MOWING HEIGHT, NITROGEN RATE AND SOURCE EFFECTS ON

ESTABLISHMENT AND MAINTENANCE OF TIFWAY

AND TIFSPORT BERMUDAGRASS

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Christy Agnew Hicks

Certificate of Approval:

______________________ David Y. Han Associate Professor Agronomy and Soils	______________________ Elizabeth A. Guertal, Chair Alumni Professor Agronomy and Soils
______________________ David H. Teem Professor Agronomy and Soils	______________________ Robert H. Walker Professor Agronomy and Soils

____
Stephen L. McFarland
Dean
Graduate School

MOWING HEIGHT, NITROGEN RATE AND SOURCE EFFECTS ON ESTABLISHMENT AND MAINTENANCE OF TIFWAY AND TIFSPORT BERMUDAGRASS

Christy Agnew Hicks

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ESTABLISHMENT AND MAINTENANCE OF TIFWAY

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Christy Agnew Hicks

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Signature of Author

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Date of Graduation

VITA

Christy Agnew Hicks, daughter of Donnie and Patricia Agnew, was born July 19, 1978 in Monroeville, Alabama. She graduated from Monroe Academy in Monroeville, Alabama, in May of 1996. Following high school graduation, she attended Faulkner State Community College in Bay Minette, AL on a basketball scholarship. In 1997 she transferred to Alabama Southern Community College in Monroeville, AL and joined the fast pitch softball team. In the fall of 1999, she entered Auburn University and graduated in 2001 with a Bachelor of Science degree in Agronomy and Soils. After graduation she began Graduate School at Auburn University in the spring of 2002. She received a Master of Science degree in Agronomy and Soils in December, 2006.

THESIS ABSTRACT

MOWING HEIGHT, NITROGEN RATE AND SOURCE EFFECTS

ON ESTABLISHMENT AND MAINTENANCE OF

TIFWAY AND TIFSPORT BERMUDAGRASS

Christy Agnew Hicks

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Hybrid cultivars of bermudagrass (*Cynodon dactylon (L.) Pers. x C. transvaalensis* Burtt-Davy) are the predominant turfgrasses used on golf courses and athletic fields throughout the southeastern United States, and in warm, tropical climates worldwide. Hybrid bermudagrass provides a dense, high quality turf, but does require more intensive maintenance than common bermudagrass.

'Tifway' and 'TifSport' are two cultivars of hybrid bermudagrasses grown on athletic fields, lawns and fairways. Tifway is a chance F_1 hybrid that appeared in seeds of *C. transvaalensis* and was released in 1960. Currently, it is still the most popular hybrid bermudagrass in use on southeastern turfed landscapes. TifSport is an artificial cobalt 60-induced mutant of the cold tolerant cultivar Midiron, and is a more recent

release. TifSport has better cold tolerance and is a patented cultivar, ensuring genetic purity and uniformity. The objectives of this research were to: 1) examine the effect of mowing height and N rate on quality of established Tifway and TifSport hybrid bermudagrass, and 2) examine the effect of N source and N rate on establishment of TifSport and Tifway hybrid bermudagrass in newly sprigged fields.

Two year studies of each experiment were conducted, with the establishment study conducted in 2002 and 2004, and the management study conducted in 2002 and 2003. In both studies there were 4 replications of the treatments, with the treatments arranged in strip-strip plot designs. For the establishment study treatments included cultivar (Tifway or TifSport), N source (Ammonium nitrate or calcium nitrate), or N rate. For the management study treatments were cultivar, N rate and mowing height. Data collection included percent establishment, recovery from wear, clipping yield, dry weight of stolons/rhizomes, and resistance to tearing.

In the establishment study TifSport initially grew in more quickly than Tifway, but such differences were eliminated by 4 weeks after sprigging. Nitrogen rate rarely affected the rate of establishment, however, dry weight of stolons/rhizomes decreased as N rate increased.

In the management study summer shoot density quadratically increased as N rate increased, to a rate of 7.2 g N m^{-2} $month^{-1,}$ and decreased thereafter. Mowing height affected clipping yield; but little else, including resistance to tearing.

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I. LITERATURE REVIEW

Introduction

Turfgrasses have a greater impact on people's lives than is realized. A nationwide poll published in *Life* magazine showed that most Americans wish to be surrounded by green grass and trees (Hooper, 1970). Doctors agree that people surrounded by green grass and trees recover faster and feel better (Ulrich, 1986). Improved environmental conditions, a beautiful home site and better mental attitudes are a few of the contributions of turfgrass. The southwestern author J. Frank Dobie wrote: "The sight of a turf, whether of short grass carpeting the earth or tall grass waving in the wind, restores my soul. A valley of green grass is beautiful in the way that mountains, seas, and stars are beautiful" [1] (Dobie, 1972).

Turfgrass is the most important feature on golf courses and other athletic fields that require a high quality playing surface (Beard, 1973). The quality of a golf course or sports field is judged primarily by the color, density, and uniformity of the turfgrass (Beard, 1973). Turfgrass makes a tremendous difference in temperatures on athletic fields. The fact that a field of natural turfgrass can be up to 50 degrees cooler in the summer than artificial turf is another positive attribute of turfgrass (Duble, 1996).

[1] Dobie, F.J. 1972. The pleasure Frank Dobie took in grass. Speech presented at Texas A&M University, College Station

Bermudagrass *(Cynodon dactylon L.)* has been called the turfgrass of the south. It is found in over one hundred countries throughout the tropical and subtropical areas of the world (Juska and Hanson, 1964). The first introduction of bermudagrass is not recorded but it is listed as one of the principle grasses in the southern states in Mease's Geological Account of the United States, published in 1807.

Common and Hybrid Bermudagrass

Common bermudagrass (*Cynodon dactylon*) is the most widespread of the nine species of the genus *Cynodon* (Taliaferro, 1995). *C. dactylon* is highly fertile and has broad genetic variability (Assefa et al., 1999). Common bermudagrass is the primary turf-type bermudagrass variety that is established from seed. Common bermudagrass and selections from common generally have a lower N requirement than the hybrid bermudagrasses and require less cultivation to prevent thatch accumulation (Duble, 1996). In general, they have coarser turf texture, and are lower in quality than hybrid bermudagrasses.

Hybrid bermudagrasses (*C. dactylon x C. transvaalensis*) are sterile and must be propagated by stolons, rhizomes, or sod. Compared to common bermudagrass, hybrid bermudagrasses generally have greater disease resistance, fewer seed heads, finer leaf texture, and better color (Foy, 1997). Cultivars of hybrid bermudagrass have been the predominant turfgrasses used on golf courses and athletic fields throughout the southeastern USA, and in warm climate areas worldwide (Johnson, 1994). Hybrid bermudagrass provides a dense, high quality turf for athletic fields, but requires intensive maintenance (fertilizers and cultural care) to maintain high turf quality (Trenholm et al., 1999).

Examples of cultural care include topdressing, vertical mowing, and aerification. Topdressing is defined as the spreading of a thin layer of soil, such as sand, over a turf (Duble, 1996). Topdressing an established turf aids in thatch decomposition, helps level the playing surface, and reduces graininess on golf greens (Thompson and Ward, 1966). Thatch is a layer of undecomposed or partially decomposed organic matter above the soil surface (Turgeon, 2000). Vertical mowing physically removes the thatch. This is accomplished by a set of saw-like blades which are mounted on a horizontal shaft and turn vertically. Thickness and spacing of the blades can be varied. Vertical mowing also reduces graininess and promotes new shoot growth (Duble, 1996). Aerification is the removal of small cores from the turf. The holes left behind following aerification aid in the movement of air, water, nutrients and other compounds through the soil. Without these practices thatch becomes a problem, which results in scalping when mowed (White and Dickens, 1984).

Cultivars of Hybrid Bermudagrass

'Tifway'

Tifway bermudagrass is a chance F_1 hybrid of *C. dactylon and C. transvaalensis* that appeared in seeds of *C. transvaalensis* from Johannesburg, South Africa, in 1954 (Duble, 1996). Tifway was released by the Georgia Agricultural Experiment Station and Crops Research Division in 1960 (Burton, 1966). Tifway is recommended for golf course tees and fairways, home lawns, and athletic fields. Currently, it is still the most popular hybrid bermudagrass in use on southeastern turfed landscapes. Some characteristics of Tifway include a dark green color, with medium fine-textured blades.

Tifway has a high shoot density. Temperatures in excess of 38° C (100° F) are tolerated by Tifway.

Tifway sometimes exhibits undesired genetic diversity (Busey, 1997). This genetic diversity often expresses itself as areas of sod that are non-uniform and patchy, and are often called "off-types" (Busey, 1997). Off-types have three possible sources. One, mutations can result in a sudden genetic change in existing turf. Second, seed-producing varieties often yield off-type offspring that invade Tifway (Gustavo et al., 1997). Third, off-types can arise from contamination as vegetative sprigs of common or other hybrid bermudagrasses invade (Gustavo et al., 1997). The presence of such off-types has led the development of more uniform and genetically pure bermudagrass cultivars such as TifSport.

'TifSport'

TifSport was released by the University of Georgia Coastal Plain Experimental Station in Tifton, Georgia (Hanna et al., 1997). TifSport is the best of 66 fine-textured mutants derived from irradiating Midiron stolons with 8000 rads of Cobalt 60 gamma radiation (Hanna et al., 1997). Selection criteria include greater cold tolerance and reduce genetic variability within a bermudagrass cultivar (Hanna, 1998). TifSport has some improved pest tolerance, as research trials indicate the tawny mole cricket (*Scapteriscus vicinus*) is less of a problem in TifSport than in other bermudagrasses (www.tifsport.com/tifsportresearchdata.htm). TifSport was selected for its dark green color, density and upright leaf blade orientation (Williams, 2001). Because of TifSport's aggressiveness, special thatch management may be needed, such as more frequent vertical mowing and topdressing (Williams, 2001). Golf course superintendents prefer the enhanced cold tolerance and earlier green-up of TifSport (Hanna et al., 1997). Common uses of TifSport include golf course fairways, athletic fields, landscaping and lawns. TifSport is a patented cultivar; therefore permission is required from the University of Georgia to commercially market or propagate this grass (Hanna et al., 1997).

Other Cultivars of Bermudagrasses

Many other bermudagrass cultivars are used for turf. ‘Midiron’ was released by the Kansas Agricultural Experiment Station, primarily for cold tolerance. Midiron, a medium textured, dense grass, is an interspecific F_1 hybrid between cold tolerant *C. dactylon* and *C. transvaalensis* (Alderson and Sharp, 1994). ‘Tifway II’, released in 1984, is a fine textured, very dense, dark green, more cold hardy mutant of Tifway (Burton, 1985). ‘Quickstand’, released from Kentucky in 1993, is a vegetative common bermudagrass that is extremely winter hardy, aggressive, and fast spreading (Phillips et al., 1997). It is not as fine textured or dense as hybrid bermudagrass, but is an alternative in areas that may experience winterkill. ‘GN-1’ is a vegetative selection of *Cynodon dactylon* introduced by Greg Norman Turf Company (www.shark.com/gnturf/gn1.php). GN-1 is a hybrid with darker green color and more aggressive growth than Tifway. GN-1 is less cold hardy than TifSport and Quickstand (Anderson et al., 2002). ‘Celebration’ was developed in Australia by Sodsolutions (www.sodsolutions.com). It has a dark blue-green color, low growing habit and excellent drought tolerance. There is no published scientific literature which studies the cultivars GN-1 or Celebration, and most available information has been published in turf trade journals or commercial web sites.

Nitrogen Fertilization for Turfgrass

Among the nutrients present in turfgrasses, nitrogen is present in the greatest quantities, ranging from 2%-5% by weight in dry leaf tissue (Landshoot and Miller, 2003). It is also the nutrient applied in the greatest quantity to bermudagrass, typically at rates of 50 kg N ha^{-1} per growing month. As N is taken up by the plant it is assimilated into amino acids that provide the basis for formation of key N compounds basic to plant growth and metabolism (Landshoot and Miller, 2003).

Nitrogen has a major influence on a number of plant responses, including color, shoot and root growth, shoot density, rhizome and stolon growth, cold tolerance, drought resistance, wear tolerance, thatch accumulation, and recovery potential (Carrow et al., 1987). Evaluating turfgrass response to N is commonly done by measuring color and growth rate. The dark green color for most turfgrass is achieved by N fertilization. People commonly associate dark green color with high quality; however, color can not always be used to judge the quality of grass (Beard, 1990). Moderately fertilized zoysiagrass has a medium green color and is usually deeper rooted, and able to tolerate environmental, disease, insect and traffic stresses (Dunn et al., 1995). As N levels decrease there is a gradual loss of green color (chlorosis) that first appears in older leaves (Christians, 1998). At very high N levels there is no further improvement in color. When excessive N has been applied there may be some loss of color because growth rate is so high that some dilution of chlorophyll may occur and shading results in yellowing of lower leaves, a condition especially visible after mowing (Ramos and Curbelo, 1978). One example of high N use occurs on mature bermudagrass used for intensively maintained recreational turfs in regions with long growing seasons and sandy soils

(Miller and Cisar, 1990). Additionally, grasses that are heavily fertilized may have stolons with shorter internodes (Goatley et al., 1994).

Nitrogen also affects the development of tillers, rhizomes and stolons (below and above ground stems, respectively) (Trenholm et al., 1998). One primary effect of N is on the duration of tillering (Madison, 1962). Grass with adequate N will continue to produce tillers long after grasses that are deficient in N. Also, full sunlight must be present for N to have an effect on tillering in turfgrasses (Owen, 2000).

Warm-season grasses that are established from plugs, stolons or sprigs are often fertilized at much higher rates than would be needed for established grasses (Rodriguez et al., 2002). Typical N rates for establishment of hybrid bermudagrass were 12 to 49 kg ha^{-1}, with establishment maximized at an N rate of 49 kg ha^{-1} (Rodriguez et al, 2002). However, applying excess N for an extended period of time slowed the rate of establishment (McCarty and Canegallo, 2005). Excess N caused carbohydrate movement to produce excess shoot growth, slowing growth of rhizomes and stolons (Pettit and Fagan, 1974).

Given the range of effects of N on turfgrasses, it is obvious that proper N fertilization is important to maintaining healthy, stress tolerant, and attractive turf. Also, an understanding of the soil environmental factors influencing N relationships is important when developing an N fertilization program (Landschoot and Miller, 2003).

Problems caused by excessive N fertilization include:

A. Frequent mowing –increases mowing cost (Ramos and Curbelo, 1978).
B. Root die-back – when N levels increase and stimulate leaf growth a hormone begins to partition food reserves (carbohydrates) within the

plants. Needed carbohydrates are shifted away from the roots to leaves (Ramos and Curbelo, 1978).

C. Slower recovery – depleted carbohydrate reserves restricts turf recovery potential (Goatley et al., 1994).

D. Weak sod – rhizomes and stolons develop sparingly under high N levels. Without these, the sod will not hold together when handled (Mitchell and Dickens, 1979).

E. Reduced stress tolerance – over-fertilization with N causes turfgrass to become more susceptible to environmental and biological stresses. Summer drought, winter desiccation, and heat and cold damage are a few of the conditions to which the grass can become more susceptible (Dunn et al., 1995).

F. Water stress – excess N causes higher evapotranspiration rates, thus creating the need for more frequent irrigation (Dunn et al., 1995).

G. Disease – *Rhizoctonia* brown patch, *Pythium* blight, *Helminthosporium* disease, take-all patch, *Fusarium* patch, *Typhula* blight and gray leaf spot are all diseases that are more prevalent under high N conditions (Golembiewski and Danneberger, 1998)

H. More thatch – quicker accumulation of thatch will require periodic mechanical dethatching (Sartain and Dudeck, 1982).

The N level at which negative effects occur varies with turfgrass species and cultivar, soil texture, water and clipping removal or recycling. Adding iron to turfgrass can help achieve the desired dark green color without the negative effects of excess N (Yust et al., 1984). By supplementing N with iron to enhance color one can reduce the N rate by 25%-35% (Beard, 1990).

Ensuring bermudagrass survival during dormancy is important because bermudagrass is now grown in colder climates. Not only environmental factors and genetics play a role in winter hardiness; fertility also has an impact (Trenholm et al., 1998). Several researchers have reported that late-season fertilization may extend photosynthesis activity of bermudagrass in the fall, and stimulate it early in the spring (Goatley et al., 1994). Late-season fertilization with soluble N enhanced fall and spring color of bermudagrass without directly increasing the potential for winterkill (Goatley et al., 1998). A positive attribute of late season fertilization is a significant increase in the overall green period of bermudagrass, thus prolonging the playability of high maintenance sports facilities (Richardson, 2002). Such late season responses are found with soluble N fertilizer application, slow-release N fertilizer sources provide little fall or spring response (Goatley et al, 1994; Schmidt, 2003).

Mowing

The primary cultural practice in turf management is mowing. Well managed mowing results in a more vigorous plant, with greater stress resistance and thus a better surface for athletic fields (Andersen, 2000). Density, texture, color, root development, wear tolerance, and other aspects of turf quality are all enhanced by proper mowing (Madison, 1960). A sports field that is mowed three or more times per week will have a finer turf than one that is mowed less often. A familiar rule for mowing is to mow often enough so that no more than 30% of the leaf is removed at any one mowing (Adams, 1974). The shorter the grass is mowed the more often it needs to be mowed (Williams, 2001). Bermudagrass should be mowed between 1.3 cm and 2.5 cm for the highest possible quality (Adams, 1974). An easy way to check whether the turf is being mowed often enough is to check the color just above the soil surface. The grass should be green all the way to the ground. If a brown layer has developed, the frequency of mowing should be increased. Frequent mowing allows clippings to be left on the ground (Kopp and Guillard, 2002). They will act as a slow-release source of nutrients and will not significantly increase thatch (Kopp and Guillard, 2002). Mowing bermudagrass with a reel mower will produce a more uniform cut, and is the only option at cutting heights below 2 cm (Johnson et al., 1987). Whatever the mower type, it is imperative to keep the blades sharp.

Choosing a Mowing Height

Mowing height can be a major factor in turf quality. Close mowing of stoloniferous grasses such as bermudagrass encourages development of stolons and increases tillering (Brede and Duich, 1984). When tips of the stolons are removed by mowing, the stolons are stimulated to branch and to develop new plants at each node (Mitchell and Dickens, 1979). Mowing bermudagrass too high will result in stemmy, coarse turf that is easily scalped (Madison, 1960). Frequent mowing removes only a small amount of leaf tissue at a time. This provides a maximum leaf residual to maintain a high level of photosynthesis and carbohydrate production, necessary for new leaf tissue and lateral stem growth (Krans and Beard, 1985; Younger and Nudge, 1976).

Many positive points can be made for lower mowing heights. Closer mowing encourages more plants per square foot, which results in quicker recovery from wear (Madison, 1960; 1962). Turf mowed at a lower height is easier to efficiently aerate

(Owen, 2000). Core removal is easier and topdressing material can filter through to reach underlying soil. Conversely, higher mowing heights leave more growth on top to protect the rhizomes and stolons, leaving the plant with carbohydrate resources to survive (Dunn and Nelson, 1974). A down-side to mowing at a lower height is that the turf will dry out quicker, and the turfgrass stress level may be higher (Smiley et al., 1993). Field use is a major factor in determining mowing height.

Overseeding Bermudagrass

Overseeding is seeding one grass into an established stand of another grass. In the southeast, overseeding provides temporary winter cover and color for dormant bermudagrass. Usually, perennial rye (*Lolium perenne L.*) is sown into bermudagrass (Richardson, 2004). Typical dates for overseeding in the southern U.S. are late August through October. In order for the overseeding to be successful, the seed must come into contact with the soil. This can be achieved by lightly verticutting or scalping the bermudagrass (Gill et al, 1967). Frequent but light watering is required until the seedling is visible.

Although it is called perennial ryegrass, in the southeast the species serves as an annual on playing fields, and must be reseeded every year. Overseeding with ryegrass provides an attractive playing surface as the cool-season grass is green in winter, when bermudagrass is dormant (Horgan and Yelverton, 2001). Ryegrass also protects bermudagrass from wear and reduces winter weeds (Walker and Belcher, 2000). Ryegrass has a bunch growth habit (no rhizomes or stolons) and as a result it does not grow into divoted areas (Dunn et al., 1994). If there is intense shading and competition from the ryegrass, bermudagrass could be killed (Dunn et al., 1980). To limit competition the overseeding may need to be removed culturally or chemically so it will not negatively affect bermudagrass during the critical spring transition (Horgan and Yelverton, 2001). Application of herbicides such as metsulfuron-methyl and rimsulfuron can quicken the transition from ryegrass to bermudagrass (Horgan and Yelverton, 2001). Rimsulfuron has been proven excellent (96%) control of perennial ryegrass in Tifway (Walker and Belcher, 2000). Transitioning can also be hastened by lowering the mowing height to stress the ryegrass, and allowing sunlight through to stimulate the bermudagrass (Bruneau et al., 1985; Meyers and Horn, 1970).

Conclusion

More research is needed to determine the optimum nitrogen rate and mowing height for Tifway and TifSport managed as a bermudagrass athletic field. Establishing a proven nitrogen rate for the grass to thrive will help eliminate costs of excess fertility, and possible thatch or other environmental problems caused by excess N fertilizer. Use of a correct mowing height can affect recovery rate and root strength of the grass. Determining the best mowing height for these bermudagrasses would provide athletic field managers with needed production information. Additional research is also needed to determine how well these grasses recover from wear and damage.

Objectives

The objectives of this research are to evaluate the effect of nitrogen rate and mowing height on the performance of Tifway and TifSport managed as an athletic field and to evaluate the effect of nitrogen source and nitrogen rate on the establishment of Tifway and TifSport hybrid bermudagrasses.

II. MATERIALS AND METHODS

There were two experiments performed: one was an establishment study, and the second a management study on established turf. For the establishment study, treatments were a factorial combination of cultivar, nitrogen rate and nitrogen source. Treatments were arranged in a strip-strip-strip plot design with cultivar as the main plot, nitrogen source as the second split, and nitrogen rate as the third. There were four replications of every treatment. Treatments for the management study were arranged as a factorial combination of cultivar, nitrogen rate and mowing height, arranged in a strip-strip-strip design with cultivar as the main block, nitrogen rate as the second split and mowing height as the third split. There were four replications of each treatment combination. Each experiment will be discussed in detail, below:

Management Study on Established Turf

A plot area at the Auburn University Turfgrass Research Unit (AUTGRU) was selected in August 2001. The area was fumigated with methyl bromide at a rate of 448 kg ha^{-1} and covered with plastic for 1 week. Two weeks after fumigating (16 August, 2001) the plot was hand-sprigged with Tifway and TifSport bermudagrass at 2.9×10^4 kg ha^{-1} (10 bushels/1000ft^2), then heavily topdressed with sand.

Treatments consisted of two cultivars (Tifway and TifSport), two mowing heights (19 and 25 mm) and four nitrogen fertilization rates (2.4, 4.9, 7.3 and 9.8 g m^{-2}/month). Treatments were a factorial combination of cultivar, nitrogen rate and mowing height, arranged in a strip-strip-strip design with cultivars as main blocks (7.6 m x 15.2 m), nitrogen rate as the first split (7.6 m x 3.8 m) and mowing height as the second split (1.9 m x 7.6 m). There were four replications of each treatment combination. Fertilizer treatments began in April of 2002 and 2003. Fertilizer was applied in split applications every 2 weeks. The N source was ammonium nitrate (34-0-0). In each year, N treatments were applied April through October. Mowing height treatments were applied May through August. Plots were overseeded in October at a rate of 975.7 kg ha^{-1}, using 'Fairway Master' perennial ryegrass mixture, a blend which included the cultivars 'Majesty', 'Ascend', and 'Divine' perennial ryegrass (*L. perenne L.*) and were mowed at a height of 19mm.

Plots were mowed with a Ransomes 185 triplex trim mower three times a week. Plots were managed as an athletic field with standard pest control and cultural practices. No artificial traffic was applied, with the only traffic consisting of vehicular traffic applied via athletic field maintenance equipment. The soil was a Marvyn loamy sand (fine-loamy, siliceous, thermic Typic Paleudult). Initial soil test results were as follows: P: 7.3 kg ha^{-1}, K: 128.8 kg ha^{-1}, Mg: 206.1 kg ha^{-1}, Ca: 1142.4 kg ha^{-1} and pH of 6.1. Data collection included shoot density, stolon and rhizome dry weight, recovery from wear, clipping yield and overseed density. The plot area was equipped with automatic irrigation to supply 2.5 cm water per week in the absence of rainfall.

Establishment Study

A selected plot area at the AUTGRU was fumigated with methyl bromide at a rate of 448 kg ha^{-1} and hand sprigged on 8 May 2002 at 2.9 x 10^4 kg ha^{-1} (10 bushels/1000ft^2). Treatments were started 2 weeks after sprigging. Soil test results were as follows: P: 59.4 kg ha^{-1}, K: 145.6 kg ha^{-1}, Mg: 170.2 kg ha^{-1}, Ca: 694.4 kg ha^{-1}, and a pH of 5.3. Phosphorus, potassium and lime were added prior to the study according to soil test recommendations. This entire study was repeated in 2004, with new plots sprigged on 13 May 2004, using the same sprigging rates as listed previously.

Treatments consisted of two nitrogen sources: ammonium nitrate (34-0-0) and calcium nitrate (16-0-0; 39% Ca), both applied as granular sources. Nitrogen fertilizer rates were 2.4, 4.9, 7.3 or 9.8 g N m^{-2}/week. The fertilizer was applied by hand and 0.6 cm of water was then applied. In order to balance for calcium applied in $CaNO_3$ (calcium nitrate) treatments, $CaSO_4$ (calcium sulfate), which is 29% calcium, was added to the NH_4NO_3 (ammonium nitrate) treatments. Nitrogen rate and nitrogen source treatments were applied to Tifway and TifSport hybrid bermudagrass. Treatments were a factorial combination of cultivar, nitrogen rate and nitrogen source. They were arranged in a strip-strip-strip plot design with cultivars as the main plots (7.3 m x 3.7 m), nitrogen source as the second split (3.7 m x 3.7 m), and nitrogen rate as the third split (3.7 m x .9 m). There were four replications of every treatment.

Plots were equipped with automatic irrigation to supply 2.5 cm water per week in the absence of rainfall. Data collection for the establishment study included weekly establishment measurement, stolon and rhizome dry weight, and shoot counts. Plots were maintained as athletic fields with standard pest control and cultural practices. The plots were mowed at 1.9 cm (3/4") with a Ransomes 185 triplex trim mower three times a week.

Data Collection - Establishment Study

Percent establishment was determined beginning 2 weeks after sprigging (WAS) by the line transect method. Each week, two strings, placed 30 cm apart were stretched across each plot. Each string contained 25 marks. The strings were placed in the same location each week. If a piece of plant tissue touched a mark, it was counted as a hit. Total number of 'hits' per plot, multiplied by two, equaled percent establishment (Guertal and Evans, 2006). Rate of establishment was measured for 5 weeks in both 2002 and 2004, at which time 95% establishment had been reached in both 2002 and 2004.

Once 95% establishment had been reached, shoot density was determined by randomly removing three 6.4 cm diameter plugs from each plot and counting shoots from each plug. Shoot counts were performed three times in each experiment: 9 July 2002, 29 July 2002, 13 August 2002, and 6 July 2004, 21 July 2004, and 19 August 2004. Stolon and rhizome dry weights were determined by taking three plugs with a 6.4 cm diameter plugger from each plot, removing all stolons and rhizomes, drying them, and determining their weight. Stolon and rhizome weights were measured once a year, on 13 August 2002, and 2 August 2004.

Statistical Analysis of Data

All data was analyzed using standard statistical software (SAS) via the analysis of variance procedure. Results of the analysis of variance were used to determine significance of 2 and 3-way interactions. If interaction was significant data was presented in Tables to best illustrate the effects of the interaction. If there was no significant interaction treatments were evaluated either by mean separation (cultivar, N source) or linear regression (N rate).

Data Collection - Management Study

Data collection for the management study included shoot density, recovery from wear, clipping yield, shear strength, and overseed shoot density. Shoot density was determined from three plugs (6.4 cm diameter) removed at random from each plot and the number of shoots was hand counted. Shoot counts were taken approximately once a month (25 July 2002, 20 August 2002, 3 October 2002, and 30 June 2003, 11 July 2003, 9 September 2003, and 10 November 2003). Overseed density was measured in the same manner as shoot counts, with the ryegrass and bermudagrass counted separately. Overseed density was collected on 17 March 2003, 10 November 2003, and 5 April 2004. All treatments were mowed at 1.9 cm and fertilized with 25-4-8 at 2.4 g m^{-2} $month^{-1}$ (0.5 lb N/1000ft^2/month) while overseeded. Overseeding was removed by treating with TranXit (rimsulfuron) at 140.3 g ha^{-1} (2 oz. product/A) on 1 May 2003 and 9 June 2004.

Recovery from simulated cleat wear and tear was also determined monthly in the summer/fall (August, September, and October). To create tear, a 15 cm metal disc with football cleats attached to it was weighted with 90 kg. The cleated disc and weights were threaded onto a 1-m long metal pole (7.6 cm diameter) through which a 0.6-m rod was threaded (at top). The weighted disc was placed on the turf and turned via the rod to impart a tearing action to the turf, simulating a player’s foot. Two spots were ‘torn’ in each plot each time wear was created. Recovery was measured by counting new shoot initiation within the torn area, with recovery measured until the torn area was healed.

The same device was used to determine shear strength, except a torque wrench (England Mountz, Inc. 1080 N. 11 Street St. Jose, CA) was used to turn the weighted cleat (Aldous, 1999). The cleat plate was turned until torque tension was broken, and the torque reading at which 'cleat slip' occurred was recorded. Data was recorded in Newton meters. Shear strength was measured in June and August, 2002, and June, August, and September 2003.

Thatch depth data for the established study was collected in January 2003. Three cores 6.4 cm in diameter were collected from each plot and thatch depth was measured as the distance from the top of the thatch layer to the bottom of the mat layer.

A visual rating of color and quality was taken in July, August and September 2002. A scale of one (no color or dead turf) to nine (deep green color and healthy turf) was used.

Clipping yield was determined by mowing with a Toro Greens Master 3 triplex greens mower (mowing height was 1.9 cm and 2.5 cm on respective plots). Clippings were caught, dried, and weighed twice a year.

III. RESULTS AND DISCUSSION

Establishment Study

Rate of Establishment

In 2002, at 2, 3 and 4 weeks after sprigging (WAS) establishment was significantly affected by cultivar, with TifSport having faster establishment (Fig 1). Establishment was unaffected by N rate, or any of the 2 or 3-way interactions of N rate, cultivar or N source (Fig. 2). Richardson and Boyd (2001) also reported N applications during establishment had little or no overall effect on establishment of zoysiagrass, although the 0 g m^{-2} rate was inferior to all other rates. At 5 WAS neither cultivar nor N rate significantly affected establishment.

In 2004 establishment was affected by cultivar (Fig 3), but not by N rate or the cultivar x N rate interaction. TifSport had faster establishment early in the season (2 and 3 WAS), but by 4 WAS (2004 data) there was no difference in establishment due to cultivar. In both years, TifSport and Tifway had significant differences in time of establishment. TifSport averaged around 10 to 15% faster establishment. Differences due to cultivar were largely gone by 5 and 4 WAS in 2002 and 2004, respectively. Trenholm (1999) reported TifSport had more verdure than Tifway. There was no difference in establishment due to a significant N rate x N source x cultivar interaction.

N rate may not have affected establishment because the experiment was conducted on a loamy sand soil, which has a slightly higher OM, which could make a response to added N less likely. Sandy soils would have less available nutrients; therefore N would have been more significant. Antecedent N contributes significantly to leaf N budgets, therefore sandy soil would have less N available (Fagerness et al., 2004). Johnson (1973) reported Tifway sprig establishment was not encouraged by increasing applied N from 49 to 98 kg ha^{-1}.

High N fertility promotes shoot growth, giving leaf tissue competitive priority for available root carbohydrates (Hull, 1978). Johnson (1973) found raising monthly N fertilization from 0 to 4.9 g m^{-2} during establishment increased coverage of Tifway by 17% 18 WAS. Since the fertilizer rates in this study were 2.4 to 9.8 g m^{-2} additional rates below 4.9 g m^{-2} need further examination. Lower N rates might have proven more effective in determining N significance. Most reports agree N fertilization is beneficial, but should not exceed 4.9 g m^{-2} mo^{-1} for maintenance.

Shoot Density

In 2002, for shoot density, the 3-way interaction of N source, N rate and cultivar was never significant, nor were the two-way interactions of N rate x cultivar, N rate x N source, or cultivar x N source. At 8 WAS plots sprigged with TifSport had a significantly higher density than plots sprigged with Tifway (Table 1). No such differences were observed at 11 and 14 WAS.

At one sampling there were significantly more shoots in plots fertilized with NH_4NO_3, as compared to shoot numbers in plots fertilized with $Ca(NO_3)_2$. This occurred in 2002 at 11 WAS, but not at 8 or 14 WAS (Table 1) and differed from the results of Hollingsworth et al (2005) who reported that shoot density of bermudagrass and *P. trivialis* had no consistent response to either management or N source. In 2004, shoot density of TifSport was greater than Tifway at 14 WAS, with no significant difference at 8 or 10 WAS (Table 2). As in 2002, at one sampling (10 WAS) plots that received NH_4NO_3 had greater shoot density than those receiving $Ca(NO_3)_2$.

Shoot density was not increased by N rate (Fig 4) in 2002. In 2004, however, shoot density was maximized at an N rate of 7.2 g m^{-2} N $week^{-1}$ (Fig 5). Trenholm (1998) reported excessive N fertilization increased shoot growth and subsequently depleted stored carbohydrates (Trenholm et al., 1998).

Dry Weights of Stolons and Rhizomes

None of the 2 or 3 way interactions of N source, cultivar or N rate significantly affected the dry weight of stolons and rhizomes in 2002 or 2004. However, in both years as N rate increased, the dry weight of the stolons and rhizomes decreased (Figure 6). This is in agreement with Hensler et al. (1999); lower N rates produced the largest stolons. Other researchers have shown similar reductions in carbohydrate-storage tissue as N rate increased (McCullough et al., 2006), with stolons containing the highest levels of carbohydrate reserves (Pettit and Fagan, 1974). Over-application of N reduced rhizome and stolon weights, root dry weight, and total nitrogen content in 'Tifeagle' bermudagrass (Guertal and Evans, 2006). Such reductions are attributed to increases in leaf tissue growth (Hull, 1978)**,** and can place turf at a risk of winter injury (Munshaw et al., 2001).

Management of Established Turf Study

Shoot Density

Shoot density had one significant 3 way interaction: N rate x cultivar x mowing height (10 November 2003). Significant 2 way interactions that occurred were: N rate x mowing height (20 August 2002), and N rate x cultivar (9 September 2003). N rate alone significantly affected shoot density on 3 October 2002, and on 11 July 2003: On these dates N applied at 2.4 g m^{-2} $month^{-1}$ had greatest shoot density. Spring and summer shoot density of bermudagrass was either unaffected (30 June 2003 and 11 July 2003) or slightly increased as N rate increased (25 July 2002 and 20 August 2002). In 2002, shoot density increased as N rate increased to 7.2 g N m^{-2} month $^{-1}$, but decreased thereafter (Fig 7). In 2003, shoot density was largely unaffected by N rate (Fig 7). In the fall, however (Fig 8), shoot densities of bermuda often decreased as N rate increased. Guertal and Evans (2006) reported N rates affected shoot density, with shoot populations maximized at rates ranging from 4.8 to 2.9 g N m^{-2} $week^{-1}$. Tifway had a greater shoot density when cultivar interacted with N rate and/or mowing height.

Overseeding Shoot Density

In 2003, cultivar (17 March 2003) and mowing height (10 November 2003 and 5 April 2004) significantly affected shoot density of the overseeded ryegrass (Table 3). Ryegrass in TifSport plots had a higher shoot density on 17 March 2003 and the overseeding on Tifway plots had a higher shoot density 5 April 2004. When mowing height was significant, the 2.54 cm height had greater shoot density. A two way interaction of cultivar x mowing height was significant on 17 March 2003 and 5 April 2004. The interaction of N rate x mowing height was significant on 5 April 2004.

Recovery from Wear and Torque Strength

There was one significant 3-way interaction and one 2-way interaction for these variables during this study. Cultivar x N rate x mowing height was significant on 17 August 2003 for torque strength, and N rate x mowing height was significant on 24

September 2003 for recovery. Mowing height was significant on 3 October and 7 October 2003 for recovery, with a mowing height of 2.5 cm best for quicker recovery. On 10 October 2003, N rates of between 2.4 – 4.9 g m^{-2} $month^{-1}$ were best for quickest recovery (Figs 9-11).

There were significant differences in torque strength due to cultivar, with TifSport able to withstand more twist before tearing. On 29 August 2002, TifSport tore at a torque reading of 71 Newton meters, a significantly greater resistance than shown in the Tifway plots, which tore at 67 Newton meters. Results were significant again 12 August 2003 with TifSport tearing at 65 while Tifway tore at 63 Newton meters. On 17 June 2002 and 29 August 2002, 2.4 g N m^{-2} $month^{-1}$ produced slightly stronger turf than 9.8 g N m^{-2} $month^{-1}$ (Fig 12). However, on 12 August 2003, N applied at 9.8 g N m^{-2} $month^{-1}$ produced stronger turf than that receiving any other N rate (Fig 13).

Clipping Yield

Mowing height significantly affected clipping yield on 11 October 2002, 17 July 2003, and 20 August 2003. A mowing height of 2.5 cm always had a higher clipping yield than a mowing height of 1.9 cm. N rate significantly affected yield on 17 July 2003, at that date; 4.9g m^{-2} $month^{-1}$ had the greatest amount of clippings (Fig 14). Increasing fertilizer rates were found to increase overall dry matter yield (Kopp and Guillard, 2002), however in this study the highest N rate did not consistently produce the greatest clipping yield.

IV. CONCLUSIONS

Establishment Study

1. TifSport averaged around 10-15 percent faster establishment than Tifway.
2. TifSport also had higher shoot density than Tifway at 8 WAS. No differences were observed at 11 and 14 WAS. At two samplings, plots fertilized with NH_4NO_3 had significantly more shoots than plots fertilized with $Ca(NO_3)_2$.
3. In both years of this study, as N rate increased dry weight of stolons and rhizomes decreased.

Management Study

1. In October 2002 and July 2003, N applied at 2.4 g m^{-2} $month^{-1}$ had greatest shoot density.
2. Ryegrass shoot density was greater in plots mowed at 2.54 cm.
3. N rates between 2.4 – 4.9 g m^{-2} $month^{-1}$ were best for quickest recovery.
4. TifSport was able to withstand more torque strength before tearing.

LITERATURE CITED

Adams, W.E., P.J. Bryan and G.E. Walker. 1974. Effects of cutting height and nitrogen nutrition on growth pattern of turfgrass. Int. Turfgrass Conf. Blacksburg, VA. ASA and GSSA, Madison, WI. p. 131-144.

Alderson, J. and W.C. Sharp. 1994. Grass varieties in the U.S. Agricultural Handbook No. 170 p. 47. U.S. Dept. of Agric., Soil Conservation Service, Washington, D.C.

Aldous, D.E. 1999. Handbook: International turf management handbook. Institute of Land and Food Resources, University of Melbourne. p. 238.

Andersen, M. 2000. Mowing: Height Manipulation. Sports Turf Topics: A Compendium of STMA Articles. p. 29-30.

Anderson, J., C. Taliaferro, and D. Martin. 2002. Freeze tolerance of bermudagrass: vegetatively propagated cultivars intended for fairway and putting green use, and seed propagated cultivars. Crop Sci. 42:975-977.

Assefa, S., C.M. Taliaferro, M.P. Anderson, B.G. Reyes and R.M. Edwards. 1999. Diversity among *Cynodon* accessions and taxa based on DNA amplification fingerprinting genome. Canada: National Research Council of Canada. 42:465-474.

Beard, J.B. 1973. Turfgrass: Science and Culture. Prentice Hall, Englewood Cliffs, N.J. p. 1-2.

Beard, J.B. 1990. Turfgrass Color: When green is bad. Grounds Maintenance. 25:28-32.

Brede, A.D. and J.M. Duich. 1984. Initial mowing of Kentucky bluegrass – Perennial ryegrass seedling turf mixtures. Agron. J. 76:711-714.

Bruneau, A.H., J.M. Dipaola, W.M. Lewis, W.B. Gilbert and L.T. Lucas. 1985. Overseeding bermudagrass turf. N.C. Agric. Ext. Serv. AG-352.

Burton, G.W. 1966. (Tifton 419) bermudagrass. [Reg. No.7] Crop Sci 6:93-94.

Burton, G.W. 1985. Registration of Tifway II Bermudagrass. Crop Sci. 25:364.

Busey, P. 1997. Bermudagrass identity crisis. Golf Course Mngt. 65:53-57.

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

Christians, N. 1998. Fundamentals of Turgrass Management. Ann Arbor Press. Chelsea, MI. p.50,51,117,122,143,144.

Duble, R.L. 1996. Turfgrasses: Their Management and Use in the Southern Zone. (2nd edition). Texas A&M University Press. College Station, TX. p. 3, 40, 42, 46.

Dunn, J.H. and C.J. Nelson. 1974. Chemical changes occurring in three bermudagrass cultivars in relation to cold hardiness. Agron. J. 66:28-31.

Dunn, J.H., C.J. Nelson and J.L. Sebaugh.1980. Characterization of thatch, rhizomes, carbohydrates, and spring deadspot in twenty cultivars of bermudagrass. J. Am. Soc. Hort. Sci. 105(5):653-657.

Dunn, J.H., D.D. Minner, B.F. Fresenburg and S.S. Bughrara. 1994. Bermudagrass and cool-season turfgrass mixtures: response to stimulated traffic. Agron. J. 86:10-16.

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

Fagerness, M.J., D.C. Bowman, F.H. Yelverton, and T.W. Rufty. 2004. Nitrogen use in Tifway bermudagrass, as influenced by trinexapacethyl. Crop Sci. 44:595-599.

Foy, J.H. 1997. The hybrid bermudagrass scene. USGA Green Section Record. Nov./Dec. p. 1-4.

Gill, W.J., W.R. Thompson, Jr. and C.Y. Ward. 1967. Species and methods for overseeding bermudagrass greens. Golf Superintendent. 35:10-17.

Goatley, J.M. Jr., V.L. Maddox, D.J. Lang, and K.K. Crouse. 1994. 'Tifgreen' bermudagrass response to late season application of nitrogen and potassium. Agron. J. 86:7-10.

Goatley, J.M. Jr., V.L. Maddox and K.L. Hensler. 1998. Late-season applications of various nitrogen sources affect color and carbohydrate content of 'Tiflawn' and Arizona common bermudagrass. Hort. Sci. 33:692-695.

Golembiewski, R.C. and T.K. Danneberger. 1998. Dollar spot severity as influenced by trinexapac-ethyl, creeping bentgrass cultivar and N fertility. Agron. J. 90:466-472.

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

Gustavo, C., L.M. Callahan and P.M. Gresshoff. 1997. The origin of bermudagrass (*Cynodon*) off-types inferred by DNA amplification fingerprinting. Crop Sci. 37:81-87.

Hannah, W.W., R.N. Carrow, and A.J. Powell. 1997. Registration of "Tift 94" bermudagrass. Crop Sci. 37:1012.

Hannah, W. 1998. The future of bermudagrass. Golf Course Mngt. 66:49-52.

Hensler, K.L., M.D. Richardson, and J.R. Bailey. 1999. Implications of seeded bermudagrass planting date and morphology on cold tolerance. *In* J.R. Clark and M.D. Richardson (ed.) Horticultural studies 1998 (Research Series 466). Ark. Agric. Exp. Stn., Univ. of Ark. Div. of Agric., Fayetteville, AR. p. 70.

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.

Hooper, B. 1970. The real change has just begun. Life. 68 (1): 102-106.

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

Hull, R.J. 1978. A carbon-14 technique for measuring photosynthate distribution in field grown turf. Agron. J. 68:99-102.

Johnson, B.J. 1973. Herbicides, sprigging rates, and nitrogen treatments for establishment of Tifway bermudagrass. Agron. J. 65:969-972.

Johnson, B.J., R.N. Carrow and R.E. Burns. 1987. Bermudagrass turf response to mowing practices and fertilizer. Agron. J. 79:677-680.

Johnson, B.J. 1994. Influence of plant growth regulators and mowing on two bermudagrasses. Agron. J. 86:805-810.

Juska, F.V. and A.A. Hanson. 1964. Bermudagrass varieties for general purpose turf. USDA Handbook 270. Washington D.C.

Krans, J.V. and J.B. Beard. 1985. Effects of clipping on growth and physiology of 'Merion' Kentucky bluegrass. Crop Sci. 25:17-20.

Kopp, K.L. and K. Guillard. 2002. Clipping management and N fertilization of turfgrass. Crop Sci. 42:1225-1231.

Landschoot, P. and G. Miller. 2003. Feast or Famine Fertility. Grounds Maintenance. 38:14-20.

Madison, J.H. 1960. The mowing of turfgrass I. The effect of season, interval, and height of mowing on the growth of seaside bentgrass turf. Agron. J. 54:449-452.

Madison, J.H. 1962. Turfgrass Ecology. Effects of mowing, irrigation, and N treatments of *agrostis palustris* 'Seaside' and *Agrostis tennis* 'Highland' on population, yield, rooting and cover. Agron. J. 54:407-412.

McCarty, B. and A. Canegallo. 2005. Tips for managing ultradwarf bermudagrass greens. Golf Course Mgmt. 73: 90-91.

McCullough, P.E., L. Haibo, L.B. McCarty, T. Whitwell and J.E. Toler. 2006. Bermudagrass putting green growth, color, and nutrient partitioning influenced by nitrogen and trinexapac-ethyl. Crop Sci. 46:1515-1525.

Meyers, H.G. and G.C. Horn. 1970. Transition from overseeded to permanent warm-season grasses. Golf Superintendent. 38(1):62-65.

Miller, G.L. and J.L. Cisar. 1990. Maintaining Athletic Fields. University of Florida Cooperative Extension Service Publication. Bulletin 262.

Mitchell, C.H. and R. Dickens. 1979. Nitrogen fertilization and mowing height effects on tensile strength of bermudagrass sod. Agronomy J. 71:1061-1062.

Munshaw, G.C., D.W. Williams, and P.L. Cornelius. 2001. Management Strategies during the establishment year to enhance production and fitness of seeded bermudagrass stolons. Crop. Sci. 41:1558-1564.

Owen, M. 2000. Spread Out! Tillers, Rhizomes and Stolons. Sports Turf Topics: A Compendium of STMA Articles. August. p. 115-117.

Pettit, R.D. and R.E. Fagan. 1974. Influence of nitrogen and irrigation on carbohydrate reserves of buffalograss. J. Range Manage. 27:279-282.

Phillips, T.D., D.P. Belesky and A.J. Powell, Jr. 1997. Registration of 'Quickstand' bermudagrass. Crop Sci. 37:1674.

Ramos, N.F. and F. Curbelo. 1978. Sources and levels of nitrogen in bermudagrass. Cuban Journal of Agricultural Science. 12:289-297.

Richardson, M.D. 2002. Turf quality and freezing tolerance of 'Tifway' bermudagrass as affected by late-season nitrogen and trinexapac-ethyl. Crop Sci. 42:1621-1626.

Richardson, M.D. 2004. Morphology, turf quality and heat tolerance of intermediate ryegrass. Hort. Sci. 39:170-173.

Richardson, M.D. and J.W. Boyd. 2001. Establishing *Zoysia japonica* from sprigs: Effects of topdressing and nitrogen fertility. Hort. Sci. 36:377-379.

Rodriguez, I.R., G.L. Miller and L.B. McCarty. 2002. Bermudagrass establishment on high sand-content soils using various N-P-K ratios. Hort. Sci. 37:208-209.

Sartain, J.B. and A.E. Dudeck. 1982. Yield and nutrient accumulation of Tifway bermudagrass and overseeded ryegrass as influenced by applied nutrients. Agron. J. 74:488-491.

Schmidt, R.E. 2003. Late-season fertilization of bermudagrass. Golf Course Mngt. 71:125-127.

Smiley, R.W., P.H. Dernoeden and B.B. Clarke. 1993. Compendium of turfgrass disease. APS Press, Pilot Knob, MN.

Taliaferro, C.M. 1995. Diversity and vulnerability of bermuda turfgrass species. Crop Sci. 35:327-332.

Thompson, W.R. and C.Y. Ward. 1966. Prevent thatch accumulation on Tifgreen bermudagrass greens. Golf Course Rep. 34:20-38.

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. 38:168-173.

Trenholm, L.E., R.R. Duncan, and R.N. Carrow. 1999. Wear tolerance, shoot performance, and spectral reflectance of seashore paspalum and bermudagrass. Crop Sci. 39:1147-1152.

Turgeon, A.J. 2000. Controlling thatch. Grounds Maintenance. 35:48-49,56.

Ulrich, R.S. 1986. Human responses to vegetation and landscapes. Landscape Urban Planning. 13: 29-44.

Walker, R.H. and J. Belcher. 2000. Removal of perennial ryegrass and rough bluegrass from Tifway bermudagrass with herbicides. Southern Weed Science Society. 53:49.

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

Williams, S. 2001. Color TifSport dark green. Golf Course Mngt. 69:33-42.

Younger, V.B. and F.J. Nudge. 1976. Soil temperature, air temperature and defoliation effects on growth and nonstructural carbohydrate of Kentucky bluegrass. Agron. J. 68:257-260.

Yust, A.K., D.J. Wehner and T.W. Fermanian. 1984. Foliar application of N and Fe to Kentucky bluegrass. Agron. J. 76:934-938.

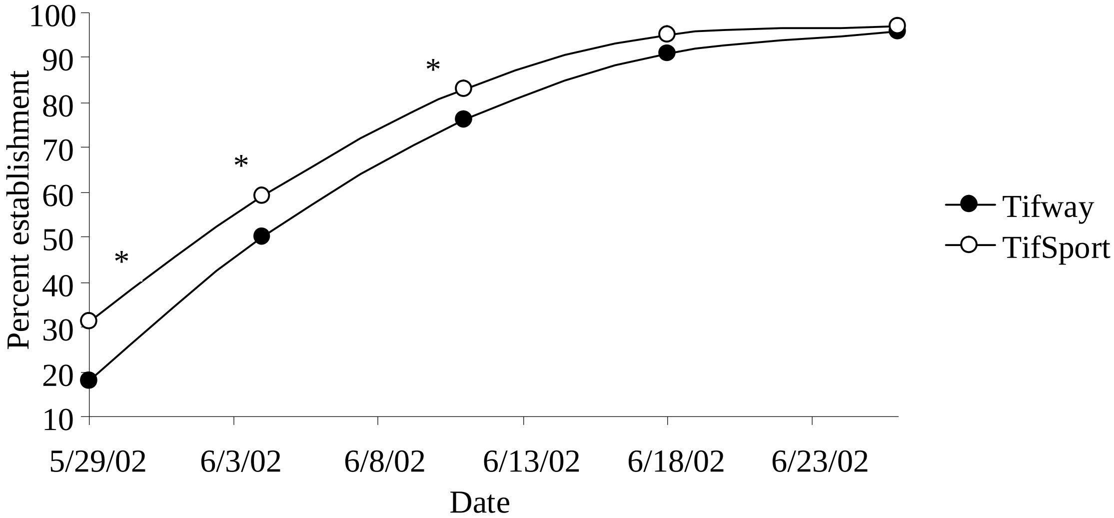
www.tifsport.com/tifsportresearchdata.htm

www.shark.com/gnturf/gn1.php

www.sodsolutions.com

APPENDIX

Figure 1. Percent establishment of hybrid bermudagrass as affected by cultivar and date of data collection, 2002



‘*’: Establishment significantly different due to cultivar at $\alpha = 0.05$.

Figure 2. Percent establishment of hybrid bermudagrass as affected by N rate at 3, 4, 5 and 6 WAS, 2004

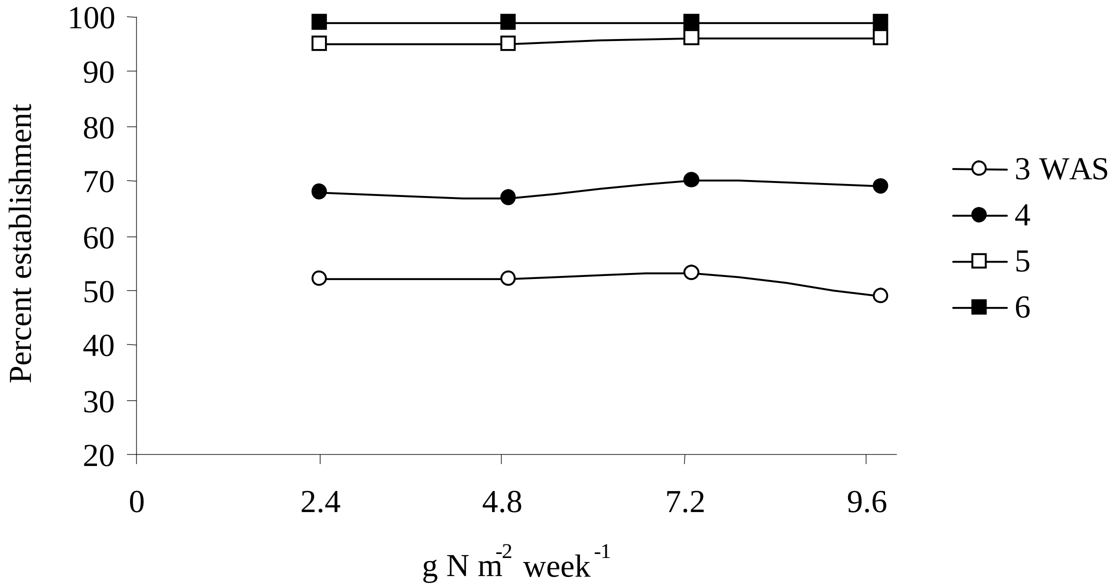
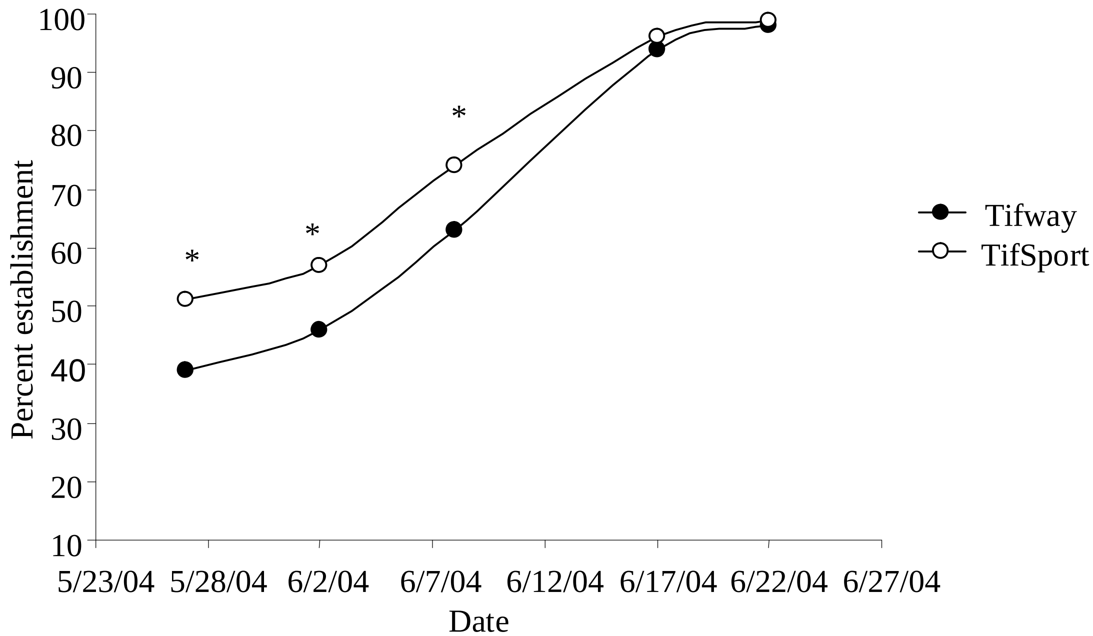


Figure 3. Percent establishment of hybrid bermudagrass as affected by cultivar and date of data collection, 2004



‘*’: Establishment significantly different due to cultivar at α = 0.05.

Figure 4. Shoot density of TifSport and Tifway bermudagrass at 8, 11 and 14 WAS as affected by N rate, 2002, Establishment study.

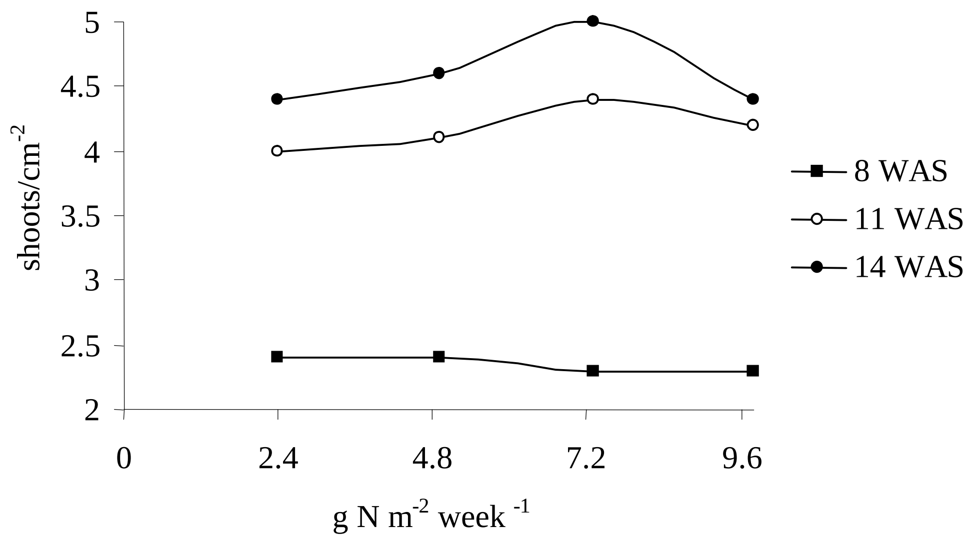


Figure 5. Shoot density of TifSport and Tifway bermudagrass at 8, 10 and 14 WAS as affected by N rate, 2004, Establishment study

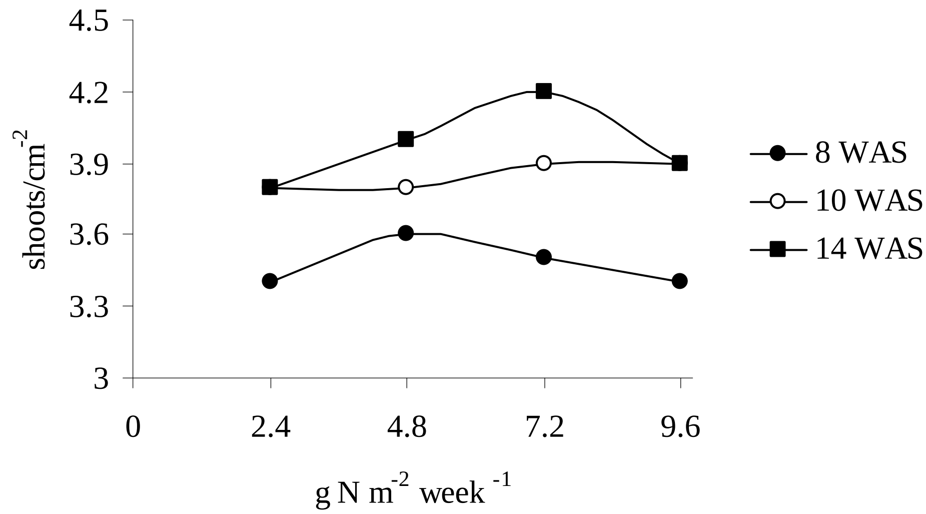


Figure 6. Dry weight of harvested stolons and rhizomes as affected by N rate, 2002 and 2004, Establishment study

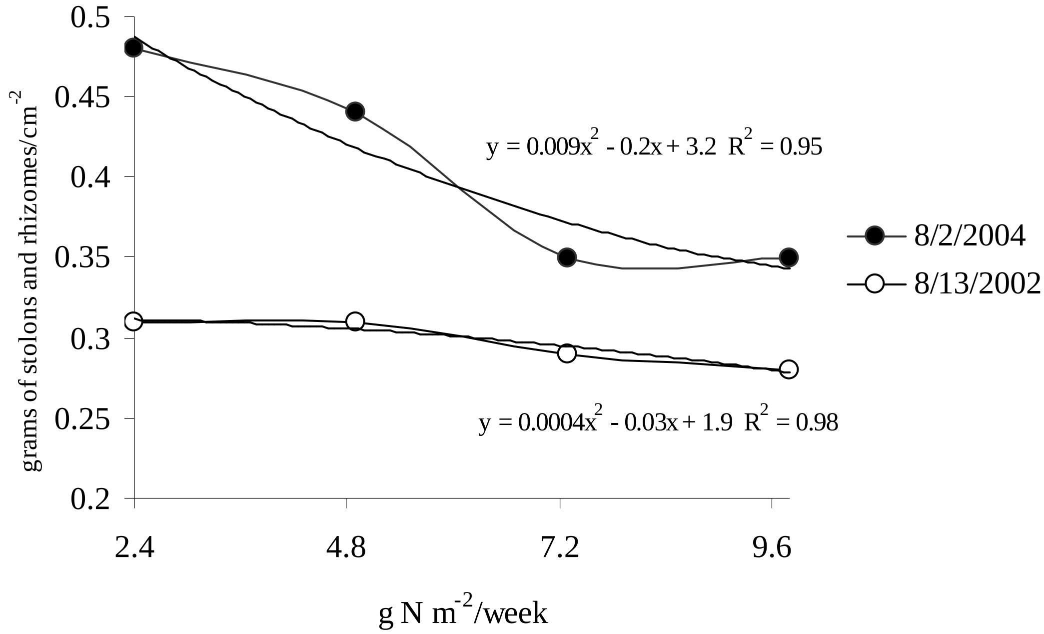


Figure 7. Summer shoot density of hybrid bermudagrass (averaged over cultivar) as affected by N rate and sampling date, 2002 and 2003, Management study

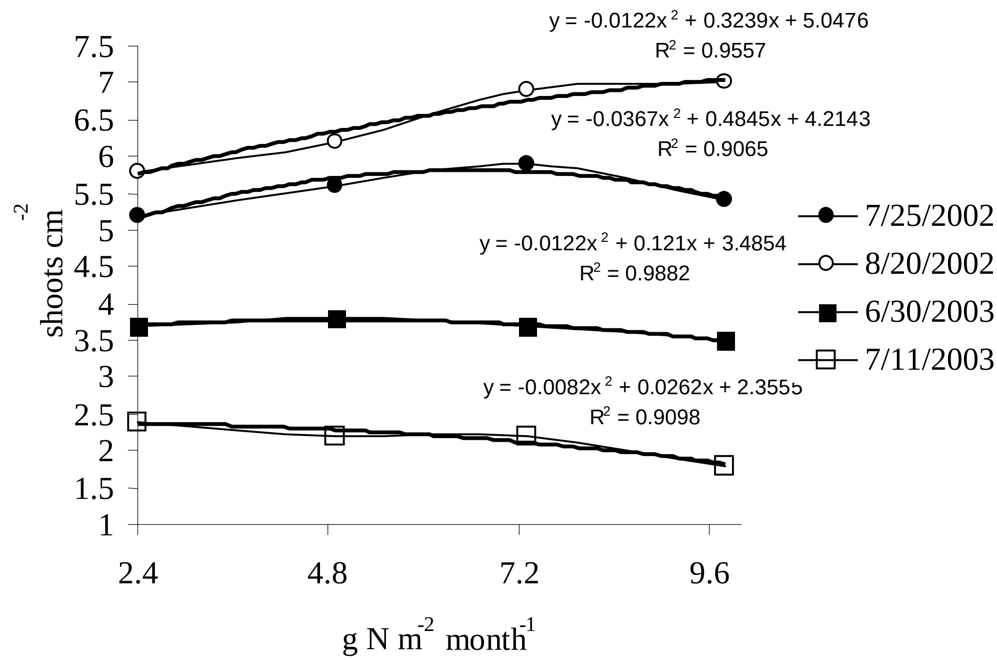


Figure 8. Fall shoot density of hybrid bermudagrass (averaged over cultivar) as affected by N rate and sampling date, 2002 and 2003, Management study

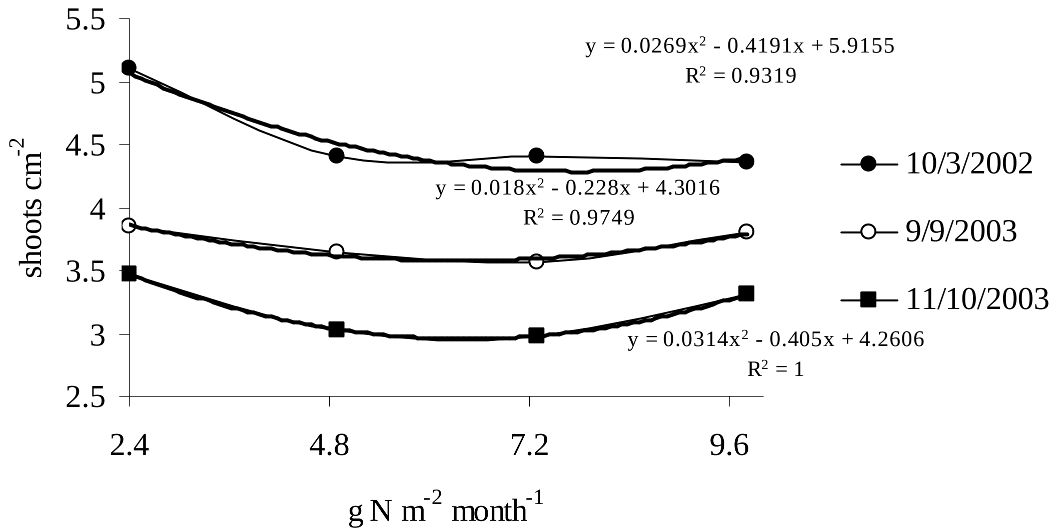


Figure 9. Turf recovery from artificial tearing at 3 and 6 days after tearing, Management study, August, 2003

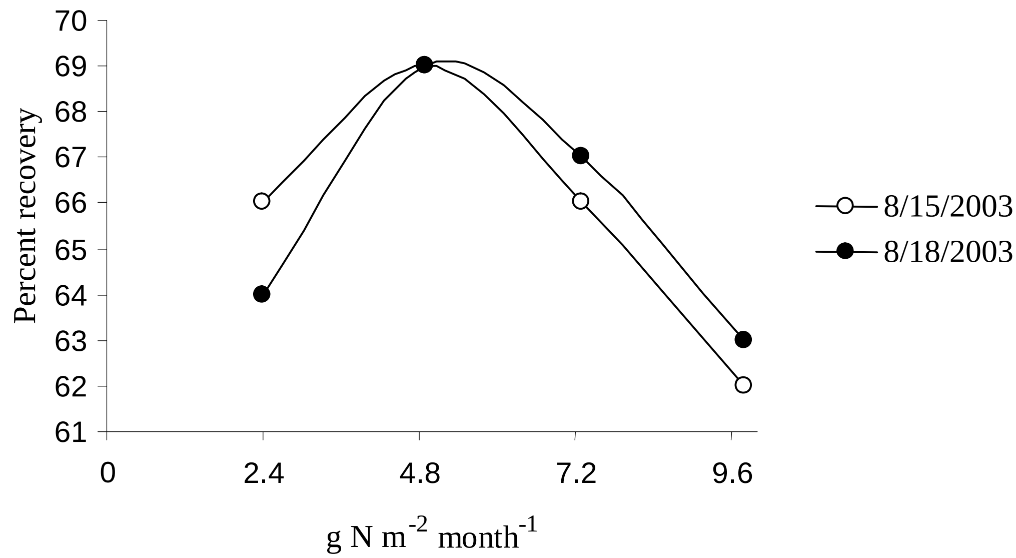


Figure 10. Turf recovery from artificial tearing at 2, 4 and 7 days after tearing, Management study, September, 2003

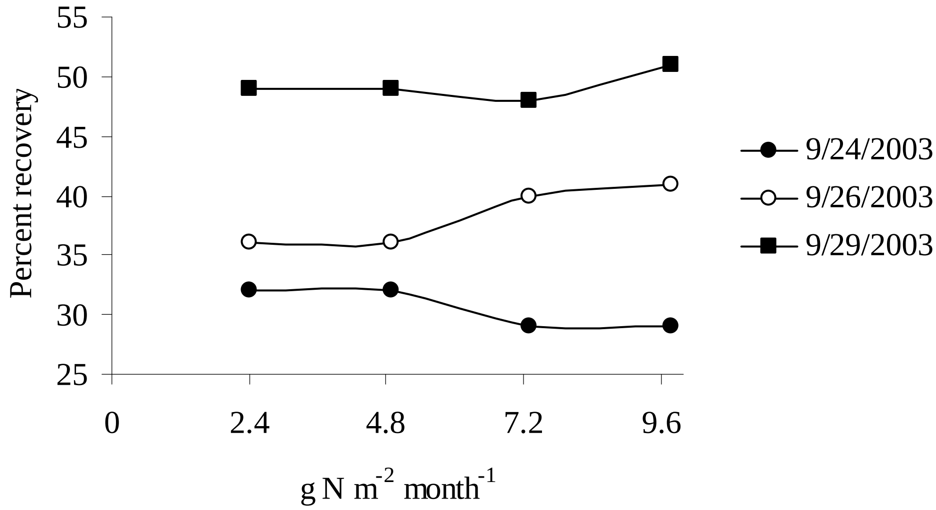


Figure 11. Turf recovery from artificial tearing at 11, 15 and 18 days after tearing, Management study, October, 2003

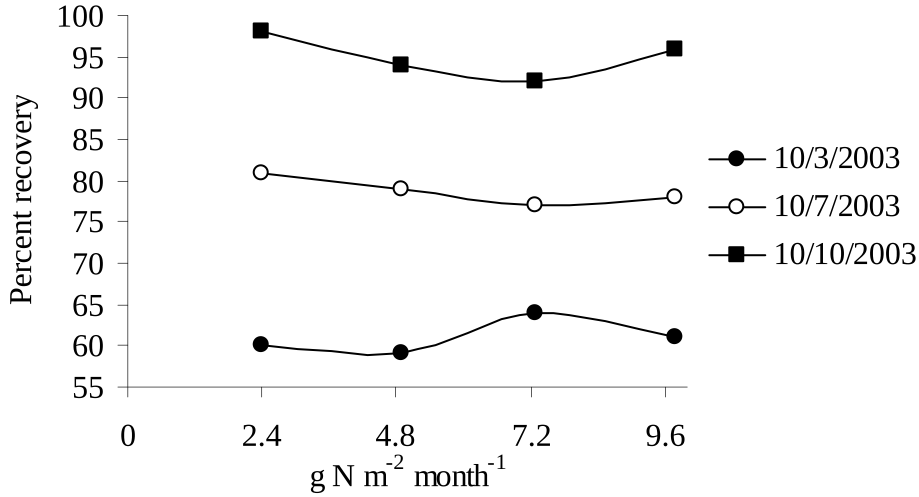


Figure 12. Torque strength required to tear hybrid bermudagrass sod as affected by N rate and sampling date, Management study, 2002

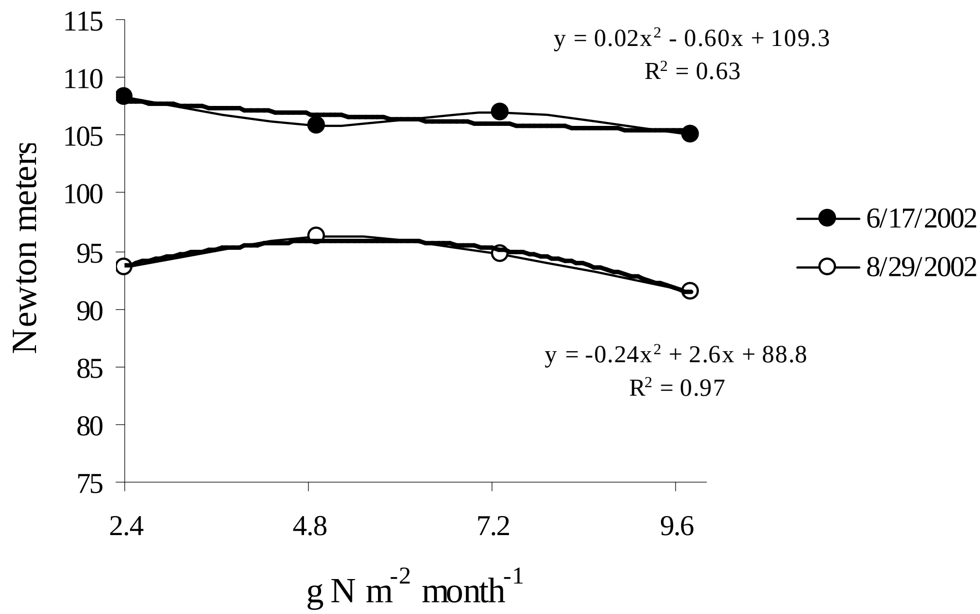


Figure 13. Torque strength required to tear hybrid bermudagrass sod as affected by N rate and sampling date, Management study, 2003

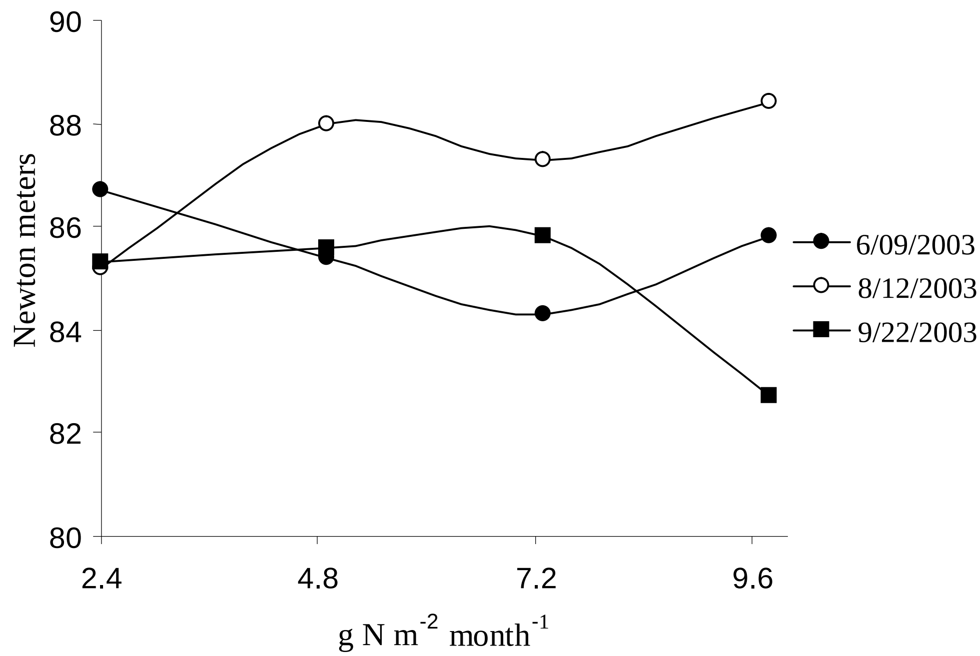


Figure 14. Dry weight of clippings as affected by N rate and sampling date, Management study, 2002 and 2003

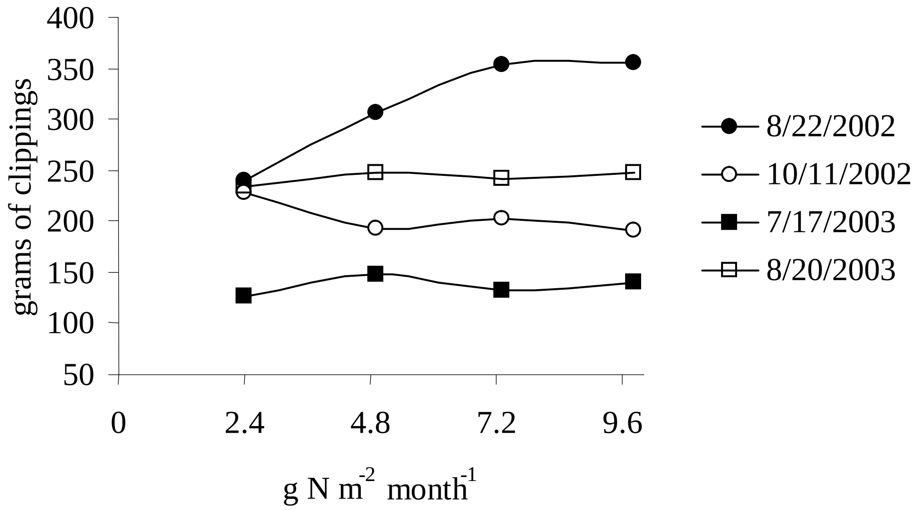


Table 1. Shoot density of Tifway and Tifsport hybrid bermudagrass as affected by N source and cultivar, 2002, Establishment Study

Cultivar	Weeks after Sprigging		
	8	11	14
	Shoots cm^{-2}		
Tifway	2.2 b†	4.1 a	4.7 a
Tifsport	2.5 a	4.2 a	4.5 a
N Source			
$Ca(NO_3)_2$	2.4 a	4.0 b†	4.7 a
NH_4NO_3	2.3 a	4.3 a	4.6 a

† Within each sampling date and experimental variable means followed by the same letter are not significantly different from each other at $\alpha = 0.05$.

Table 2. Shoot density of Tifway and Tifsport hybrid bermudagrass as affected by N source and cultivar, 2004, Establishment Study

Cultivar	Weeks after Sprigging		
	8	10	14
	Shoots cm^{-2}		
Tifway	3.5 a	3.9 a	3.7 b†
Tifsport	3.5 a	4.1 a	4.0 a
N Source			
$Ca(NO_3)_2$	3.4 a	3.8 b†	3.8 a
NH_4NO_3	3.5 a	4.2 a	3.8 a

† Within each sampling date and experimental variable means followed by the same letter are not significantly different from each other at $\alpha = 0.05$.

Table 3. Shoot density of overseeded ryegrass as affected by mowing height, cultivar and sampling date, 2003, Management study. shoots/cm^{-2}

Mowing Height	TifSport	Tifway
cm	March 2003	
1.9	6.4 a	6.3 a
2.5	6.5 a	5.5 b
	Nov 2003	
1.9	3.4 b†	3.1 b†
2.5	3.7 a	3.7 a
	April 2004	
1.9	4.2 a	4.0 b†
2.5	4.2 a	4.7 a

† Within each sampling date and experimental variable means followed by the same letter are not significantly different from each other at $\alpha = 0.05$.