southeastern US. In the early to mid 1970’s, however, patches of different-looking bermudagrass began to occur in hybrid bermudagrass greens that were around 10 years old. Most of these ‘off-types’ made consistent maintenance difficult and were removed as soon as spotted by the superintendent. Superintendents and turf breeders made selections of these different-looking areas that seemed to be superior to their existing bermudagrass, and some attempted to plant greens with their selections (Moncrief, 1975).

In the last 10 to 15 years some of these collected off-types have emerged as new cultivars. Collectively termed the ultradwarfs (White et al., 2004), these ultradwarf cultivars are often selections of superior off-types from Tifdwarf and Tifgreen. Examples of such cultivars include ‘Champion’ and ‘MS Supreme’ (Krans et al., 1999). Alternatively, other ultradwarf cultivars were developed through controlled mutations of other bermudagrasses. The most common of these is ‘TifEagle’, a selected Co_{60}-irradiated mutant from ‘Tifway II’ (Hanna and Elsner, 1999).

TifEagle is a cultivar derived from irradiating stolons of Tifway II, a bermudagrass used in golf course fairways and athletic fields. This was done to produce a high quality, broadly adapted, and genetically stable turf that could withstand prolonged mowing at heights of 3.2 mm, and could be mowed as low as 2.5 mm. TifEagle also has finer leaves and shorter internodes, produces more shoots, and maintains a better fall color than Tifdwarf (Hanna, 1998; Gray and White, 1999).

Thatch Production in Hybrid Bermudagrass

Although finer leaves, shorter internodes and increased shoot production promotes a smoother denser putting surface that is beneficial to the golfer, these same characteristics can be detrimental to the prolonged well-being of the turf itself. One major problem that has arisen with TifEagle, when compared to Tifdwarf, is the production of excess thatch (Guertal and White 1998; Hollingsworth et al., 2005).

Thatch is defined as “an intermingled organic layer of dead and living shoots, stems, and roots of grasses that develops between the turf canopy of green vegetation and the soil surface” (Beard, 2002). Shallow thatch can provide surface resiliency and wear tolerance, while excessive or deep thatch can lead to increased disease and insect problems, shallow roots, poor fertilizer and pesticide response, decreased drought tolerance, increased susceptibility to environmental stresses, and scalping (Hurto et al., 1980; Ledeboer and Skogley, 1967).

When compared to the underlying soil, thatch has higher (>10 times) carbon (C) and nitrogen (N) content, greater microbial biomass, lower bulk density and greater porosity (Raturi et al., 2004). Thatch, and the surface soil that underlies thatch, has a lower infiltration rate and less moisture retention when compared to a thatch free surface soil (Hurto et al., 1980). Ledeboer and Skogley (1967) reported that high amounts of lignin in thatch may lead to reduced microbial degradation, inhibition of thatch decomposition, and further thatch buildup.

TifEagle, with its high shoot density and shorter internodes, is more prone to thatch production than Tifdwarf (Hollingsworth et al., 2005). In order to combat detrimental accumulations of thatch, cultivation techniques aimed toward controlling and maintaining an acceptable thatch layer must be implemented. These techniques may include topdressing, water injection, vertical mowing, or some type of tine aeration.

Cultivation Techniques for the Control of Thatch

Topdressing

Topdressing, the application of a thin layer of sand or sand-soil to established putting greens, is a recommended cultural management practice for thatch control (Duble, 1996). If applied correctly, topdressing promotes thatch decomposition and recovery from injury and disease, smoothes the playing surface, creates a denser and finer textured turf, and reduces grain (the tendency of turf to grow in one direction). Topdressing material should match the growth medium of the turf on which it is applied so as to prevent layering of different soil textures, which can lead to air and water movement issues. Topdressing can smother the turf if it is applied too thick, and can also introduce weeds if the topdressing material is not sterilized prior to application (Duble, 1996). Topdressing is usually applied with a mechanical powered topdresser and then brushed or watered into the turf (Foy, 1991).

Light topdressing two to three times per month is recommended to smooth the putting surface and aid in reduction of thatch accumulation (Guertal and White, 1998). More rapid thatch decomposition has been observed when the thatch is in close contact with mineral soil (topdressing), due to improvement in the microenvironment needed for thatch decomposition (Ledeboer and Skogley, 1967). Plant residues were more decomposed with frequent topdressings, as compared to topdressing once per year. Multiple topdressings per year were more beneficial, helping firm the surface and prevent scalping, on younger putting greens, when compared to older, well established greens (White and Dickens, 1984). White and Dickens (1984) also found that topdressing four times per year was more effective in reducing thatch accumulation than a single yearly application, but that thatch levels were not significantly reduced below those at the beginning of the study. In another study, when topdressing either biweekly and light, or as one heavy application per year were compared, both were found to be an insufficient thatch control/reduction method (White et al., 2004). Others have also found topdressing to be insufficient for thatch control, with thatch depth on a velvet bentgrass (*Agrostis canina* L.) putting green unaffected by topdressing (Boesch and Mitkowski, 2007). Last, in a zoysiagrass (*Zoysia japonica* Steud.) lawn, application of topdressing did not affect mat (underground rhizomes and thatch) depth (Dunn et al., 1995).

Hollingsworth et al. (2005) found that multiple (14 times) light topdressings per year increased thatch depth, compared to fewer (3 times) heavy topdressings per year, likely a result of sand accumulation. This finding was similar to that of Callahan, which also showed that thatch depth might be greatly affected by sand accumulation. Because of this accumulation some researchers do not measure thatch as depth, but instead measure it as percent organic matter, using a loss on ignition method (Callahan, 1997).

Topdressing to a depth of 6.4 mm once and twice per year on a Tifway bermudagrass lawn reduced thatch by 44% and 62% respectively (Carrow et al., 1987). When used as a cultivation tool other than for thatch removal, topdressing was found to be an ineffective method in promoting spring bermudagrass emergence on an overseeded bermudagrass putting green (Mazur and Wagner, 1987). Topdressing a creeping bentgrass green both 3 and 6 times per year was a significant method of reducing thatch, compared to zero topdressing (Callahan et al., 1998). In another study on creeping bentgrass, topdressing alone was ineffective in controlling or preventing thatch accumulation (McCarty et al., 2005).

Core Aerification/Cultivation

Core aerification is the mechanical removal of small soil and grass cores (6.4 to 19 mm wide and to a depth of 5 to 10 cm) from the turf surface. Once removed, the cores are either collected and disposed of, or pulverized and worked back into the putting surface. A topdressing application commonly follows core aerification. Core aerification is detrimental to the turf surface and greatly reduces the playability of the putting green until recovery from aerification is complete. The benefits, however, far outweigh these setbacks. Aerification relieves soil compaction, allows faster penetration of water, pesticides, fertilizer, and topdressing, enhances gas exchange, improves drainage and reduces localized dry spots, increases rooting, and improves environmental conditions that promote microorganism activity that leads to thatch decomposition (McCarty and Canegallo, 2005). Aerifying is done with aerifying machines on large scale (>30 m^2) projects and can also be done on a smaller scale with hand held, human powered aerifiers.

In one study on three bermudagrasses, no difference was found in the rate of thatch accumulation between monthly and twice yearly core aerification treatments. The more frequent aerification did reduce scalping (White and Dickens, 1984). In a study on creeping bentgrass, no thatch control effects occurred with four core cultivations annually, and turf quality declined due to scalping (McCarty et al., 2005). Core aerification alone was found to be ineffective as a thatch reduction method on creeping bentgrass (Callahan et al., 1998). Increasing aeration frequency decreased the organic thatch layer on a Tifdwarf bermudagrass putting green (Smith, 1979). Murphy et al. (1992) reported no reduction in total organic matter due to core aerification. They also reported an increase in thatch depth, and a decrease in thatch organic matter fraction on a creeping bentgrass green. Core aerification once or twice yearly, whether the cores were removed or returned, was found to not be effective against thatch accumulation (Carrow et al., 1987). Core aerification plots were found to have lower turf quality than control plots in a study on overseed transition, and aerification was not effective in speeding up transition from perennial rye (*Lolium perenne* L.) to bermudagrass (Mazur and Wagner, 1987). Core aerification did not speed the disappearance of the overseed, and was found to reduce bermudagrass shoot density (Horgan and Yelverton, 2001). Changing the entry angles of aerification tines did not improve water infiltration on a bentgrass putting green (Baldwin et al., 2006).

Another form of cultivation similar to core aerification is water injection cultivation. Water injection cultivation is the high pressure injection of water pulses to reduce compaction while having minimal impact on playing surface quality. In a study on creeping bentgrass, water injection cultivation was found to be equal or superior to core aerification in increasing porosity and saturated hydraulic conductivity and reducing bulk density, but was not found to be an effective thatch control method compared to core aerification (Murphy and Rieke, 1994).

Vertical Mowing

Vertical mowing is the utilization of whirling blades turning in a vertical plane mounted on a horizontal shaft to slice the turf and reduce thatch. Blade width, spacing, and depth of cut are all adjustable, whether by adjusting a single machine, or using special vertical mowing reels mounted on a reel mower. This flexibility of vertical mowing severity contributes to the varying utilizations of vertical mowers. Routine vertical mowing improves the turf by aiding in the removal of grain, stimulation of new shoot development, and thatch removal (Duble, 1996). Thatch removal is positively correlated to the severity of the vertical mowing, as is putting surface disturbance and recovery time.

Severe vertical mowing is normally achieved by using stand alone vertical mowing units such as a Graden vertical mower (Graden Turf Machinery, 29 Scammel Street, Campbellfield, Victoria, Australia). These units typically cut deeper (2.5 cm) into the turf leaving visible slits and debris that must be removed. Topdressing typically follows this type of severe vertical mowing (Hollingsworth et al., 2005).

Less severe vertical mowing is less detrimental to the turf surface and can be done more frequently. This type of vertical mowing does produce visible slits in the turf, requires debris cleanup, and topdressing after vertical mowing. This can be done by adjusting a stand alone vertical mower to shallower depths or by replacing the mowing reels on a greens mower with vertical mowing reels. Less severe vertical mowing can be done on a more regular basis and is sometimes implemented biweekly between spaced out severe vertical mowing (White and Dickens, 1984).

Frequent light vertical mowing, or grooming, is the least severe vertical mowing practice currently utilized on putting greens. This light, non-invasive vertical mowing is achieved by attaching a grooming reel to greens mowers in front of the cutting blades. The blades on the groomer are typically spaced 0.64 cm apart and serve to groom the surface by standing up grass blades before they are mowed. The groomers also nick or slice stolons to produce new shoot development, and remove thatch near the surface (McCarty, 2005).

In a study evaluating both grooming and severe invasive vertical mowing on Tifdwarf bermudagrass, it was found that thatch depth was similar on plots groomed weekly compared to plots that received severe invasive vertical mowing twice yearly (White et al., 2004). White and Dickens (1984) found biweekly light vertical mowing of a bermudagrass green to be no more effective than twice yearly severe vertical mowing, and that the twice yearly treatment was less deleterious to the turf surface than was the biweekly treatment. Compared to control plots of Tifway bermudagrass not vertical mowed, vertical mowing once yearly to the depth of the soil surface had no effect on thatch accumulation while twice yearly vertical mowing of the same depth showed an 8% thatch depth reduction (Carrow et al., 1987).

On Tifway bermudagrass maintained at a height of 2.5 cm, vertical mowing deep enough to just groove the soil surface reduced thatch accumulation compared to plots not vertical mowed. In the same study, no significant difference was found between one, two, three, or six times per year vertical mowing. However, plots vertical mowed three or more times per year had the best turf quality (Johnson, 1979). On ultradwarf bermudagrass, grooming was found to be most advantageous on young stands of turf, but it was detrimental to mature stands by creating avenues for disease entry (White et al., 2004). In another study on ultradwarf bermudagrass putting greens, less severe (1.3 cm) monthly vertical mowing in the summer months produced more thatch than standard severe (2.5 cm) twice yearly vertical mowing, and it was concluded that ultradwarf bermudagrass may not require frequent deep vertical mowing for thatch control (Hollingsworth et al., 2005). Vertical mowing twice yearly alone, or grooming twice weekly alone, had no effect on thatch depth on a creeping bentgrass green, when compared to plots receiving only topdressing. However, when vertical mowing twice yearly, grooming twice weekly, and core aerification four times per year were part of the same cultivation program, thatch depth was reduced compared to topdressing alone (McCarty et al., 2005). In another study on creeping bentgrass, Callahan et al. (1998) found that the most effective thatch reduction technique was vertical mowing to the soil surface four to eight times per year, or vertical mowing plus core aerification, each four times per year. Grooming creeping bentgrass once and twice per month did not affect green speed, color, quality, or root production (Salaiz et al., 1995). Vertical mowing weekly in two directions to a depth of 2 mm below the soil surface, in an effort to promote spring emergence of overseeded bermudagrass, was found to be detrimental to bermudagrass coverage and overall turf quality (Mazure and Wagner, 1987). Vertical mowing in order to reduce *Poa annua* in an overseeded Tifway bermudagrass putting green reduced spring turf quality versus turf not vertical mowed (Johnson, 1986).

Conclusion

There is little research evaluating grooming, the least severe vertical mowing technique, in ultradwarf bermudagrass management. Of the grooming research, it largely examined grooming frequency, and no research has been reported that examines groomer spacing. Thus, the objective of this research is to evaluate grooming frequency and groomer blade spacing on the quality and performance of a TifEagle putting green.

II. METHODS AND MATERIALS

The 2-year study was conducted at the Auburn University Turfgrass Research Unit in Auburn, AL on a native soil push-up type putting green. The study was initiated in May of each year (2006 and 2007), following spring greenup of the 3-year-old TifEagle putting green. Soil type was a Marvyn loamy sand (Fine-loamy, siliceous, thermic Typic Kanhapludult). The study consisted of: 1) grooming frequencies of never, 1, 3, and 6 times per week, and, 2) groomer spacing of 12.8 (1/2 in) and 6.4 (1/4 in) mm. The study was a factorial design of 3 grooming frequencies and 2 groomer spacings, plus the ungroomed control, arranged in a randomized complete block design with three replications. Each plot was 3.2 x 2.6 m, with a 1.6 m alley between each plot so that the mower could be turned outside the plot area. A directional mowing scheme was used so that the plots were always mowed/groomed in a different direction at each mowing. For example, plots were mowed North to South one day, and Northeast to Southwest the next, followed by East to West on the third day. This ensured that groomed plots were groomed in varying directions. All plots were mowed at 3.2 mm, with groomers set at 25% below mowing height.

Soil samples 7.5 cm deep were taken from the research area on 19 December, 2005, to determine baseline soil nutrient levels and adjustments for P, K, and pH were made accordingly (112 kg ha^{-1} K_2O and 2240 kg ha^{-1} lime were applied to correct medium K levels and acidic soil conditions, respectively) (Adams et al., 1994).

Thereafter, soil tests were administered yearly to monitor fertilizer and lime needs throughout the remainder of the study (Table 1). N was applied monthly during the growing season at 1.3 g N m^{-2} (NH_4NO_3, 34-0-0).

On 30 May, 2006, grooming treatments were initiated. Treatments were applied with 2 Jacobson GreensKing 522 walk-behind putting green mowers (Jacobson, A Textron Company, 11108 Quality Dr., Charlotte, NC). One mower was fitted with a grooming reel having blades spaced 12.8 mm (1/2 in) apart and the other with a grooming reel with 6.4 mm (1/4 in) blade spacing. In 2006 all plots were mowed with the mower equipped with the 6.4 mm spaced grooming reel because the 12.8 mm spaced grooming reel was not available. Grooming reels with both spacings were available for 2007. The grooming reels could be turned off and on. Plots that were groomed 1 time per week were mowed with groomers activated on Wednesday, plots that were groomed 3 times per week were groomed on Monday, Wednesday and Friday, and plots that were groomed 6 times per week were groomed every day but Sunday. All plots not receiving treatments on any given day were mowed with groomers deactivated so that all plots were mowed every day except Sunday. All clippings were caught in the mower baskets and removed. Treatments were applied from initiation in May 2006 until fall dormancy in September 2006. Treatments were resumed May, 2007 and continued until fall dormancy in September 2007. All plots were overseeded in October (2006 and 2007) with *Poa trivialis* at 8.4 kg ha-1. The overseed was chemically removed in May prior to initiation of treatments with TranXit herbicide (Rimsulfuron, Sulfonylurea, DuPont).

Data Collected

From May until fall dormancy in September of each year the following data was collected: 1) monthly shoot density, 2) relative color and quality, 3) monthly dry weight of clippings, and 4) monthly thatch depth. Other data determined included dry weight of harvested rhizomes and stolons, soluble carbohydrate concentration (TNC), and overseed shoot density. Ball roll data via stimpmeter was also collected in 2007. The methods used to collect this data are described below.

Shoot Density

Monthly shoot density was obtained by hand-separating and counting shoots (a shoot was considered a node that produced leaf and/or root tissue) in a defined harvested area. Five 19 mm (3/4 in) diameter cores were removed from each plot. Shoots in each core were hand separated and counted. The numbers obtained were then added together and reported as number of shoots per 14.17 cm^2 (total area of all cores combined).

Color and Quality

Relative color and quality were determined visually and rated on a 1-9 scale. For color, 1 was considered completely brown and 9 was lush green. For quality, 1 was for dead turf and 9 was highest quality.

Clipping Dry Weight

Monthly dry weight of clippings was established by harvesting a known area of clippings with the mower. All clippings (excluding 28 September, 2006) were collected from an area of 1.46 m^2 (one pass across the 2.6 m width of the plot with the .56 m wide mower). On 28 September, 2006, this area was doubled to 2.92 m^2 because two passes with the mower were needed in order to collect a desirable amount of clippings.

Collected clippings were then dried in a forage (forced air oven) dryer at 70° C and weighed. All clipping dry weights were reported in grams of dry clippings per cm^2.

Thatch Depth

Each month three profile samples were removed from each plot (6 cm wide x 10 cm deep), and thatch depth was measured. Thatch depth was measured as the distance from the bottom of the green tissue to the soil thatch interface. Measurements in mm for the three thatch samples from each plot were averaged and reported as the thatch level depth for each plot per month.

Stolon and Rhizome Dry Weight

Stolon and rhizome dry weight (above and below ground stem tissue) was determined by first removing three 5.7 cm diameter cores from each plot. All roots and leaf tissue were removed from each core leaving only rhizomes and stolons. These were then washed free of all soil and loose organic matter and dried in a forced air oven at 70° C. Dried samples were weighed and their weights were recorded.

Soluble (TNC) Carbohydrates

The same collection procedure used for stolon and rhizome dry weight was used for soluble (TNC) carbohydrate determination, with the following modifications. First, all collected plant material was immediately placed in plastic bags and then on ice while in the field. All plant material was kept chilled during transport. Shoots were immediately trimmed off with scissors and cores were placed in a forced air oven at 100° C for 1 hour. After 1 hour, samples were transferred to a different dryer set at 60° C and allowed to dry for 48 hours. Once dried, all soil was shaken off the plant material, and dry weights were recorded. All roots, rhizomes, and stolons were analyzed for soluble (TNC) carbohydrate following the procedures described by Smith (1981).

Overseed Shoot Density

Overseed shoot density was determined in the same manner as monthly shoot density with the only exception being that once all shoots were separated, only overseed plant material was counted and recorded.

Ball Roll via Modified Stimpmeter

In 2007, ball roll data was collected via a modified stimpmeter. The stimpmeter, a ball roll or green speed measuring device, was created by the United States Golf Association in 1977. The stimpmeter is a 0.9 m long grooved aluminum bar with a ball release notch located 76 cm from its beveled end. The release notch works to release the ball when the unbeveled end of the stimpmeter is raised to 20° above horizontal (Radko, 1980; Gaussoin et al., 1995). A typical bermudagrass green speed is 2.13-3.05 m. Therefore, the stimpmeter must be modified for use on small research plots. Modified stimpmeters of varying lengths were found to be consistent and effective in measuring green speed in small-plot turfgrass research (Gaussoin et al., 1995). The modified stimpmeter had a release notch located 38 cm from the beveled end. In each plot, three golf balls were rolled using this modified stimpmeter and distances of each roll were recorded. The same three golf balls were then rolled in the opposite direction to account for any slope in the green and these distances were also recorded. The six measurements were averaged and recorded as ball roll via modified stimpmeter.

III. RESULTS AND DISCUSSION

Effect of Grooming Frequency and Groomer Blade Spacing on Shoot Density

TifEagle bermudagrass shoot density was collected in August and September of 2006 and monthly throughout the growing season (May-September) in 2007. Shoot density of the dormant bermudagrass was also collected in March of 2007 and 2008, when the *Poa trivialis* overseed counts were made. At the majority of the samplings grooming frequency and groomer blade spacing had no effect on shoot density, and the interaction of the two treatment variables never significantly affected shoot density.

Grooming frequency did have a significant impact on shoot density at two of seven sampling dates (Table 2). In August 2006 plots that were groomed six times/week had significantly more shoots than those never groomed and those groomed three times/week, but not significantly more than those groomed once/week. There was no significant difference between the ungroomed, once/week, and three times/week plots. The August 2006 data collection represented the first time shoot data was collected, occurring four months after grooming had started. Higher shoot density in the more frequently groomed plots may have been a result of the initial need to reduce thatch in the experimental area, and grooming more frequently may have helped to a greater degree.

In August 2007 plots groomed three times per week had significantly more shoots than those never groomed and those groomed one time/week, but not significantly more than those groomed six times/week. There was no significant difference between the ungroomed, once/week, and six times/week plots. The only two times that grooming affected shoot density occurred in the August (2006 and 2007) data collections. Because it is a warm-season turf, bermudagrass would be actively growing in August, compared to breaking dormancy in May and entering dormancy in September. Thus, active growth and shoot production would have occurred in late summer of each year, and thus perhaps the most frequent grooming would have had the greatest effect.

Because grooming frequency could be viewed as a quantitative (increasing frequency from zero to 6 times/week) variable (Swallow, 1984), regression analysis could also be used to view turf response over treatment range. However, in the strictest sense grooming frequency is not completely quantitative, as grooming frequency can only be applied as a whole integer. Thus, both means separation and regression techniques were used to analyze the data sets (Swallow, 1984).

When shoot density at selected sampling dates was plotted against grooming frequency (Figure 1), results were similar to those observed from the treatment means (Table 2). At 3 of the 5 graphed sampling dates there was no response to grooming frequency: March, 2007, June, 2007, and July 2007. Only the August sampling dates showed a response. August, 2006 shoot density increased slightly as grooming frequency increased, while August 2007 shoot density was maximized at 3 groomings/week (Figure 1).

Others have observed similar results with grooming and vertical mowing. Vertical mowing monthly at 1.3 cm depth versus twice yearly at 2.5 cm depth affected ultradwarf bermudagrass shoot density at only two of seven sampling dates but results were not consistent and there were no differences at any of the other five samplings

(Hollingsworth et al., 2005). Average shoot densities of TifEagle in that study were typically lower (average of 5.3 shoots cm^{-2} over 7 samplings) but that study utilized severe vertical mowing, which often damaged the turf more a month after (Hollingsworth et al., 2005). In months of maximum growth (July) shoot density more often matched those observed in this study (10.1 shoots cm^{-2} for the Hollingsworth study, as compared to 10.4 shoots cm^{-2} for this study).

Vertical mowing to a depth just above the soil surface once/year and twice/year significantly reduced shoot density of Tifway bermudagrass maintained at 1.9 cm (Carrow et al., 1987). Tifway may have responded negatively to the severe vertical mowing (to the soil layer would be comparatively deep) because that grass is a hybrid bermudagrass used for lawns and fairways. It has a lower shoot density than an ultradwarf putting green bermudagrass, and would be less likely to recover from a severe vertical mowing.

In 2006 only the 6.4 mm spaced grooming reel was used, therefore the 2006 groomer blade spacing data is best reported as groomed versus ungroomed plots. In August 2006 groomed plots had significantly higher shoot density than those never groomed (Table 3). As noted with grooming frequency, this result may have occurred as an initial response to grooming, as the research area had not been extensively cultivated prior to the start of the experiment. There was no significant difference in shoot density of groomed and ungroomed plots in September 2006. There were never any significant differences between shoot densities of ungroomed, 6.4 mm blade spacing, or 12.8 mm blade spacing plots in 2007. To our knowledge, there is no other published research which has examined groomer spacing. Previous research which did include groomers either did not report spacing or had a stated spacing of 13 mm (Salaiz et al., 1995). In that case, the method of vertical mowing was not technically grooming, as blades were set so as to only enter the turf canopy (Salaiz et al., 1995).

Effect of Grooming Frequency and Groomer Blade Spacing on Thatch Depth

Thatch depth was determined in August 2006, in April 2007 (before beginning treatments), in May and August 2007 (during treatments), and in October 2007 (after treatments had been stopped). The interaction of grooming frequency and groomer blade spacing never affected thatch depth. Neither groomer spacing nor frequency significantly affected thatch depth in August 2006 (Table 4). In April 2007 ungroomed plots had significantly less thatch than those groomed once and three times/week, but not significantly different from those groomed six times/week. There was no significant difference in thatch depth between plots groomed one, three, and six times/week. In May 2007 plots groomed six times/week had significantly less thatch than those groomed one time/week. However, these plots were not significantly different than those never groomed or those groomed three times/week. Grooming frequency did not affect thatch depth in August or October 2007.

The lack of treatment differences on thatch depth agrees with previous work in the area of thatch accumulation. In our study average thatch depth increased 9% during the April to August (2007) measurement period, indicating that grooming alone was not reducing or maintaining consistent thatch. In a similar result, no significant difference was observed between biweekly and twice yearly vertical mowing with regard to organic matter (thatch) accumulation on a bermudagrass putting green and neither treatment stopped accumulation of thatch over the course of the study (White and Dickens, 1984).

Hollingsworth et al. (2005) observed significantly more thatch in four of 18 samplings when ultradwarf bermudagrass putting greens were vertical mowed monthly at 1.3 cm depth versus plots vertical mowed twice/year at 2.5 cm depth. Twice yearly vertical mowing to a depth just above the soil surface reduced thatch by 8%, as compared to plots of Tifway bermudagrass that were not vertically mowed (control). However, there was no significant difference in thatch depth when the thatch depth of control plots was compared to that in plots that were vertically mowed once/year (Carrow et al., 1987). Vertical mowing either twice/year at 6.4 mm depth or four times/year at 19.1 mm depth was not effective in reducing or controlling accumulation of thatch on a creeping bentgrass golf green (McCarty et al., 2005). Also, grooming twice/week from April to September at 3 mm depth did not significantly reduce or control thatch accumulation (McCarty et al., 2005). Conversely, vertical mowing to just above the soil surface four and eight times/ year on a bentgrass putting green successfully reduced thatch 18% and 20% respectively. There was no significant difference between frequencies of vertical mowing (Callahan et al., 1998).

Groomer spacing significantly affected thatch depth at only one sampling. In April 2007 ungroomed plots had significantly less thatch than cultivated with a 6.4 mm groomer blade spacing. However, no significant difference was observed between plots groomed with a 12.8 mm blade spacing and either the 6.4 mm blade spacing or the ungroomed plots.

Effect of Grooming Frequency and Groomer Blade Spacing on Stolon and Rhizome Dry Weight

The interaction of grooming frequency and groomer blade spacing never affected stolon and rhizome dry weight. Grooming frequency significantly affected stolon and rhizome dry weight on one of six sampling dates (Table 5). In August 2006 plots groomed three times/week had significantly more stolons and rhizomes than all plots receiving the other grooming frequencies. Although there were no other significant differences, the data showed a trend towards maximization of stolon and rhizome dry weight at one to three groomings/week with dry weights dropping off as grooming increased to six times/week.

Figure 2 illustrates stolon and rhizome dry weights at five sampling dates throughout 2006 and 2007. Regression lines are included to show response. Although a trend can be used for observation a calculation of slope components or maximum inflection would not be useful, as grooming frequency can only be applied as whole integers. For example, in August 2006 and July 2007 stolon and rhizome dry weight was maximized at a grooming frequency of around 3.5 and 3.2 (August 2006 and July 2007, respectively) groomings/ week. Since it is impossible to have 0.2 or 0.5 groomings, the best generalization is that there was a slight quadratic response for stolon and rhizome dry weight to be maximized at three groomings/week (August 2006 and July 2007). In other months of sampling there was a slight downward trend for decreased dry weight of stolons and rhizomes as grooming frequency increased. Although linear regression did detect these slight response trends, mean separation did not usually separate significant differences between grooming frequency (Table 5).

In 2006 only one groomer blade spacing (6.4 mm) was available. There was no significant difference in the dry weight of stolons and rhizomes from the groomed plots, as compared to ungroomed. In July 2007 plots groomed with the 12.8 mm spaced groomer had rhizomes and stolons with a greater dry weight than those from ungroomed or those from groomed (6.4 mm spaced) plots. In June, or August 2007 there were no significant differences in dry weight due to groomer spacing (Table 6).

Effect of Grooming Frequency and Groomer Blade Spacing on Clipping Yield

The interaction of grooming frequency and groomer blade spacing never affected clipping yield. In 2006, there was one time (out of 3 collections) when clipping yield was affected by grooming frequency. This was in August, when plots that were most frequently groomed had a greater clipping yield as compared to those that were not (Table 7). However, no significance was observed between these plots and the one and three times/week grooming frequencies. There were no other significant differences in clipping yield due to grooming frequency at any other 2006 sampling, nor were there any consistent trends for clipping yield to increase or decrease as grooming frequency increased.

In 2007, clipping yield was never significantly affected by grooming frequency (Table 8). When clipping yield from July and August 2007 were combined into a total summer clipping yield, plots groomed once/week had significantly more clipping production than ungroomed plots. Clipping yield from plots groomed once/ week was not significantly different from those groomed three and six times/week. No significance was observed when clipping yields from summer 2006 were combined. Groomer spacing never significantly affected clipping yield in either year of the study (Tables 9 & 10).

Effect of Grooming Frequency and Groomer Blade Spacing on Fall Total Nonstructural Carbohydrates (TNC)

Fall carbohydrate content was never significantly affected by the interaction of grooming frequency and groomer blade spacing. Also, TNC was never significantly affected by either of the treatment variables by themselves (Table 11). There were not any year-to-year trends with TNC content, and levels of measured carbohydrates also varied from year to year. In 2006 the average carbohydrate content was 8.2 g kg^{-1}, compared to the 2007 average of 17.3 g kg^{-1}. Second year mean data is similar to that observed in other work with ultradwarf bermudagrasses. Trenholm et al. (1998) measured average TNC contents of 15.7 g kg^{-1} in Floradwarf hybrid bermudagrass. Total nonstructural carbohydrate content in a Tifdwarf green also showed wide variation between years, sampling month, mowing height, and cultivar (Miller and Dickens, 1996). Regardless of the actual TNC value, carbohydrate levels in bermudagrass managed as a putting green were affected by nitrogen (Guertal and Evans, 2006; Trenholm et al., 1998), cultivar (Miller and Dickens, 1996), and time of year (Miller and Dickens, 1996). The effect of turf management strategies of TNC content has received less study, with TNC variation due to mowing height being most studied (Miller and Dickens, 1996; Guertal and Evans, 2006).

Effect of Grooming Frequency and Groomer Blade Spacing on Golf Ball Roll

The interaction of groomer spacing and grooming frequency never significantly affected the length of a golf ball roll, as measured by Stimpmeter. Grooming frequency significantly affected ball roll at one of two sampling dates. In August 2007 ungroomed plots had significantly higher ball roll distance than plots groomed three times/ week.

There was no significant difference between these plots and those groomed once or six times/ week. There were no significant differences within treatments due to grooming frequency in September 2007. Groomer spacing never affected distance of ball roll (Table 12).

When distance of golf all roll was regressed against grooming frequency some similar responses were identified in both data sets (Figure 3). In August ball roll was highest in ungroomed plots, and then declined as grooming frequency increased towards 3 times/week. In September ball roll distance decreased as grooming frequency increased.

Ball roll data can be difficult to interpret, as maximum ball roll can be obtained in low mown, flattened (rolled) and dry turf. Turfgrass with excessive shoot growth, or "grainy" growth (stolons and rhizomes tend to grow in one direction) may have reduced ball roll. In our study stolon and rhizome weight either slightly decreased (August 2007) or was increased up to 3 groomings/week (July 2007) (Figure 2). In 2007, shoot density was slightly maximized at 3 groomings/week (Figure 1).

Vertical mowing a creeping bentgrass green four times/year at 6.4 mm depth reduced ball roll distance by 4%, compared to bentgrass plots receiving only topdressing (McCarty et al., 2005). Plots receiving vertical mowed twice/year at 19.1 mm depth did not show significant differences in ball roll distance (McCarty et al., 2005). Vertical mowing once or twice/month on a creeping bentgrass putting green (depth such that the vertical blades just entered the turf surface) did not significantly affect ball roll distance, versus plots not vertical mowed (Salaiz et al., 1995).

Effect of Grooming Frequency and Groomer Blade Spacing on *Poa trivialis* Shoot Density and Bermudagrass Color and Quality

Overseed shoot density was never significantly affected by grooming frequency, groomer blade spacing, or the interaction of the two treatment variables (Table 13). Frequent vertical mowings did not consistently improve overseed establishment on a bermudagrass putting green (White and Dickens, 1984). There was no significant difference regarding overseed density on ultradwarf bermudagrass putting green plots vertically mowed monthly at 1.3 cm depth versus those vertically mowed twice/year at 2.5 cm depth (Hollingsworth et al., 2005). Grooming frequency, groomer blade spacing, and the interaction of the two treatment variables never significantly affected bermudagrass color and quality (data not shown).

IV. CONCLUSIONS

1. Grooming frequency or groomer spacing never affected fall carbohydrate content, *Poa trivialis* overseed density, or stimpmeter speed.
2. Although shoot density was affected by grooming frequency and groomer spacing, the effects were not consistent and varied from month to month.
3. Grooming alone did not prevent thatch from accumulating.
4. Grooming frequency had no sustained, long-term positive benefits on TifEagle hybrid bermudagrass performance.

LITERATURE CITED

Adams, J.F., C.C. Mitchell and H.H. Bryant. 1994. Soil test fertilizer recommendations for Alabama crops. Agronomy and Soils Dept. Series No. 178.

Baldwin, C.M., H. Liu, and P.J. Brown. 2006. Effects of core cultivation tine entry angle on golf putting greens. HortTechnology. 16(2):265-269.

Beard, J.B. 2002. Turf management for golf courses. 2nd ed. Ann Arbor Press. Chelsea, MI. 766.

Burton, G.W. 1966. Tifdwarf bermudagrass. Crop Sci. 6:94.

Callahan, L.M., W.L. Sanders, J.M. Parham, C.A. Harper, L.D. Lester, and E.R. McDonald. 1997. Comparative methods of measuring thatch on a creeping bentgrass green. Crop Sci. 37:230-234.

Callahan, L.M., W.L. Sanders, J.M. Parham, C.A. Harper, L.D. Lester, and E.R. McDonald. 1998. Cultural and chemical controls of thatch and their influence on rootzone nutrients in a bentgrass green. Crop Sci. 38:181-187.

Carrow, R.N., B.J. Johnson, and R.E. Burns. 1987. Thatch and quality of Tifway bermudagrass turf in relation to fertility and cultivation. Agron. J. 79:524-530.

Duble, R.L. 1996. Turfgrasses: their management and use in the southern zone. 2nd ed. Texas A&M University Press. College Station, TX. 189-198.

Dunn, J.H., Minner, D.D., Fresenburg, B.F., Bughrara, S.S, and Hohnstrater, C.H. 1995. Influence of core aerification, topdressing, and nitrogen on mat, roots, and quality of 'Meyer' zoysiagrass. Agron. J. 87:891-894.

Foy, J.H. 1991. Going for the gold with bermudagrass greens. USGA Green Section Record. 29(4):1-5.

Gaussoin, R., J. Nus, and L. Leuthold. 1995. A modified stimpmeter for small-plot turfgrass research. HortScience. 30(3):547-548.

Guertal, E.A., and R. White. 1998. Dwarf bermudagrasses demand unique care. Golf Course Mngt. 66(7):58-60.

Guertal, E.A., and D.L. Evans. 2006. Nitrogen rate and mowing height effects on TifEagle bermudagrass espablishment. Crop Sci. 46:1772-1778.

Gray, J.L. and R.G. White. 1999. Maintaining the new dwarf greens-type bermudagrasses. Golf Course Mngt. 67:3:52-55.

Hanna, W.W., and J.E. Elsner. 1999. Registration of 'TifEagle' bermudagrass. Crop Sci. 39:1258.

Hanna, W. 1998. The future of bermudagrass. Golf Course Management. 66(9):49-52.

Hein, M.A. 1961. Registration of varieties and strains of bermudagrass, III [*Cynodon dactylon* (L.) Pers.]. Agron. J. 53:276.

Hollingsworth, B.S., E.A. Guertal, and R.H. Walker. 2005. Cultural management and nitrogen source effects on ultradwarf bermudagrass cultivars. Crop Sci. 45:486-493.

Horgan, B.P., and F.H. Yelverton. 2001. Removal of perennial ryegrass from overseeded bermudagrass using cultural methods. Crop Sci. 41:118-126.

Hurto, K.A., A.J. Turgeon and L.A. Spomer. 1980. Physical characteristics of thatch as a turfgrass growing medium. Agron. J. 72:165-167.

Johnson, B.J. 1979. Vertical mowing and herbicide treatments on thatch in bermudagrass (*Cynodon dactylon*) turf. Weed Sci. 27(1):14-17.

Johnson, B.J. 1986. Response to vertical mowing and ethofumesate treatments for annual bluegrass control in bermudagrass turf. Agron. J. 78:495-498.

Krans, J.V., H.W. Philley, J.M. Goatley Jr., and V.L. Maddox. 1999. Registration of 'MS Supreme' bermudagrass. Crop Sci. 39(1):287.

Ledeboer, F.B., and C.R. Skogley. 1967. Investigations into the nature of thatch and methods for its decomposition. Agron. J. 59:320-323.

Mazur, A.R. and D.F. Wagner. 1987. Influence of aeration, topdressing, and vertical mowing on overseeded bermudagrass putting green turf. HortScience. 22(6):1276-1278.

McCarty, L.B., M.F. Gregg, J.E. Toler, J.J. Camberato, and H.S. Hill. 2005. Minimizing thatch and mat development in a newly seeded creeping bentgrass golf green. Crop Sci. 45:1529-1535.

McCarty, L.B., and A. Canegallo. 2005. Tips for managing ultradwarf bermudagrass greens. Golf Course Management. 73(6):90-95.

Miller, G.L., and R. Dickens. 1996. Bermudagrass carbohydrate levels as influenced by potassium fertilization and cultivar. Crop Sci. 36:1283-1289.

Moncrief, J.B. 1967. Tifdwarf – bermudagrass for championship greens. USGA Green Section Record. 5(3): 1-5.

Moncrief, J.B. 1975. What is happening to our bermudagrass?. USGA Green Section Record. 13(6):8-10.

Murphy, J.A. and P.E. Reike. 1994. High pressure water injection and core cultivation of a compacted putting green. Agron. J. 86:719-724.

Murphy, J.A., P.E. Rieke, and A.E. Erickson. 1992. Core cultivation of a putting green with hollow and solid tines. Agron. J. 85:1-9.

Radko, A.M. 1980. The USGA Stimpmeter for measuring the speed of putting greens, p. 473-476. In: J.B. Beard (ed.). Proc. 3rd Intl. Turf Res. Conf. Amer. Soc. Agron., Madison, Wis.

Raturi, S., K.R. Islam, M.J. Carroll, and R.L. Hill. 2004. Thatch and soil characteristics of cool- and warm-season turfgrasses. Communications in soil science and plant analysis. 35(15&16):2161-2176.

Salaiz, T.A., G.L. Horst, and R.C. Shearman. 1995. Mowing height and vertical mowing frequency effects on putting green quality. Crop Sci. 35:1422-1425.

Smith, D. 1981. Removing and analyzing carbohydrates from plant tissue. Wisconsin Agric. Exp. Stn. Rep. R2107. Madison.

Smith, G.S. 1979. Nitrogen and aerification influence on putting green thatch and soil. Agron. J. 71:680-684.

Swallow, W.H. 1984. Those overworked and oft-misused mean separation procedures – Duncan’s, LSD, etc. Plant Disease. 68:919-921.

Taliaferro, C.M., D.L. Martin, J.A. Anderson, M.P. Anderson, and A.C. Guenzi. 2004. Broadening the horizons of turf bermudagrass. USGA Turfgrass and Environmental Research Online. 3(20):1-9.

Trenholm, L.E., A.E Dudeck, J.B. Sartain, and J.L. Cisar. 1998. Bermudagrass growth, total nonstructural carbohydrate concentration, and quality as influenced by nitrogen and potassium. Crop Sci. 38:168-174.

White, R.H., and R. Dickens. 1984. Thatch accumulation in bermudagrass as influenced by cultural practices. Agron. J. 76:19-22.

White, R.H., T.C. Hale, D.R. Chalmers, M.H. Hall, J.C. Thomas, and W.G. Menn. 2004. Cultural management of selected ultradwarf bermudagrass cultivars. Plant Management Network. www.plantmanagementnetwork.org/pub/cm/research/2004/ultradwarf/

APPENDIX

Table 1. Soil test results on a TifEagle hybrid bermudagrass putting green, Auburn, AL.

Year	P	K	Mg	Ca	pH
	--------------------------------kg ha^{-1}------------------------------				
2005	95 (H)†	90 (M)	29 (H)	315	5.4
2006	74 (H)	34 (VL)	59 (H)	377 (H)	5.6
2007	86 (H)	88 (M)	74 (H)	524 (H)	6.3

† Very high (H), high (H), medium (M), low (L), and very low (VL) designations based on Auburn University soil test recommendations (Adams et al., 1994).

Table 2. Effect of grooming frequency on shoot density of TifEagle hybrid bermudagrass, Auburn, AL.

Frequency	Aug. 2006	Sep. 2006	May 2007	June 2007	July 2007	Aug. 2007	Sep. 2007	Summer[‡] 2007
	--------------------	--------------------	--------------------	Shoots / cm^{-2}	--------------------	--------------------	--------------------	--------------------
Never	10.7 b[†]	11.1 a	5.7 a	8.6 a	10.4 a	10.5 b	10.4 a	9.8 a
Once per week	12.1 ab	10.9 a	5.7 a	8.4 a	10.4 a	10.4 b	9.8 a	9.7 a
Three times per week	11.1 b	11.9 a	6.0 a	8.2 a	10.6 a	12.0 a	10.1 a	10.3 a
Six times per week	12.8 a	11.2 a	5.8 a	7.6 a	10.3 a	10.6 ab	10.2 a	9.5 a

† Within each month means followed by the same letter are not significantly different from each other at $\alpha = 0.10$.
‡ Summer 2007 is the average of the months June, July, and August.

Table 3. Effect of groomer blade spacing on shoot density of TifEagle hybrid bermudagrass, Auburn, AL.

Blade Spacing	Aug. 2006	Sep. 2006	May 2007	June 2007	July 2007	Aug. 2007	Sep. 2007	Summer 2007§
	--Shoots / cm^{-2}---							
Not Groomed	10.7 b†	11.1 a	5.7 a	8.6 a	10.4 a	10.5 a	10.4 a	9.8 a
6.4 mm	12.0 a	11.3 a	5.4 a	8.0 a	10.4 a	11.0 a	10.0 a	9.8 a
12.8 mm	NA‡		6.4 a	8.1 a	10.6 a	11.1 a	10.1 a	9.9 a

† Within each month means followed by the same letter are not significantly different from each other at $\alpha = 0.10$.

‡ Data not collected in 2006.

§ Summer 2007 is the average of the months June, July, and August.

Table 4. Effect of grooming frequency and groomer blade spacing on thatch depth of a TifEagle hybrid bermudagrass putting green, Auburn, AL.

Gr. Freq	Aug 06	Apr 07	May 07	Aug 07	Oct 07
	-- mm depth --				
None	14.4 a[†]	16.5 b	19.5 ab	20.4 a	19.7 a
1x/wk	15.0 a	20.8 a	21.8 a	21.7 a	19.3 a
3x/wk	14.0 a	21.0 a	20.9 ab	21.7 a	19.7 a
6x/wk	15.3 a	18.3 ab	18.3 b	20.8 a	18.2 a
Gr. Space					
None	14.4 a	16.5 b	19.5 a	20.4 a	19.7 a
6.4 mm	14.8 a	21.0 a	19.4 a	21.2 a	18.7 a
12.8 mm	NA[‡]	19.1 ab	21.2 a	21.6 a	19.4 a

† Within each month means followed by the same letter are not significantly different from each other at $\alpha = 0.10$.
‡ Data not collected in 2006.

Table 5. Effect of grooming frequency on the dry weight of stolon and rhizomes harvested from TifEagle hybrid bermudagrass, Auburn, AL.

Frequency	Aug. 2006	Oct. 2006	June 2007	July 2007	Aug. 2007	Summer 2007‡
	---------------------Stolon and Rhizome dry wt. (g / plot)---------------------					
Never	11.7 b†	17.1 a	8.5 a	6.3 a	6.0 a	12.4 a
Once per week	10.7 b	15.0 a	8.5 a	8.0 a	5.0 a	13.1 a
Three times per week	13.7 a	15.3 a	8.2 a	8.1 a	5.6 a	13.7 a
Six times per week	11.9 b	14.3 a	7.4 a	7.1 a	4.8 a	12.2 a

† Within each month means followed by the same letter are not significantly different from each other at $\alpha = 0.10$.

‡ Summer 2007 = June + July + August

Table 6. Effect of groomer blade spacing on the dry weight of stolon and rhizomes harvested from TifEagle hybrid bermudagrass, Auburn, AL.

Blade Spacing	Aug. 2006	Oct. 2006	June 2007	July 2007	Aug. 2007	Summer 2007
	--Stolon and Rhizome dry wt. (g / plot)--					
Not Groomed	11.7 a[†]	17.1 a	8.5 a	6.3 b	6.0 a	12.4 a
6.4 mm	12.1 a	14.9 a	8.3 a	6.7 b	5.2 a	11.9 a
12.8 mm	NA[‡]	NA	7.8 a	8.8 a	5.1 a	14.3 a

† Within each month means followed by the same letter are not significantly different from each other at $\alpha = 0.10$.

‡ Data not collected in 2006.

Table 7. Effect of grooming frequency on clipping yield of TifEagle hybrid bermudagrass, Auburn, AL, 2006.

Frequency	July	August	Summer	September
	----------clipping dry weight (grams/plot)----------			
Never	8.3 a†	6.6 b	13.0 a	5.3 a
Once per week	7.0 a	7.6 ab	15.3 a	5.0 a
Three times per week	6.5 a	7.4 ab	13.5 a	3.5 a
Six times per week	7.7 a	11.8 a	19.8 a	3.9 a

† Within each month means followed by the same letter are not significantly different from each other at $\alpha = 0.10$.

Table 8. Effect of grooming frequency on clipping yield of TifEagle hybrid bermudagrass, Auburn, AL, 2007.

Frequency	June	July	August	Summer	September
	--clipping dry weight (grams/plot)--				
Never	2.5 a†	3.9 a	2.2 a	6.1 b	2.8 a
Once per week	2.3 a	4.8 a	2.5 a	7.3 a	2.6 a
Three times per week	2.3 a	4.5 a	2.3 a	6.8 ab	3.0 a
Six times per week	2.5 a	4.1 a	2.4 a	6.6 ab	2.7 a

† Within each month means followed by the same letter are not significantly different from each other at $\alpha = 0.10$.

Table 9. Effect of grooming on clipping yield of TifEagle hybrid bermudagrass, Auburn, AL, 2006.

Groomed/Not Groomed	July	August	Summer	September
	-------------------------------------clipping dry weight (grams/plot)---			
Groomed	7.3 a†	8.9 a	16.2 a	4.1 a
Not Groomed	8.3 a	6.6 a	13.0 a	5.3 a

† Within each month means followed by the same letter are not significantly different from each other at α = 0.10.

Table 10. Effect of groomer blade spacing on clipping yield of TifEagle hybrid bermudagrass, Auburn, AL, 2007.

Blade Spacing	June	July	August	Summer	September
	----------clipping dry weight (grams/plot)----------				
Not Groomed	2.5 a†	3.9 a	2.2 a	6.1 a	2.8 a
6.4 mm	2.3 a	4.3 a	2.4 a	6.6 a	2.7 a
12.8 mm	2.5 a	4.7 a	2.5 a	7.2 a	2.8 a

† Within each month means followed by the same letter are not significantly different from each other at $\alpha = 0.10$.

Table 11. Fall (September) carbohydrate content (dry matter basis) of a TifEagle hybrid bermudagrass putting green, Auburn, AL.

Frequency	2006	2007
	------------------------------g kg^{-1}[§]	------------------------------
Never	8.0 a[†]	17.6 a
Once per week	7.8 a	17.7 a
Three times per week	8.7 a	16.2 a
Six times per week	8.1 a	17.8 a
Blade Spacing		
Not Groomed	NA[‡]	17.6 a
6.4 mm	NA	16.2 a
12.8 mm	NA	18.2 a

† Within each month means followed by the same letter are not significantly different from each other at $\alpha = 0.10$.

‡ Data not collected in 2006.

§ Dry matter basis (Smith, 1981).

Table 12. Effect of grooming frequency and groomer blade spacing on golf ball roll on TifEagle hybrid bermudagrass, Auburn, AL.

Frequency	August 2007	September 2007
	----------------------Ball roll distance (cm)--------------------	
Never	175.8 a†	165.0 a
Once per week	170.8 ab	162.8 a
Three times per week	155.5 b	154.9 a
Six times per week	162.1 ab	153.1 a
Blade Spacing		
Not groomed	175.8 a	165.0 a
6.4 mm	165.4 a	159.2 a
12.8 mm	160.2 a	154.7 a

† Within each month means followed by the same letter are not significantly different from each other at $\alpha = 0.10$.

Table 13. Overseed (*Poa trivialis*) shoot density on a TifEagle hybrid bermudagrass putting green, Auburn, AL.

Frequency	2006	2007
	---------------------------shoots cm^{-2}---------------------------	
Never	13.1a[†]	15.9 a
Once per week	14.3 a	16.9 a
Three times per week	11.0 a	16.9 a
Six times per week	12.8 a	18.5 a
Blade Spacing		
Not groomed	NA[‡]	15.9 a
6.4 mm	NA	17.1 a
12.8 mm	NA	17.8 a

† Within each year means followed by the same letter are not significantly different from each other at $\alpha = 0.10$.
‡ Data not collected in 2006.

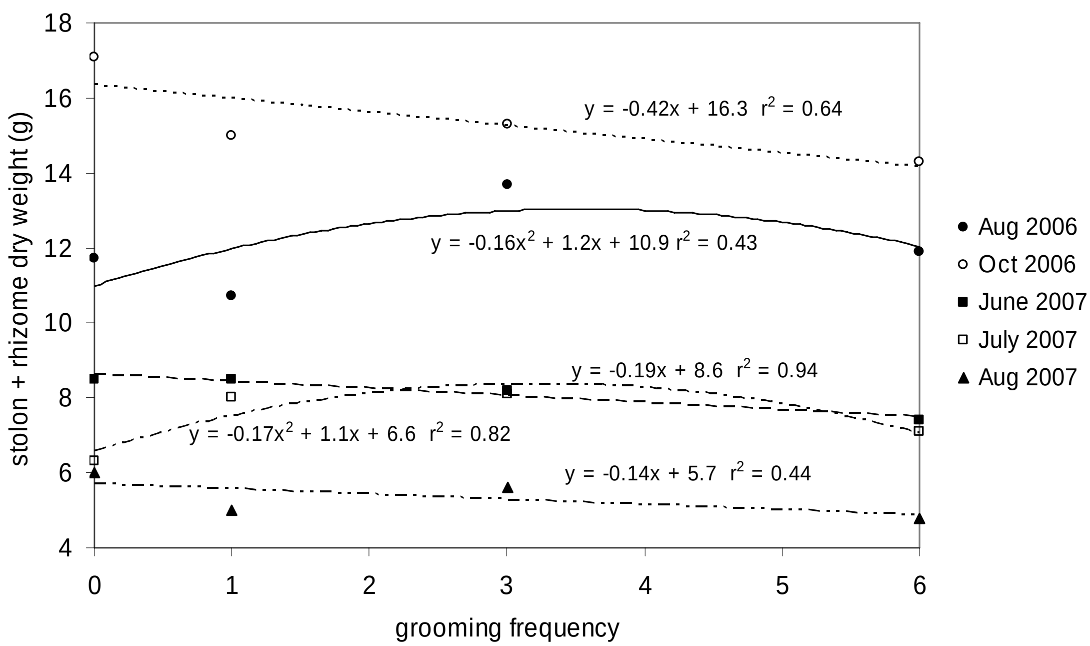

Figure 1. Effect of grooming frequency on the shoot density of TifEagle hybrid bermudagrass, Auburn, AL.

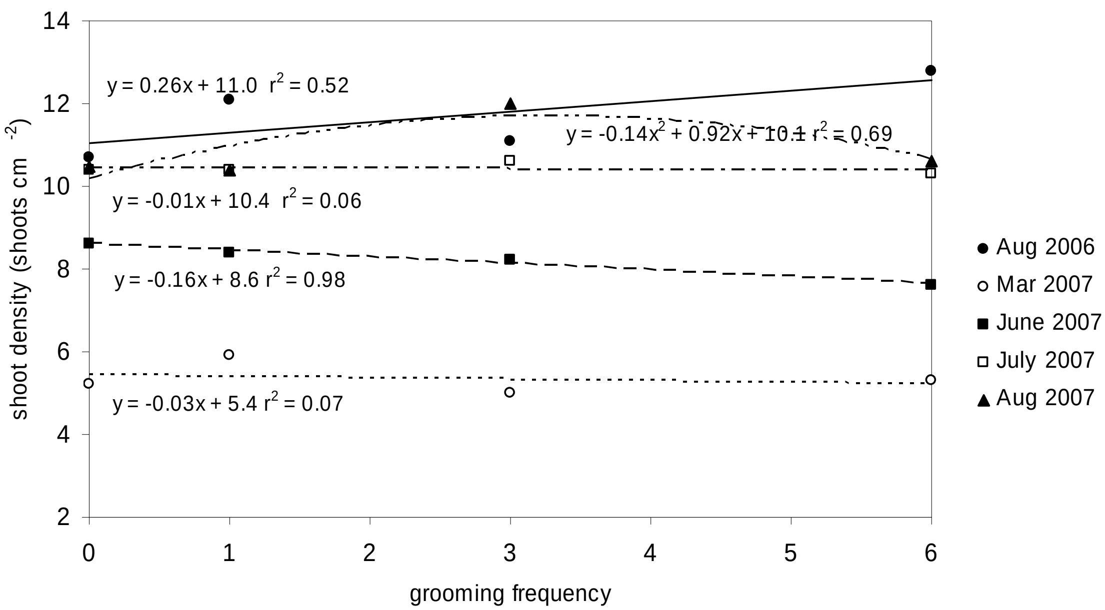

Figure 2. Effect of grooming frequency on the dry weight of stolons and rhizomes harvested from TifEagle hybrid bermudagrass, Auburn, AL

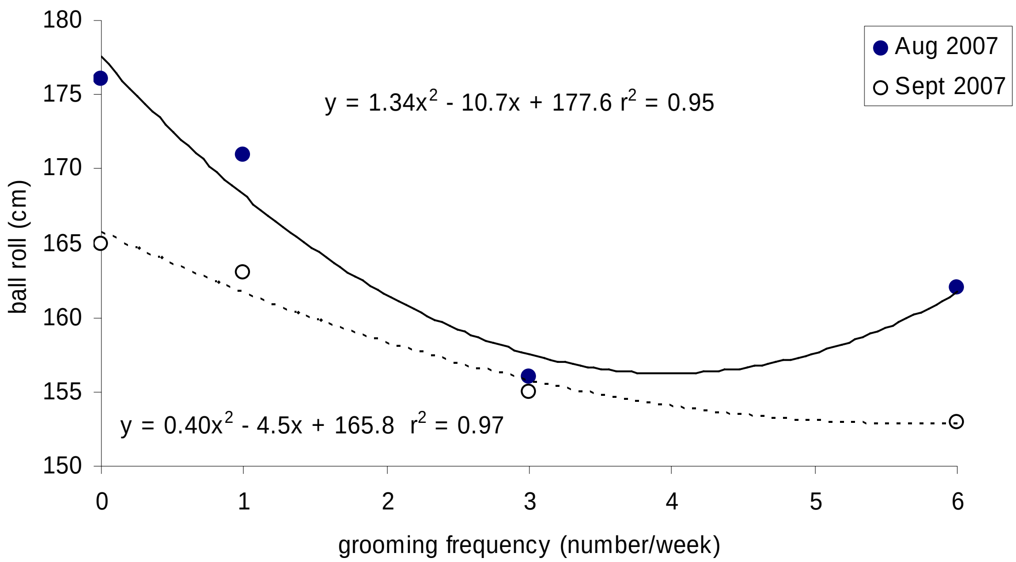

Figure 3. Effect of grooming frequency on golf ball roll, Auburn, AL.