Abstract

WILLIAM CASEY REYNOLDS. Establishment Rates and Growth Characteristics of Six Bermudagrass Cultivars for use on Athletic Fields and Golf Course Fairways. (Under the direction of Dr. Charles Peacock)

Bermudagrass (*Cynodon spp*.) is the primary choice for athletic fields and golf course fairways in the southeastern United States. Its superior heat and drought tolerance as well as excellent recuperative capacity allow it to withstand many of the stresses often associated with recreational turf. There are several new cultivars on the market with little available information regarding their performance. Six cultivars of bermudagrass, 'TifSport', 'Tifway', 'GN-1', 'Quickstand', 'Navy Blue', and 'Tifton 10' were established by sprigs on a Candor sand (Sandy, siliceous, thermic, Arenic Paleudult) at the rate of $0.1m^3/100m^2$ on 28 June 2001 at the Sandhills Research Station in Jackson Springs, NC. During year one of the study, data were taken on establishment, rooting, disease incidence, fall color, and spring green-up of each of the six bermudagrasses. Tifton 10 demonstrated the ability to establish faster than all other cultivars based on its ranking on all observation dates followed by Quickstand and GN-1, which had five and four top rankings, respectively. No differences in rooting density were found among the six cultivars. Navy Blue exhibited significantly more dollar spot (*Sclerotinia homoeocarpa* F.T. Bennett) incidence than all other cultivars, while GN-1 had significanctly higher incidence of Large patch (*Rhizoctonia solani*). During April 2002, 10.8 cm diameter plugs were taken from the field plots for the low temperature study. Sixty stolons per cultivar were excised from the plugs and placed into a Low Temperature Stress Simulator (LTSS) where they were exposed to four different temperatures of 2°C, 0°C, –2°C, and -4 °C for a period of 24 hr. No significant differences

were found among cultivars in their ability to tolerate low temperatures, but mortality did increase as temperature decreased. After the field plots had achieved one year of growth, data were taken on growth characteristics such as root and rhizome mass, recuperative potential, surface hardness, seedhead production, and overall quality. No significant differences were found in root or rhizome mass among the six cultivars. Quickstand produced a harder surface than all other cultivars on 24 July, while Tifton 10, GN-1, and TifSport were the softest. TifSport consistently produced the highest turf quality of the six cultivars followed by Tifway, GN-1, and Navy Blue. Quickstand and Tifton 10 had the poorest quality over four observation dates, primarily due to their coarse texture and off-green color. Differences among these six bermudagrass cultivars imply that they may not all be suitable for the same situation. Turfgrass managers can match this data to their intended use and more accurately choose which cultivar will perform best under their specific conditions.

ESTABLISHMENT RATES AND GROWTH CHARACTERISTICS OF SIX BERMUDAGRASS CULTIVARS FOR USE ON ATHLETIC FIELDS AND GOLF COURSE FAIRWAYS

by
William Casey Reynolds

A thesis submitted to the graduate faculty of
North Carolina State University
in partial fulfillment of the requirements for the degree of
Master of Science

Crop Science

Raleigh, North Carolina

APPROVED BY:

Chair of Advisory Committee	**Co-Chair of Advisory Committee**

Dedication

I would like to dedicate this thesis to my parents, Bill and Vivan Reynolds, for their continued support throughout my college education. Their emotional and financial support have allowed me to focus my efforts on my education, inside and outside of the classroom, and I owe all of my success to them. I would also like to thank my brother, Clifton, for what I have learned from him as well as his encouragement and support. He has taught me that being successful in life does not lie in having a college education. It lies in hard work, dedication, and common sense. I look forward to continue to learn from him for many years to come. Thanks also to my Aunt Karen and Uncle Wayne for all of the Sunday dinners that have helped make Raleigh feel like home. This thesis, and my college education, is dedicated to all of them.

Thanks for everything!

Casey Reynolds

Personal Biography

William Casey Reynolds was born on 28 September 1978 to Bill and Vivian Reynolds, and has an older brother who was born two years prior to that on 28 April 1976. He grew up in Midland, North Carolina before graduating in 1996 from Central Cabarrus High School. Upon graduation he attended North Carolina State University in the fall where he started work on a Bachelor of Science Degree in Crop Science with a concentration in turfgrass management which he received in May 2000.

At that point, Mr. Reynolds decided to stay in school and pursue a Master of Science degree in the same curriculum. He began his thesis study under the direction of Dr. Charles Peacock, Dr. Rich Cooper, Dr. Art Bruneau, and Dr. Rob Mikkelsen. He also decided to pursue a minor in business management working with Dr. Mitzi Montoya-Weiss.

Over the span of his college education, Mr. Reynolds spent his summers working in the turfgrass industry. He spent the summer of 1997 at Pine Lake Country Club and the summer of 1998 at Providence Country Club, both in Charlotte, NC. After two summers in the golf industry he decided to broaden his horizons by taking a job in athletic field construction and maintenance with Carolina Green Corporation. Carolina Green is a private sports turf contracting company based in Indian Trail, NC. He worked with Carolina Green throughout the remainder of college and has developed a specific interest in this field.

Mr. Reynolds currently resides in Raleigh, North Carolina until completion of his college education after which he is on to wherever life takes him.

Acknowledgements

I wish to express my sincere gratitude to Dr. Charles Peacock and Dr. Rich Cooper for all of their advice and guidance during my time in graduate school here at North Carolina State University. I would also like to thank Dr. Art Bruneau for his advice and willingness to allow me to learn from him by riding along on several extension calls. Thanks also to Dr. Peacock, Dr. Cooper, and Dr. Bruneau for letting me speak at field days, conferences, and workshops, which gave me the chance to interact with the public and share the work that we have completed. Thanks to Dr. Mikkelsen for his input and support as well as the knowledge that I took away from soil fertility class.
My minor in business management could not have been completed without the help I received from Dr. Montoya-Weiss, so thanks to her as well.

I would also like to recognize the help and guidance that I received from fellow students such as David Lee, Patrick Gregg, Jimmy Kerns, Tara Liebler, Travis Gannon, Hennen Cummings, and Lee Butler. My time here would have been much more difficult without their help and friendship.

Thanks also to Emily Erickson for her help and guidance in fulfilling my teaching responsibilities, as well as Mark Thompson, Les Privette and Bill Whaley for their help in my field studies.

Table of Contents

List of Tables

<u>Literature Review</u>

Hybrid bermudagrass, *C. dactylon x C. transvaalensis*, is a warm-season perennial grass that spreads by rhizomes and stolons (Turgeon, 2002). It has been widely used throughout the world as both a forage grass and as a turfgrass. Bermudagrass typically grows in subtropical and tropical climates but has been documented to survive as far north as 50^{o}N in Europe and up to 4000 m elevation in the Himalayas (Hanna, 1999). Bermudagrass can produce a high quality turf on athletic fields, golf courses, and home lawns in the southern and southeastern United States. Bermudagrass is among the best of the warm-season grasses in heat and drought tolerance, and also has a high recuperative capacity, primarily due to lateral spread by rhizomes and stolons. Lateral growth is very important for athletic fields due to the amount of wear they receive from sports such as football and soccer. Likewise, golf course fairways require an aggressive grass that can fill in divots and recover from cart traffic. Another reason that bermudagrass is widely used is that it responds well to adequate fertilization, irrigation, and mowing resulting in a high quality turf. The popularity of bermudagrass for athletic fields has encouraged the development of many new cultivars of vegetatively propagated bermudagrass. Among those currently available are ‘Tifway’, ‘TifSport’, ‘GN-1’, ‘Quickstand’, ‘Navy Blue’, and ‘Tifton 10’. There is little available information on how these cultivars perform under athletic field and golf course conditions.

Tifway is a fine textured hybrid that has been the standard for use on recreational turf for many years. It is a naturally occurring triploid hybrid (2n=3x=27) identified in a lot of *C. transvaalensis* seed from South Africa and was released by the USDA in 1960. Although widely used, its adaptation is somewhat limited by its lack of cold hardiness

(Hanna, 1999). There is also the concern of genetic vulnerability. The fact that Tifway is so popular means that a disease and/or insect outbreak to which it may be susceptible would be devastating to turf managers worldwide. This created the need to develop a variety that was more cold tolerant than Tifway and genetically different. TifSport was bred to fill this niche.

TifSport, originally named 'Tift 94', was developed at the University of Georgia Coastal Plain Experiment Station in Tifton, Georgia. Stolons of 'Midiron' bermudagrass (*C. dactylon x C. transvaalensis*) were irradiated with 8000 rads of Cobalt 60 gamma radiation and 66 fine textured mutants resulted, one of which was developed into TifSport, a 2n=3x=27 triploid hybrid (Hanna et. al, 1997). It was initially evaluated at seven locations including Tifton, GA; Stillwater, OK; Lexington, KY; Lake Wales, FL; Ft. Bluff, TN; Franklin, TN; and Lincoln, NE. TifSport produced significantly higher turf quality than 'Midiron' and quality that was equal to or significantly better than both Tifway and Tifway II. It was also shown to be significantly more cold hardy than Tifway or Tifway II at experiments in Franklin, TN and Stillwater, OK.

Tifton 10, a hexaploid (2n=6x=54), is another variety of bermudagrass released by the University of Georgia Coastal Plain Experiment Station in Tifton, Georgia. It is a vegetatively propagated grass that was first observed and collected by G. W. Burton in 1974 from a lawn in Shanghai, China (Hanna and Burton, 1998). Tifton 10, a natural selection *of C. dactylon* establishes rapidly from rhizomes and stolons and performs well under low maintenance conditions. In tests conducted at the University of Georgia, Tifton 10 produced quality ratings similar to Tifway and Tifway II under low management conditions consisting of 2.5 lbs N/1000ft^2/year, irrigated only in dry periods, and mowed once per week at 1.5 inches. Tifton 10 has also exhibited early spring green-up and winter hardiness in New Jersey and Blairsville, GA where it received good winter survival ratings. This is a very coarse textured grass and therefore may not be suitable for high quality athletic fields and golf courses. Previous studies indicate that Tifton 10 should be well suited for low maintenance situations such as roughs, roadsides, low budget athletic fields, and some landscape areas.

Navy Blue bermudagrass is a natural selection of *C. dactylon* discovered in Annapolis, Maryland in 1990 near the Chesapeake Bay (Kidwell, 1998). It possesses texture and color similar to Tifway, and producers claim superior wear and cold tolerance. However, these statements are based on private industry research.

The USDA-ARS and the University of Kentucky Agricultural Experiment Station released Quickstand bermudagrass jointly in 1993. Quickstand is a tetraploid (2n=4x=36) and was released based upon its combination of winter hardiness, rapid establishment and spread, and lower incidence of spring dead spot (Phillips et al., 1997). Quickstand is vigorous with medium-green leaves and is similar to ‘Vamont’ in quality, with a somewhat finer texture. Quickstand has been evaluated at the University of Kentucky, and was also included in the 1986 National Bermudagrass Test (Phillips et al., 1997). In a greenhouse study, Quickstand exhibited the ability to spread rapidly and produced significantly more stolons than four other entries (Phillips et al., 1997). However, Quickstand has not been evaluated to date in the transition zone of North Carolina and Virginia.

GN-1 is the last of six cultivars of bermudagrass to be evaluated in this study. GN-1 is a cultivar that originated in Australia where it is known as ‘CT-2’. Some attributes of GN-1 include a dark color, decumbent growth habit, and good recuperative capacity.

Bermudagrass (*Cynodon* spp.) is a highly variable species. Vast differences exist in growth characteristics and environmental adaptations between cultivars. Significant differences in freeze tolerance have been found among some of the most commonly used cultivars today. Anderson and Taliaferro (2002) found that GN-1 was significantly less freeze tolerant than TifSport and Quickstand, but not significantly different than Tifway (Anderson et al. 2002). Anderson (2002) also found in another study that Quickstand was significantly more cold hardy than Tifgreen (Anderson et al. 2002). Although studies such as these have been conducted, there is still only limited amounts of data available on the cold tolerance of these and other cultivars. Cultivars such as Tifsport, Tifway, GN-1 Quickstand, Navy Blue, and Tifton 10 need to be studied further in order to more accurately quantify their relative freeze tolerance.

Vast differences also exist between cultivars in their overall quality and performance. Previous studies have evaluated these characteristics on bermudagrass cultivars such as Tifway, Vamont, Tufcote, and Midiron. One study (Shoulders and Schmidt, 1985) evaluated the establishment rate and root production of Tifway and Vamont from dormant sod and sprigs. Sowers and Welterlen (1988) also looked at Midiron, Tufcote, and Vamont regarding the effect that different plastic and straw mulches had on their establishment rates and winter hardiness after sprigging. They found that survival under of all bermudagrass cultivars included in the study was higher under under plastic compared to no mulch or straw mulch. They also found that Midiron was consistently more cold hardy than Vamont and Tufcote. Dudeck et al. (1985) looked at the nitrogen fertilization response of nine bermudagrasses with data being taken on ground cover, rate of regrowth, overall turf quality, and spring greenup. This study incorporated Tiflawn, Tifway, and Arizona common bermudagrass as standard golf course fairway grasses. While Tifway is still a standard fairway grass, newer cultivars such as TifSport and GN-1 are becoming more commonly used than some of the older varieties such as Tiflawn and Arizona. This prompts the need for similar studies to be done on these cultivars as well.

Although there has been limited research on some of these cultivars, research comparing all six under athletic field or golf course conditions is lacking. Data are needed regarding establishment rates, lateral spread, cold tolerance, salinity tolerance, fertilizer requirements, root production, fall color retention, spring green-up, disease susceptibility, overseeding performance and overall quality. Data such as this will help turf managers make more informed decisions on which cultivar suits their individual needs best. A cultivar that is particularly cold tolerant might be the best choice for the mountains and western North Carolina, whereas this factor might not play a significant role in the eastern part of the state. Likewise the inverse may be true for a cultivar with a high level of salinity tolerance. Selecting the right cultivar, depending on its intended use, will likely save time and money in managing turfgrass areas and may also prevent the costly process of re-establishment. Data on these cultivars, particularly the newer ones, will without a doubt have an impact on which cultivars are commercially produced and sold within North Carolina in addition to everywhere else bermudagrass is widely used.

This benefit will be agronomic as well as economic and can only improve our understanding of the differences that exist between these six different cultivars of bermudagrass.

Literature Cited

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

Anderson, J.A., and C.M. Taliaferro. 2002. Freeze tolerance of seed-producing turf bermudagrasses. Crop Sci. 42:190-192.

Dudeck, A.E., Peacock, C.H., and T.E. Freeman. 1985. Response of selected bermudagrasses to nitrogen fertilization. p. 495-504. *In* F. Lemaire (ed.) Proc.5th Int. Turfgrass Res. Conf., Avignon, France. 1-5 July. Inst. Natl. de la Rcherche Agron., Paris, France.

Hanna, W. 1999. Tift 94 Bermudagrass. USDA-ARS, Athens, GA.

Hanna, W., and G.W. Burton. 1998. Notice of release of Tifton 10 bermudagrass. USDA-ARS, Tifton, GA. Crop Sci. 37: 1674.

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

Kidwell, Jack. 1998. Navy Blue: New Bermudagrass Release. U.S. Patent 09/121,850

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

Shoulders, J.F., and R.E. Schmidt. 1985. Establishing *Cynodon* spp. from dormant vegetative propagules. p. 307-310. *In* F. Lemaire (ed.) Proc.5th Int. Turfgrass Res. Conf., Avignon, France. 1-5 July. Inst. Natl. de la Rcherche Agron., Paris, France.

Sowers, R.S., and M.S. Welterlen. 1988. Seasonal establishment of bermudagrass using plastic straw mulches. Agron J. 80:144-148.

Turgeon, A.J. 2002. Turfgrass Management: Sixth Edition. Prentice-Hall Inc. New Jersey.

Establishment Rates and Growth Characteristics of Vegetatively Propagated Bermudagrasses

Abstract

Bermudagrass (*Cynodon spp*.) is the primary choice for athletic fields and golf course fairways in the southeastern United States. Its superior heat and drought tolerance as well as excellent recuperative capacity allow it to withstand many of the stresses often associated with recreational turf. There are several new cultivars on the market with little available information regarding their performance. Six cultivars of bermudagrass, 'TifSport', 'Tifway', 'GN-1', 'Quickstand', 'Navy Blue', and 'Tifton 10' were established by sprigs on a Candor sand (Sandy, siliceous, thermic, Arenic Paleudult) at the rate of $0.1m^3/100m^2$ on 28 June 2001 at the Sandhills Research Station in Jackson Springs, NC. Data were taken on establishment, rooting, disease incidence, fall color, and spring green-up of each of the six bermudagrasses. Tifton 10 demonstrated the ability to establish faster than all other cultivars based on its ranking on all observation dates followed by Quickstand and GN-1, which had five and four top rankings, respectively. No differences in rooting density were found among the six cultivars. Navy Blue exhibited significantly more dollar spot (*Sclerotinia homoeocarpa* F.T. Bennett) incidence than all other cultivars having means of 6.6 dollar spots/$7.5m^2$ and 19.5 dollar spots/$7.5m^2$ on 9 and 27 September 2001, respectively. Large patch (*Rhizoctonia solani*) was observed in the field plots on 11 October 2001 and GN-1 had a higher incidence than all other cultivars with 2.1 patches/$7.5m^2$. TifSport and Navy Blue had no incidence of

large patch. TifSport retained its color longer in the fall than all other cultivars except Tifway, and these were followed by Navy Blue, which was not different than Tifway on the final rating date. Tifton 10 and Quickstand exhibited less ability to maintain fall color by ranking in the lowest group on the last four observation dates. During spring 2002, cultivars were rated for spring green-up. TifSport had the highest rating on the first observation date, although it was ultimately surpassed by Tifway and GN-1 during week two. After this point, Tifway ranked in the top category in five of the remaining six weeks, and GN-1 ranked in the top category all six weeks. Tifton 10 and Quickstand ranked consistently low regarding spring green-up. Data from this study illustrate the differences that exist between these six bermudagrass cultivars. This data can be used by turfgrass managers in the southeastern United States to decide which cultivar of bermudagrass is most suitable for their individual needs.

Introduction

Bermudagrass (*Cynodon spp.*) is commonly planted for athletic fields and golf course fairways in the southern and southeastern United States. It has superior heat and wear tolerance making it ideal for these uses. There are many different cultivars on the market, each claiming to possess various characteristics or growth habits. One characteristic of concern when choosing a cultivar is its speed of establishment. Most cultivars of bermudagrass commonly used for athletic turf can only be established vegetatively by sprigs or sod. Expense often limits establishment by sod. However, one factor that may limit sprigging bermudagrass in the transition zone is the minimal time available for full establishment (Sowers and Welterlen, 1988). Establishment rate and rate of lateral spread are important characteristics for a cultivar to possess because they translate into good recuperative potential.

Establishment rates of bermudagrass have been measured by several different methods including visual estimation, line intersect methods, plant counts, and most recently, digital image analysis. Visual estimation has been the most commonly used method of measuring turfgrass establishment. This involves trained evaluators observing plots of turfgrass and subjectively rating them for percent cover at given intervals over time. Visual estimation can produce accurate results, although the data can be highly variable and difficult to repeat by other investigators. However, this method is still commonly employed and is generally considered to be an adequate means of measuring turfgrass establishment.

Line-intersect and line transect methods have also been used to measure bermudagrass establishment. The line-intersect method involves setting up a grid over an entire plot and counting the number of plants that touch each intersection of the grid. The number of intersections is then multiplied by the area of each grid section and divided by the total area of the entire grid to determine the percent of a species that is present (Richardson et al., 2001). The line transect method is somewhat different in that it involves sprigging in rows and setting lines on each side at known distances from the center of the sprigged row. Counts are then periodically taken to see how many stolons have crossed each line (Mueller et al., 1992). One drawback to this method is that the sprigs need to be planted in rows. Although sprigs are commonly row-planted on athletic fields it would be difficult to accurately measure their lateral growth using the line transect method. This method is more suitable in forage situations.

Digital Image Analysis is a relatively new technology that can be used to measure turfgrass cover. It involves taking a digital picture of a given area, which is then downloaded onto a computer and analyzed using a software program called SigmaScan Pro (v.5.0, SPSS, Inc., Chicago, IL). The software calculates the number of green pixels, or total number of pixels representing turf, present in a given area. This number is then divided by the total number of pixels in the picture to yield percent cover.

The primary objective of this study was to evaluate the establishment rate of six culitvars of hybrid bermudagrasses as well as observe their respective root mass, fall color retention, and spring green-up.

Materials and Methods

The experiment was conducted at the Sandhills Research Station in Jackson Springs, NC. The soil at the site is classified as a Candor sand (Sandy, siliceous, thermic Arenic Paleudult) with 0 to 1 percent slope and an initial pH of 5.5. The Candor series consists of very deep, somewhat excessively drained soils with rapid permeability in the upper sandy horizons and moderate to moderately slow permeability in the lower horizons (USDA-NRCS Soil Survey Division, 1999). The mean annual temperature at the site is 16^{o} C. The mean annual high at the site is 21^{o}C, while the mean annual low temperature is 11^{o}C. The mean annual precipitation is 47 inches.

The experiment utilized a randomized split-split-plot design with four replications. Whole plots were 16.4m x 8.2m, with subplots of 5.5m x 8.2m, and sub-

subplots measuring 2.7m x 2.7m. Whole plot factors consisted of an overseeded or non-overseeded treatment. Subplot factors were fertilization regimes providing 200 (low), 300 (medium), or 400 (high) kg N/hectare/year applied in 50kg N/hectare increments. These regimes were initiated in May 2002. Finally, sub-subplots consisted of various cultivars of bermudagrass. Cultivars included in this study were 'TifSport', 'Tifway', 'GN-1', 'Quickstand', 'Navy Blue', and 'Tifton 10'. The split-split plot design allowed the most precision in determining cultivar performance treatments, and the least precision in evaluating overseeded/non-overseeded treatments.

The soil in the experimental area was fumigated on 21 June 2001 with an 80:20 mixture of methyl bromide/chloropicrin at the rate of 450 kg/hectare. The area remained covered for seven days after which the plastic tarp was removed. The soil was then limed at the rate of 1040 kg $CaCO_3$/hectare to raise the pH to around 6.0, which is more suitable for turf. Scotts ProTurf High K Fertilizer® (15-0-30) was also incorporated at 50kg of K/hectare based on soil test recommendations. The fertilizer contained urea and methylene urea forms of nitrogen with 4.5% N being slow release form. Lime and fertilizer were incorporated to a depth of 15 to 20 cm. The area was then graded to promote adequate surface drainage. On 28 June 2001 the plots were sprigged by hand at a rate of $0.1m^3/100m^2$. A bushel was defined as $0.01m^3$. This rate is typical of the accepted rate for athletic fields of $10\text{-}15m^3$/hectare (400-600 bushels/acre). Individual plots of each cultivar had an area of 7.5 m^2.

Fertility treatments for the establishment phase began on 12 July 2001 and are detailed in Table 1:

Table 1. Fertilizer regime during 12-week establishment phase of six bermudagrass cultivars during 2001 at the Sandhills Research Station in Jackson Springs, NC

Fertilizer	Application Rate	Application Date
	kg N ha^{-1}	2001
34-0-0	0.45	12 July
34-0-0	0.45	30 July
17-17-17	0.45	17 August
34-0-0	0.45	31 August
34-0-0	0.45	13 September

† All grasses were sprigged on 28 June 2001 at $0.1m^3/100m^2$.

Establishment rates. Bermudagrass establishment was first rated two weeks after sprigging on 12 July 2001 using visual estimation. Percent cover of each plot was determined every 14 days over a 12-week period. The last visual observations were taken on 20 September 2001.

Root mass. After the plots had achieved full turf coverage, the root mass of each cultivar was measured. On 17 October 2001, one plug was taken from each non-overseeded plot using a standard 10.8cm diameter x 20.3cm deep putting green cup-cutter. Samples were labeled, placed in plastic bags, and washed within 24 hours using a root washer. Samples were washed with a shower head nozzle at low pressure until all plant material, including any thatch layer, was removed from the soil plug. The remaining roots and soil were emptied into a # 14 sieve and placed in the root washer until all of the soil was removed from the system. Samples were then placed into paper bags and oven dried at 60^o C for 72 hours. After weighing each oven dried sample, they were placed in a muffle furnace overnight at 500^0 C. Samples were weighed again and the difference was taken as the amount of roots produced by each variety.

Disease incidence. Dollar spot (*Sclerotinia homoeocarpa* F.T. Bennett) and Large patch (*Rhizoctonia spp.*) were observed on some cultivars after establishment. Dollar spot incidence was determined on 9 and 27 September 2001 by counting the number of dollar spots in each plot. Large patch incidence was also measured and recorded on 11 October 2001 by counting the number of patches in each plot.

Fall color retention. Observations of fall color retention were taken to determine if any of the cultivars maintained its color longer in the fall. The first observations were taken on 4 October 2001 and continued weekly until the grasses reached full dormancy. Color was rated on a scale of 1 being completely dormant to 9 being dark green.

Spring green-up. The plots were visually rated for spring green-up on a weekly basis beginning on 25 March 2002 and continued until full green-up. Green-up was rated using a scale of 1 to 9 with 1 being completely dormant and 9 being full green-up.

Data analysis. All data on establishment, root mass, disease incidence, fall color retention, and spring green-up were subjected to an Analysis of Variance (ANOVA) using the Statistical Analysis System (SAS Institute Inc., 2001). Data were subjected to mean separation using the Waller-Duncan k-ratio t-test (k-ratio=100) when the ANOVA F-test indicated that treatment effects were significant at $P \leq 0.05$. Establishment data were transformed prior to the ANOVA using an arcsin transformation, [(sqrt(cover/100)]. This data transformation was necessary due to the fact that the establishment data were expressed as percentages and covered a wide range of values. It was also performed to achieve homogeneity of variance (Steel and Torrie, 1980).

Results and Discussion

Establishment rate. The various cultivars differed greatly in their ability to establish from sprigs during 2001 as detailed in Table 2.

Table 2. Visual ratings of percent cover during 12-week establishment period for six bermudgrasses during 2001†.

Variety	Days After Sprigging (DAS) 14	32	42	56	70	84
	% cover					
TifSport	7.7d*	32.9d	60.0d	84.0c	93.5c	94.9c
Tifway	14.8c	55.8c	82.3b	97.3ab	99.5a	98.0 b
GN-1	13.5c	62.1b	87.5a	98.7ab	99.9a	99.8a
Quickstand	24.0b	66.5ab	85.2ab	98.9a	99.9a	100.0a
Navy Blue	13.8c	51.5c	77.1c	96.2b	98.2b	98.9a
Tifton 10	29.6a	67.8a	85.4ab	98.8a	100.0a	100.0a

* Means within columns followed by the same letter are not significantly different at the 5% level using Waller-Duncan k-ratio t test. Establishment data were transformed prior to ANOVA using an arcsin transformation [sqrt(cover/100)]

† All grasses were sprigged on 28 June 2001 at the rate of $0.1m^3/100m^2$

A trend emerged over the 12 week establishment period that was fairly consistent on each rating date. Fourteen days after sprigging (DAS), Tifton 10 was better established than all other cultivars. This was followed by Quickstand which had achieved greater coverage than Tifway, Navy Blue, and GN-1. TifSport had less ground cover at 14 DAS than all other cultivars. TifSport was the slowest establishing cultivar throughout the study while Tifton 10 ranked in the highest establishment group on every observation date. It also achieved 25, 50, and 75% cover faster than all other varieties except Quickstand as indicated in Table 3.

Table 3. Time required for six bermudagrasses to reach 25%, 50%, and 75% cover following sprigging during 2001†.

	% Cover		
Variety	25	50	75
		Weeks	
Tifton 10	1.8a*	3.0a	4.5a
Quickstand	2.1a	3.2ab	4.6a
GN-1	2.5b	3.5bc	4.7ab
Tifway	2.6b	3.7cd	5.1bc
Navy Blue	2.7b	3.9d	5.5c
TifSport	3.6c	5.2e	7.2d

*Means within columns followed by the same letter are not significantly different at the 5% level using Waller-Duncan k-ratio t test.

† All grasses were sprigged on 28 June 2001 at the rate of $0.1m^3/100m^2$.

Tifton 10 was released, in part, due to its rapid establishment and lateral growth characteristics, especially at low fertility levels (Hanna and Burton, 1998). Quickstand was also released due to its rapid lateral growth characteristics (Phillips et al., 1997). Results support the superior establishment rates of Tifton 10 and Quickstand. Quickstand ranked in the highest group of establishment along with Tifton 10 at every rating interval except 14 DAS when it was better established than all cultivars except Tifton 10.

At 42 DAS, GN-1 was established as well as Tifton 10 and Quickstand. This was also true at 23, 70, and 84 DAS. This trend is also supported by the data involving the time it took each variety to achieve 50% and 75% cover (Table 3). After its slow start immediately following sprigging, GN-1 did not differ from Quickstand in the time it took to reach 50% cover. It also did not differ from Tifton 10 and Quickstand in the time it took to reach 75% cover. Tifway experienced an initial lag period slightly longer than GN-1. At 56 DAS, establishment of Tifway was not different than that of Tifton 10, Quickstand, or GN-1. Navy Blue was slower to establish than Tifton 10 and Quickstand on every rating date except at 84 DAS, however it was also better established than TifSport over the entire establishment period. Overall, Tifton 10, Quickstand, and GN-1 seemed to establish more rapidly than all other varieties. These superior establishing varieties were followed by Tifway and Navy Blue. TifSport was significantly slower to establish than all other cultivars on every rating date during the study. It was observed during sprigging that the TifSport plant material appeared to consist largely of leaf tissue, which could be one explanation for its slow rate of establishment. This would mean it is simply a grower effect. However, it could also be a variety difference. Establishment trends for the varieties are supported by a lateral spread study that was completed during August 2002 after the plots had experienced one year of growth.

Root mass. No differences in root mass were found among varieties. Although there were small differences in root mass by variety, significant differences were difficult to establish, perhaps in part due to a high coefficient of variation within plots of the same cultivar. This is common in field studies where natural variation can often be large.

Disease incidence. During September 2001, the disease dollar spot became prevalent on some of the bermudagrass varieties (Table 4).

Table 4. Disease incidence on six bermudagrass cultivars during fall 2001†.

	Disease‡		
	Dollar spot		Large patch
Cultivar	9 Sept	27 Sept	11 Oct
	Dollar spots/m^2		patches/m^2
Navy Blue	0.9a*	2.6a	0.0b
Tifway	0.05b	0.0c	0.02b
TifSport	0..01b	0.17bc	0.0b
GN-1	0.0b	0.09c	0.3a
Quickstand	0.0b	0.5b	0.05b
Tifton 10	0.0b	0.02c	0.04b

*Means within columns followed by the same letter are not significantly different at the 5% level using Waller-Duncan k-ratio t test.

† All grasses were sprigged on 28 June 2001 at the rate of $0.1m^3/100m^2$.

‡ Dollar spot and large patch incidence was determined by counting the number of affected areas per plot.

Navy Blue experienced more disease incidence than all other cultivars on both dates with a mean incidence of 6.6 spots/7.5 m^2 on 9 September 2001 and 19.5 spots/7.5m^2 on 27 September 2001. No other cultivars averaged even one spot/7.5m^2. Subsequent ratings on 27 September confirmed Quickstand exhibited a lower incidence of dollar spot than Navy Blue but a higher incidence than GN-1, Tifton 10, and Tifway.

Environmental conditions favoring the development of dollar spot include temperatures between 15°C and 30°C and sustained periods of high humidity. Low nitrogen levels and low soil moisture resulting in stressed turf can also be contributing factors (Tani and Beard, 1997). The high incidence of dollar spot was unexpected given the fact that the plots received 50 kgN/hectare every two weeks during the establishment period. 50 kgN/hectare every four weeks is considered adequate for bermudagrass, so low nitrogen levels should not be a problem. Plots also received adequate moisture via irrigation. Dollar spot fungi can survive periods of unfavorable growth as mycelia in infected plants. When the turfgrass environment favors fungal activity, the mycelia within the infected tissue begin to colonize foliar tissue and the dollar spot symptoms appear (Smiley et al., 1992). One possibility is that the dollar spot fungus was introduced into the field plots by means of the Navy Blue sprigs. However, this is unlikely due to the fact that if the pathogen was introduced via the Navy Blue sprigs it could be expected that it would have spread to the plots immediately adjacent to the Navy Blue plots. It is more likely that it was introduced by some other means, and Navy Blue is simply more susceptible to the pathogen (L.P Tredway, personal communication, 2002).

Large patch was also observed on the field plots on 11 October 2001. Large patch occurs on bermudagrass during the spring and fall when the grass is exiting and entering winter dormancy (Tani and Beard, 1997). It is favored by air temperatures around 20^{o}C and begins as small circular patches that gradually increase in size. Unlike brown patch, large patch infections of warm-season grasses occur on the leaf sheath, where water-soaked black lesions are observed. Foliar dieback occurs as a result of this (Tredway and Burpee, 2001). The only difference among cultivars occurred with GN-1 which had greater large patch incidence than all other cultivars (Table 4). TifSport and Navy Blue had no incidence of large patch.

Fall Color Retention. Fall color retention was evaluated weekly from 4 October to 30 November 2001(Table 5).

Table 5. Fall color retention of bermudagrass cultivars from 4 October through 30 November 2001†.

	Fall Color Ratings‡							
	October				November			
Cultivar	4	11	17	25	1	9	16	30
Tifton 10	8.7a*	8.3a	7.9a	7.0ab	4.3bc	2.5d	1.7c	1.3d
GN-1	8.4ab	8.2a	8.0a	7.6a	5.0ab	3.5c	2.3b	1.8c
Tifway	8.0bc	7.9ab	7.5ab	7.2ab	5.3a	4.4b	2.7ab	2.2ab
TifSport	7.6cd	7.4bc	7.5ab	6.8b	5.6a	5.6a	3.1a	2.3a
Quickstand	7.6cd	7.3c	7.1b	5.4c	3.8c	2.5d	1.7c	1.8c
Navy Blue	7.5d	7.3bc	7.1b	6.1c	4.8a b	4.3bc	2.3b	1.9bc

*Means within columns followed by the same letter are not significantly different at the 5% level using Waller-Duncan k-ratio t test.

† All grasses were sprigged on 28 June 2001 at the rate of $0.1m^3/100m^2$.

‡ Fall Color Rating scale: 1= dormant turf; 9= dark green turf.

Tifton 10 ranked among the highest varieties during October. During November, however, both GN-1 and Tifton 10 lost their color rapidly and were rated lowest by the end of the month. TifSport and Tifway retained their color as well as the other varieties during October and maintained the highest fall color rating during November. TifSport has produced fall color ratings similar to Tifway in studies performed at Tifton, GA and Franklin, TN (Hanna, 1999). Data from the 1997-2001 National Turfgrass Evaluation Program (NTEP) bermudagrass trials show similar results (Morris, 2001). TifSport and Tifway consistently had better fall color than the other culitvars evaluated including ‘Midlawn’, ‘Patriot’, ‘Celebration’, ‘Mini-Verde’, and ‘Cardinal’ (Morris, 2001). The results of this study support previous research that TifSport and Tifway possess superior fall color retention. Quickstand consistently ranked in the lowest group on every rating date except 30 November. Quickstand did not possess good fall color retention in comparison to the other cultivars.

Spring Green-up. Spring green-up ratings were made weekly from 3 March until 13 May 2002 (Table 6)

Table 6. Spring greenup ratings of bermudagrass cultivars from 25 March through 13 May 2002†.

	Spring Green-up Ratings‡							
	March	April					May	
Cultivar	25	3	9	16	22	30	6	13
TifSport	1.8a*	4.1b	4.3b	4.9ab	6.6bc	7.8a	7.8a	8.1a
Quickstand	1.2b	4.0b	4.0b	4.3c	5.9d	7.0b	7.0b	8.0a
Tifway	1.1bc	4.6a	4.7a	5.2a	6.6bc	7.8a	7.8a	8.1a
Navy Blue	0.8cd	3.8b	3.9b	4.6bc	6.2cd	7.8a	7.8a	8.0a
GN-1	0.7d	4.8a	4.8a	5.2a	7.2a	7.8a	7.8a	8.0a
Tifton 10	0.3e	3.4c	3.4c	4.5bc	6.9ab	7.9a	7.9a	8.1a

*Means within columns followed by the same letter are not significantly different at the 5% level using Waller-Duncan k-ratio t test.

† All grasses were sprigged on 28 June 2001 at the rate of $0.1 m^3/100 m^2$.

‡ Spring Green-up Rating scale: 1= dormant turf; 9= dark green turf.

On 25 March, TifSport exhibited more spring green-up than all other cultivars. This was followed by Quickstand and Tifway. Over the entire eight-week period of spring green-up, the largest increase in color among all cultivars occurred between 25 March and 3 April with GN-1 experiencing the largest increase with a rating of 0.7 on 25 March and 4.8 on 3 April. During April and May, GN-1 was among the highest ranked varieties for spring green-up on every date. From 3 April through 13 May Tifway was among the highest ranked varieties on six of seven rating dates. Tifton 10 consistently ranked the lowest in color until 22 April after which it was equal to or better than all other cultivars. Although Quickstand ranked second in color on 25 March, it ultimately ranked among the poorest varieties for spring green-up as the study continued. Beginning 16 April, it was significantly less green than all other cultivars except Navy Blue on 22 April. The overall trend was that TifSport experienced the earliest spring green-up followed by GN-1 and Tifway. Tifton 10 had the latest spring green-up which was slightly slower than Navy Blue and Quickstand.

Literature Cited

Hanna, W. 1999. Tift 94 Bermudagrass. USDA-ARS, Athens, GA.

Hanna, W., and G.W. Burton. 1998. Notice of release of Tifton 10 bermudagrass. USDA-ARS, Tifton, GA.

Morris, Kevin. 2001. National Turfgrass Evaluation Program:1997 National Bermudagrass Test.USDA-ARS. Beltsville, Maryland.

Mueller, J.P., Green, J.T., Nelson, L.A., and J.V Hall. 1992. Establishment of two bermudagrasses in three soil environments. Agron. J. 84: 38-43.

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

Richardson, M.D., Karcher, D.E., and L.C. Purcell. 2001. Quantifying turfgrass cover using digital image analysis. Crop. Sci. 41: 1884-1888.

SAS Institute, Inc. 2001. The SAS system for Windows. Release 8.0 SAS Inst., Cary, NC.

Smiley, R.W., Dernoeden, P.H., and B.B. Clarke. 1992. Compendium of Turfgrass Diseases. 2nd ed. American Phytopathological Society.

Sowers, S.R., and M.S. Welterlen. 1988. Seasonal establishment of bermudagrass using plastic and straw mulches. Agron. J. 80: 144-148.

SPSS Science. 2002. Sigmascan Pro. SPSS Science. Chicago, IL.

Steel, R.G. and J.H. Torrie. 1980. Principles and Procedures of Statistics: A biometrical approach. 2nd ed. McGraw-Hill Inc. New York, NY.

Tani, T. and J.B. Beard. 1997. Color Atlas of Turfgrass Diseases. Ann Arbor Press. Chelsea, MI.

Tredway, L.P. and L.L. Burpee. 2001. *Rhizoctonia* Diseases of Turfgrass. The Plant Health Instructor. DOI:10.1094/PHI-I-2001-1109-01.

USDA-NRCS Soil Survey Division. 1999. Official Series Description [Online] Available at http://www.statlab.iastate.edu/cgi-bin/osd/osdname.cgi?-P (Verified 14 August 2002.)

Growth Characteristics of Vegetatively Propagated Bermudagrasses After One Growing Season

Abstract

One of the first decisions that turfgrass managers in the southeastern United States must face when sprigging bermudagrass is which cultivar will likely give them the best performance. There are several cultivars available on the market today, each with different strengths and weaknesses. The purpose of this investigation was to determine how six bermudagrass cultivars differ in growth characteristics including root and rhizome mass, recuperative potential, surface hardness, seedhead production, and overall quality. Data were taken from one-year-old bermudagrass plots at the Sandhills Research Station in Jackson Springs, NC during the summer of 2002. Cultivars included in the study were 'TifSport', 'Tifway', 'GN-1', 'Quickstand', 'Navy Blue', and 'Tifton 10'. No significant differences were found in root or rhizome mass among the six cultivars. However, similarities were found over two sampling dates within the rhizome data showing that TifSport produced 119% more rhizomes than Quickstand on 5 July and 95% more rhizomes on 24 July. Tifway also produced 83% and 82% more rhizomes than Quickstand over the two sampling dates. Lateral growth into 10.8 cm plugs was measured over a six week period through the use of Sigmascan Pro digital imaging software. After two weeks, GN-1, Tifton 10, and Quickstand had an average of 19% more lateral growth than Tifway, 35% more lateral growth than TifSport, and 55% more lateral growth than Navy Blue. This trend continued over the entire six weeks with only GN-1 and Tifton 10 achieving 100% coverage by the end of the study. This data

correlates with establishment data taken on the six cultivars during summer 2001. A Clegg impact soil tester (CIST) was used to determine if differences existed in surface hardness between the six cultivars. Quickstand produced a harder surface than all other cultivars on 24 July, while Tifton 10, GN-1, and TifSport were the softest. The only differences found on 2 and 7 August were between Tifton 10, which had the lowest CIST readings and Quickstand, which had the highest. All other cultivars were equal on these two dates. Seedhead production was rated by a ring toss method and visual estimation on 16 June. Data from the ring toss experiment show that Navy Blue produced more seedheads than all other cultivars except GN-1. Visual ratings of seedhead production support these findings by showing that Navy Blue produced more seedheads than all other cultivars, and GN-1 produced more seedheads than all other cultivars except Navy Blue. TifSport consistently produced the highest turf quality of the six cultivars followed by Tifway, GN-1, and Navy Blue. Quickstand and Tifton 10 had the poorest quality over four observation dates, primarily due to their coarse texture and off-green color. Differences among these six bermudagrass cultivars imply that they may not all be suitable for the same situation. Turfgrass managers can match this data to their intended use and more accurately choose which cultivar will perform best under their specific conditions.

Introduction

Bermudagrass (*Cynodon spp.*) possesses many growth characteristics that make it ideal for use on athletic fields and golf courses in the southeastern United States. Its aggressive nature allows it to tolerate traffic and compaction stresses often associated with these areas while still maintaining a high level of quality. Its rhizome and stolon production allow it to recover from divots, cart traffic, and wear especially under high levels of fertility. Although Tifway has historically been the standard cultivar used on athletic fields and golf courses, several new cultivars have been recently released for use. Cultivars such as TifSport, GN-1, Quickstand, Navy Blue, and Tifton 10 are gaining popularity, however additional research is needed to evaluate their growth characteristics and suitability for athletic field and golf course use.

One growth characteristic of primary concern on athletic fields and golf courses is recuperative potential. Heavy traffic can result in two types of damage to the turfgrass plant; physical injury to shoots and/or decreased rooting due to increased soil compaction (Trenholm et al., 2000). Once turfgrass shoots are damaged by the tearing and abrasive actions associated with traffic, the result is decreased turf quality and density. Excessive traffic levels can result in a total loss of the turfgrass stand. New growth from rhizomes and stolons can overcome traffic stresses and allow the turf to recover and retain high levels of density and quality.

The ability of bermudagrass to produce rhizomes has beneficial aspects as well. Rhizomes grow beneath the soil surface and therefore are not exposed to the same stresses as stolons. They do not receive the direct abrasive effects that shoots and stolons are subjected to, and they are also insulated from weather extremes. Rhizomes typically experience freezing stress later than shoots and stolons due to the buffering effect of the surrounding soil (DiPaola and Beard, 1992). Increased rhizome production by a cultivar would be expected to give it an advantage over others in its traffic and cold stress tolerance.

In addition to physical injury to shoots, increased soil compaction due to traffic can result in decreased rooting. Much work has been done to illustrate the effects of traffic on root production in grasses. The most notable response of traffic on roots is altered root distribution (Carrow and Petrovic, 1992). O'Neil and Carrow (1983) showed higher percentages of perennial ryegrass (*Lolium perenne* L.) roots in the surface zone (0 to 5cm) and decreased levels in the lower zones in response to increased levels of compaction. Agnew and Carrow (1985) found similar results for Kentucky Bluegrass *(Poa pratensis* L.) with treatments of compacted and uncompacted turf. Madison (1971) stated that compaction was the foremost problem in maintaining healthy turfgrass on recreational sites. Although compaction was not a treatment in this study, the ability of different turfgrass cultivars to produce roots would certainly play a role in their ability to perform well in high-wear areas.

One instrument used to measure soil compaction is the Clegg Soil Impact Tester (Lafayette Instrument Co., Lafayette, IN). This device was originally developed for measuring surface hardness during road construction. Surface hardness is evaluated by dropping a weight of known mass from a known height. The deceleration of the mass is calculated and taken as an indication of surface hardness (Rogers and Waddington, 1992). The Clegg Soil Impact Tester (CIST) was used in this study to determine if any particular cultivar offered a greater "cushioning effect" due to its shoot, stolon, and rhizome production. This might be important in situations where player safety is an issue.

The remaining growth characteristics observed in this study were overall quality and seedhead production. Excessive seedhead production by bermudagrasses can result in an unsightly playing surface, especially when budget constraints may limit mowing frequency and application of plant growth regulators, both of which will reduce the appearance of seedheads. Seedhead production also shifts the energy of the plant from vegetaive growth to reproductive growth. Overall quality is also important due to the fact that certain situations may require different levels of acceptable quality. A cultivar that is suited well for a high school level field may not be acceptable for professional athletics. Conversely, a cultivar with very high-quality may also carry with it very high maintenance requirements which may not be feasible in low budget situations.

One of the objectives of this study was to determine which of these cultivars might be suited for the many different situations that turf managers routinely face. This was accomplished by evaluating field plots of six bermudagrass cultivars on growth characteristics such as root and rhizome mass, recuperative potential, surface hardness, seedhead production, and turfgrass quality. Growth characteristics such as these are important in selecting cultivars best suited for a turf manager's individual situation. Increased data regarding these six cultivars will be useful in making recommendations for their use by the turfgrass industry.

Materials and Methods

The experiment was conducted at the Sandhills Research Station in Jackson Springs, NC on existing bermudagrass plots that were established in June 2001. They were established according to the materials and methodology given in Chapter 1. The soil at the site is classified as a Candor sand (Sandy, siliceous, thermic Arenic Paleudult) with 0 to 1 percent slope and an initial pH of 5.5. The Candor series consists of very deep, somewhat excessively drained soils with rapid permeability in the upper sandy horizons and moderate to moderately slow permeability in the lower horizons (USDA-NRCS Soil Survey Division, 1999). The mean annual temperature at the site is 16^{o} C. The mean annual high at the site is 21^{o}C, while the mean annual low temperature is 11^{o}C. The mean annual precipitation is 47 inches.

The experiment utilized a randomized split-split-plot design with four replications. Whole plots were 16.4m x 8.2m, with subplots of 5.5m x 8.2m, and sub-subplots measuring 2.7m x 2.7m. Whole plot factors consisted of an overseeded or non-overseeded treatment. Subplot factors were fertilization regimes providing 200 (low), 300 (medium), or 400 (high) kg N/hectare/year applied in 50kg N/hectare increments. These regimes were initiated in May 2002. Finally, sub-subplots consisted of various cultivars of bermudagrass. Cultivars included in this study were TifSport, Tifway, GN-1, Quickstand, Navy Blue, and Tifton 10. The split-split plot design allowed the most precision in determining cultivar performance treatments, and the least precision in evaluating overseeded/non-overseeded treatments.

Rhizome mass. Plugs of each cultivar (10.8cm-diameter x 20.3cm-deep) were taken from the field plots on 5 and 24 July 2002 using a standard putting green cup-cutter. Soil and roots were washed from the samples leaving the rhizomes and stolons exposed. Rhizomes were manually excised from the samples and oven-dried for 48 h at 60 ^{o}C. Samples were then weighed to determine the amount of rhizomes produced by each cultivar.

Root mass. On 2 September 2002, one plug 10.8cm-diameter x 20.3cm-deep was taken from each non-overseeded plot using a standard putting green cup-cutter. Samples were labeled, placed in plastic bags, and washed within 24 h using a root washer. All shoots, stolons, and thatch were removed from the soil plug. Remaining roots and soil were emptied into a #14 sieve and placed in the root washer until all of the soil was removed. Samples were then placed into paper bags and oven dried at 60^{o} C for 72 h. After weighing, each oven dried sample was placed in a muffle furnace overnight at 500^{0} C. Samples were weighed again and the difference was taken as the amount of roots produced by each variety.

Recuperative potential. The lateral growth rate of each cultivar was determined from 3 July 2002 to 14 August 2002. Plugs were removed from existing plots on 3 July 2002 using a standard 10.8 cm-diameter x 20.3 cm-deep putting green cup-cutter. The holes were back-filled with coarse sand and turf surrounding the hole was allowed to grow into the bare area until full coverage was complete. Digital images were recorded weekly using an Olympus C4040Zoom digital camera mounted on a vertical stand 1.0 m above the plots with a horizontal arm extending 0.5 m away from the vertical axis. This allowed the images to be taken without any interference from the photographer. Images were taken using a color depth of 16.7 million colors and an image size of 1280 by 960 pixels. Images were then downloaded onto a personal computer and analyzed using SigmaScan Pro digital imaging software (v.5.0, SPSS, Inc., Chicago, IL). This software allows the user to choose a range of colors that will be selected and counted in the measurement mode. An initial hue range of 0 to 154 and a saturation range of 0 to 100 were selected. Desired colors of green pixels can then be further selected manually for measurement. The total number of green pixels counted are then be divided by the total number of image pixels to estimate percent cover.

Clegg soil impact data. Clegg soil impact readings were taken from each plot receiving 300 kg N/hectare/year on 24 July 2002, as well as 2 and 7 August 2002 using a Clegg impact soil tester (Lafayette Instrument Co. Lafayette, IN). The Clegg soil impact tester consists of a metal guide tube 5 cm in diameter, an LCD screen with a digital readout, and a 0.5kg hammer weight which is dropped down the tube from a height of 45 cm. The hammer weight contained a sensor which measured the peak deceleration of the hammer when it struck the surface. The hammer was dropped four consecutive times on the same area and the highest value was recorded as the Clegg soil impact reading. Clegg soil impact readings represent an indication of surface hardness with increasing values indicating increasing hardness. Each set of measurements made was taken after no significant rainfall or irrigation had occurred for one day to ensure that soil moisture content was relatively consistent for each date.

Seedhead production. Observations of seedhead production for each cultivar were made on 16 July 2002. Plots were visually rated for seedhead production on a scale of 1 to 5 with 1 representing no seedheads visible and 5 representing 100% seedheads. A ring toss method was also incorporated in which three 12.7cm rings were randomly tossed into each plot. Seedheads within the rings were counted and recorded.

Turfgrass quality. Turfgrass quality was visually rated every two weeks from 13 June 2002 through 2 August 2002. Quality ratings were based on density, uniformity, texture, and color. Plots were rated on a scale of 1 to 9 with 1 being bare soil and 9 being an ideal plot of dark green, dense turf.

Data analysis. All data regarding rhizome and root production, seedhead production, recuperative potential, surface hardness, and turfgrass quality were subjected to Analysis of Variance (ANOVA) using the Statistical Analysis System (SAS Institute Inc., 2001). Data were subjected to means separation using the Waller-Duncan k-ratio t-test (k-ratio=100)when the ANOVA F-test indicated that treatment effects were significant at $P \leq 0.05$.

Results and Discussion

Rhizome mass. Extensive rhizome development by bermudagrass is a characteristic that makes it suitable for high-wear areas such as athletic fields and golf courses. The ability of a cultivar to produce significantly more rhizomes than another cultivar might give it a definite advantage in its ability to recover from stresses such as wear and compaction. In this study, rhizome mass was measured and no significant differences were found among cultivars. However, some non-significant trends were observed over both sampling dates regarding cultivars (Table 7).

Table 7. Rhizome mass† of six bermudagrass cultivars on 5 and 24 July 2002.

	July	
Cultivar	5	24
	$g/1.8 \times 10^{-3}\ m^3$	
TifSport	2.3a*	2.7a
GN-1	1.9a	1.6a
Tifway	1.9a	1.9a
Navy Blue	1.9a	1.5a
Tifton 10	1.5a	1.5a
Quickstand	1.0a	1.4a

* Means within columns followed by the same letter are not significantly different at the 5% level using Waller-Duncan k-ratio t test. All data were transformed using a log transformation (log Y).

† Rhizome mass represents oven-dry weight(g) of rhizomes excised from 10.8-cm diameter x 20.3cm-deep plugs.

On 5 and 24 July 2002, TifSport produced 119% and 95% more rhizomes, respectively, than Quickstand. On 5 July, GN-1 produced 83% and Tifway 82% more rhizomes than Quickstand. On 24 July the difference was much smaller with Tifway having 38% and GN-1 having 18% more rhizomes than Quickstand. One reason for the lack of statistical differences may be due to the high natural variation often associated with field measurements such as these.

Root mass. Adequate root production by bermudagrass is vital to the overall health and survival of the plant. This is especially true when the turfgrass area is subjected to traffic stress. No significant differences were noted among cultivars when root mass was determined on 2 September 2002. These results agree with the root mass data observed during 2001 when no differences were found there either. This may again be attributed to the high level of natural variation in the field. However, it is also possible, and perhaps even likely, that all six cultivars possess similar capabilities regarding root production.

Recuperative potential. The ability of bermudagrass to readily fill in divots and wear areas is a principal reason it is the primary choice for athletic fields and golf courses in the south. Under proper management, bermudagrass can tolerate high levels of traffic and still maintain a high level of quality. This is due in part to the aggressive nature of its rhizomes and stolons. Data taken on the recuperative potential of each cultivar is presented in Table 8.

Table 8. Lateral spread† of six bermudagrass cultivars from 3 July to 14 August 2002 rated at bi-weekly intervals.

	Weeks of regrowth		
Cultivar	2	4	6
	% coverage		
GN-1	63a*	97a	100a
Tifton 10	67a	95a	100a
Quickstand	67a	86b	98a
Tifway	47b	64c	97a
TifSport	31c	48d	95a
Navy Blue	11d	41e	70b

* Means within columns followed by the same letter are not significantly different at the 5% level using Waller-Duncan k-ratio t test.

† 10.8cm diameter plugs were taken on 3 July 2002 from each plot and allowed to cover from adjacent growth for six weeks. Digital pictures were taken and analyzed using Sigmascan pro digital imaging software. All data were transformed using an arcsin transformation [sqrt(cover/100)].

After two weeks of regrowth, GN-1, Tifton 10, and Tifway had filled in more rapidly than all other cultivars, followed by Tifway. TifSport and Navy Blue exhibited the slowest rate of recovery when rated after two weeks and were significantly slower than all other cultivars. A similar trend was observed at week four. After four weeks of growth GN-1 had produced significantly more lateral growth than all other cultivars except Tifton 10. TifSport and Navy Blue again exhibited the slowest rate of recovery. By six weeks of regrowth, GN-1 and Tifton 10 were the only two cultivars to reach 100%, but were not different than Quickstand, Tifway, or TifSport which had each achieved at least 95%. Navy Blue was the only cultivar that had a slower rate of recovery than all other cultivars after six weeks by achieving only 70% coverage. Much of this data corresponds with the establishment data taken during the summer of 2001 during which GN-1, Tifton 10, and Quickstand consistently exhibited the most rapid establishment rates from sprigs. Tifton 10 and Quickstand were both released in part due to their rapid establishment and lateral spread (Hanna and Burton, 1998; Phillips et al., 1997). TifSport and Navy Blue were consistently the slowest to establish during 2001 which also agrees with their recuperative potential rankings in 2002. The statistical design of the experiment incorporated a low, medium, and high N treatment consisting of 200, 300, or 400 kgN/hectare/yr, respectively. All of the plugs for the recuperative potential study were removed from the 300 kgN/hectare/yr treatment. This was done in order to make sure that the bermudagrass had enough nitrogen to adequately recover, but not so much that any cultivar differences might be masked by excessive growth.

Clegg Impact Soil Tester (CIST). Maintaining a safe and aesthetically pleasing playing surface is the principal objective of athletic field managers. One factor that plays a significant role in field safety is surface hardness. Surface hardness can be affected by many things including compaction, soil moisture, and grass species. The objective of this experiment was to determine if there were any differences among cultivars in regard to surface hardness. Clegg impact readings were taken on 24 July 2002 as well as 2 and 7 August 2002. Clegg impact data is presented in Table 9.

Table 9. Clegg impact soil readings for six bermudagrass cultivars taken during 2002†.

	July	August	
Cultivar	24	2	7
Tifton 10	6.6a*	7.0a	6.4a
GN-1	7.7ab	6.9a	6.9ab
TifSport	8.0ab	8.7ab	8.0ab
Tifway	8.2b	9.1ab	7.5ab
Navy Blue	8.2b	8.8ab	7.4ab
Quickstand	9.7c	9.8b	8.7b

* Means within columns followed by the same letter are not significantly different at the 5% level using Waller-Duncan k-ratio t test.

† Clegg impact soil readings were taken using a 0.5kg hammer weight. Higher numbers reflect harder surfaces.

On 24 July, Tifton 10, GN-1, and TifSport did not differ from each other in their CIST readings, each exhibiting the least amount of surface hardness. Quickstand had a higher impact value than all other cultivars on this date indicating it possessed the hardest surface. Quickstand plots also had higher surface hardness values than GN-1 and Tifton 10 on 2 August and a higher surface hardness value than Tifton 10 on 7 August. Tifton 10, GN-1, and Quickstand all possess rapid lateral growth characteristics as indicated by the establishment data from summer 2001 and the recuperative potential data from summer 2002. Both of these data sets imply that these three cultivars produce large amounts of rhizomes and stolons that allow them to spread rapidly.

One factor that plays a role in reduced surface hardness of bermudagrass fields is development of a substantial thatch layer. A cultivar that rapidly accumulates thatch due to extensive rhizome and stolon development would be expected to have lower CIST readings. This holds true for GN-1 and Tifton 10, but not for Quickstand. One possible explanation for this might be the lack of shoot density that Quickstand possesses. Quickstand is very similar to common bermudagrass (*Cynodon dactylon* L. Pers.) in its texture and density. The turf canopy of Quickstand is not as dense as Tifton 10 and GN-1, which might have contributed to its higher CIST readings. Even so, no research has been conducted to define what actually constitutes a safe or unsafe playing surface regarding CIST readings. Thus, it is not accurate to say from this study that any cultivar is safer than another for use on athletic fields. More research is needed to determine a specific threshold level for safety of bermudagrass athletic fields.

Seedhead production. Excessive seedhead production by bermudagrass can result in an unsightly playing surface. It can also result in a weaker plant due to the shift from vegetative growth to reproductive growth. Therefore, a bermudagrass cultivar with decreased seedhead production may be desirable in order to reduce mowing and use of plant growth regulators, which are two methods currently used to reduce seedhead development. Seedhead production of each cultivar is listed in Table 10.

Table 10. Seedhead production of six bermudagrass cultivars as rated by two methods on 16 June 2002.

Cultivar	Seedheads/m^{2}†	Visual rating‡
Navy Blue	791a*	2.6a
GN-1	641a	2.0b
Tifway	316b	1.6c
TifSport	241b	1.5cd
Tifton 10	191b	1.4cd
Quickstand	91b	1.3d

* Means within columns followed by the same letter are not significantly different at the 5% level using Waller-Duncan k-ratio t test.

† Seedheads were counted within three randomly tossed 12.7cm diameter rings per plot.

‡ Visual ratings scale: 1 = No seedheads; 5: 100% seedheads.

Visual ratings and seedhead count data were very similar. Navy Blue produced significantly more seedheads than all other cultivars when rated visually, and Navy Blue and GN-1 produced more seedheads than all other cultivars when measured using the ring toss method. Seedhead counts illustrate that Quickstand, Tifton 10, TifSport, and Tifway produced the fewest seedheads. Visual ratings of seedhead production showed a similar trend. Quickstand produced fewer seedheads than Navy Blue, GN-1, and Tifway, but was not different than TifSport and Tifton 10. The results of both experiments demonstrate that Quickstand produced the fewest seedheads while Navy Blue produced the largest amount. In fact, Navy Blue produced almost ten times as many seedheads as Quickstand based on the count data. This data implies that all other factors being equal, Quickstand may be ideal for a low-budget situation where unsightly seedheads may be a problem.

Turfgrass quality. Turfgrass quality encompasses factors including: color, density, uniformity, and texture. Turfgrass quality (Table 11) was rated on four separate dates including 13 and 25 June, 16 July, and 2 August 2002.

Table 11. Turfgrass quality ratings of six bermudagrass cultivars† during the summer of 2002.

	June		July	August
Cultivar	13	25	16	2
TifSport	7.2a*	7.7a	8.2a	8.6a
Tifway	7.0a	7.3a	8.0a	8.2b
Navy Blue	6.9a	7.1b	7.6b	8.2b
GN-1	6.7b	7.1b	7.5b	8.1b
Tifton 10	6.5bc	6.5c	7.2c	7.4c
Quickstand	6.3c	6.6c	6.6d	7.3c

* Means within columns followed by the same letter are not significantly different at the 5% level using Waller-Duncan k-ratio t test.

† Visual ratings scale: 1= Bare ground; 9= Ideal quality.

TifSport consistently produced higher quality ratings than all other cultivars except Tifway and Navy Blue on 13 June and Tifway again on 25 June and 16 August. TifSport possesses a very dark green color and fine leaf texture superior to that of other cultivars in the study. These two characteristics inherently produce higher quality ratings that have also been noted in other studies. In studies performed at seven locations including Tifton, GA; Stillwater, OK; Lexington, KY; Lake Wales, FL; Ft. Bluff, TN; Franklin, TN; and Lincoln, NE., TifSport produced significantly higher turf quality than ‘Midiron’ bermudagrass, and quality equal to or significantly better than both Tifway and Tifway II (Hanna, 1999). On 13 June, GN-1 produced lower quality turf than TifSport, Tifway, and Navy Blue but higher than Quickstand. Quickstand produced lower quality turf than all other cultivars except Tifton 10 on 13 June. GN-1 and Navy Blue produced lower quality turf than TifSport but higher quality turf than Quickstand and Tifton 10 on all other rating dates.

Quickstand and Tifton 10 consistently produced low overall quality ratings throughout the entire summer, primarily because of their coarse leaf texture. Both cultivars possess a very coarse leaf texture similar to common bermudagrass. Tifway, Navy Blue, and GN-1 are not as fine-textured as TifSport, but are noticeably finer-textured than Quickstand and Tifton 10. Quickstand also exhibits a light green color compared to Tifton 10 which possesses a blue-green color. Neither of these cultivars have the traditional dark green color that is most desirable.

Another factor contributing to the low ranking of Quickstand is its poor density. Quickstand does not particularly have a very dense turf canopy, as mentioned previously, which results in lower quality turf. Despite their low quality ratings, Quickstand and Tifton 10 produce turf that is acceptable for low-maintenance situations such as high schools, parks and recreation sites, lawns, and utility turf. TifSport, Tifway, and GN-1 are more suited to high-maintenance situations such as college and professional athletics as well as golf courses. Although there are differences among these six cultivars, they each produced acceptable turfgrass quality.

Literature Cited

Agnew, M.L. and R.N. Carrow. 1985. Soil compaction and moisture stress preconditioning on Kentucky bluegrass. II. Stomatal resistance, leaf water potential, and canopy temperature. Agron. J. 77: 878-884.

Carrow, R.N. and A.M. Petrovic. 1992. Effects of traffic on turfgrass. p. 285-324. *In* Waddington et al. Turfgrass. Agron. Monogr. 32. ASA, CSSA, and SSSA. Madison, WI.

DiPaola, J.M. and J.B. Beard. 1992. Physiological effects of temperature stress. p. 231-262. *In* Waddington et al. Turfgrass. Agron. Monogr. 32. ASA, CSSA, and SSSA. Madison, WI.

Hanna, W. 1999. Tift 94 Bermudagrass. USDA-ARS, Athens, GA.

Hanna, W., and G.W. Burton. 1998. Notice of release of Tifton 10 bermudagrass. USDA-ARS, Tifton, GA.

Lafayette Instrument Co. Clegg Impact Soil Tester Instruction Manual. Lafayette Instrument Co. Lafayette, IN.

Madison, J.H. 1971. Principles of turfgrass culture. Van Nostrand Reinhold Co., New York.

O'Neil, K.J. and R. N. Carrow. 1983. Perennial ryegrass growth, water use, and soil aeration status under soil compaction. Agron. J. 75: 177-180.

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

Rogers, J.N. and D.V. Waddington. 1992. Impact absorption characteristics on turf and soil surfaces. Agron. J. 84: 203-209.

SAS Institute. 2001. The SAS system for Windows. Release 8.0 SAS Inst., Cary, NC.

SPSS Science. 2002. Sigmascan Pro. SPSS Science. Chicago, IL.

Trenholm, L.E., Carrow, R.N., and R.R. Duncan. 2000. Mechanisms of wear tolerance in seashore paspalum and bermudagrass. Crop Sci. 40: 1350-1357.

USDA-NRCS Soil Survey Division. 1999. Official Series Description [Online] Available at http://www.statlab.iastate.edu/cgi-bin/osd/osdname.cgi?-P (Verified 14 August 2002.)

Low Temperature Tolerance of Six Cultivars of Vegetatively Propagated Bermudagrasses

Abstract

Bermudagrass (*Cynodon spp*.) is the most commonly planted species of grass on athletic fields and golf course fairways in the southeastern United States. Its aggressive growth habit and high wear tolerance make it ideal for these situations. However, one factor that limits bermudgrass use, especially in the transition zone, is its ability to survive harsh winters sometimes associated with this area. The purpose of this investigation was to evaluate the low temperature tolerance of six bermudagrass cultivars often planted in the southeast. 'TifSport', 'Tifway', 'GN-1', 'Quickstand', 'Navy Blue', and 'Tifton 10' were established from sprigs at the Sandhills Research Station in Jackson Springs, NC on 28 June 2001. During April 2002, 10.8 cm diameter plugs were taken from the field plots for the low temperature study. Sixty stolons per cultivar were excised from the plugs and placed into a Low Temperature Stress Simulator (LTSS) where they were exposed to four different temperatures of 2^{o}C, 0^{o}C, –2^{o}C, and -4 ^{o}C for a period of 24 hr. The stolons were then placed in a greenhouse with a mean day and night temperature of 41 ^{o}C and 24 ^{o}C, respectively. They were allowed to grow for 30 days after which percent survival was measured by recording the number of sprigs out of 30 that survived. No significant difference was found among cultivars, but mortality did increase as temperature decreased. This study indicates that there is no significant interaction between the different cultivars and their ability to tolerate low temperatures.

Introduction

The susceptibility of bermudagrass (*Cynodon spp*.) to winter injury is a characteristic that significantly limits its use in the upper regions of the transition zone. In fact, the likelihood of substantial winter injury is often a predominant factor in deciding whether or not to plant bermudagrass. This is a dilemma for turf managers who desire the aggressive growth and high wear tolerance bermudagrass possesses but fear the possibility of winter injury. Many factors influence the ability of bermudagrass to tolerate freezing conditions including: fertility levels, moisture content, the acclimation process (hardening off), and cultivar selection(Ibitayo and Butler, 1981; Chalmers and Schmidt, 1979). However, little work has been done regarding some of the more recently released bermudagrass cultivars.

It has been reported that fertility and tissue moisture content have a significant effect on susceptibility to winter injury. High nitrogen levels, particularly in late summer and early fall, will produce a plant that is considerably more susceptible to winter injury. However, by applying potassium this susceptibility can be dramatically reduced (Gilbert and Davis, 1971). Also, tissue with high moisture content is known to exhibit notably less freeze tolerance than dehydrated tissues (DiPaola and Beard, 1992).

Acclimation is the process by which a plant develops resistance to low temperatures (Weiser, 1970). The rate at which the plant is acclimated to cold temperatures can also play a significant role in winter injury. The ability of a plant to tolerate winter injury is directly related to its degree of acclimation. Bermudagrass typically achieves maximum resistance to winter injury during early winter and this resistance decreases during late winter/early spring (Davis and Gilbert,1970; Dunn and

Nelson,1974). This indicates that timing and duration of freezing exposure may be equally as important as the actual temperature to which the plant is subjected.

Bermudagrass is a highly variable species. Vast differences exist in growth characteristics and environmental adaptations among cultivars. Significant differences in freeze tolerance have been found among some of the most commonly used cultivars (Anderson and Taliaferro, 2002; Anderson et al., 2002). Even so, there are still only limited data available concerning the cold tolerance of most cultivars. Cultivars such as TifSport, Tifway, GN-1, Quickstand, Navy Blue, and Tifton 10 need to be studied further to more accurately quantify their relative freeze tolerance. The objective of this study was to determine the freeze tolerance of these six bermudagrass cultivars by exposing them to four temperatures in a low temperature stress simulator (LTSS).

Materials and Methods

Six cultivars of bermudagrass (Tifsport, Tifway, GN-1, Quickstand, Navy Blue, and Tifton 10) were established from sprigs at the Sandhills Research Station in Jackson Springs, NC during June 2002. The soil at the site is classified as a Candor sand (Sandy, siliceous, thermic Arenic Paleudult). The plots were maintained at a mowing height of 2.5cm, and received 50kgN/hectare/month (June through August). Irrigation was also provided to obtain sufficient growth.

During early spring (April 2002) 72 cores, each 10.8cm in diameter and 20.3cm deep, were taken from field plots on four separate dates (one date per temperature treatment). Sixty stolons of each cultivar were excised from the plugs. A stolon was defined as an above ground stem with two nodes and an internode for the purposes of this study. A Low Temperature Stress Simulator (LTSS) similar to the one described by Beard and Olien (1963) was used to accurately subject sprigs of each cultivar to four separate temperatures for a fixed period of time. 360 stolons (60/cultivar) were placed into the Low Temperature Stress Simulator and held at 3^{o}C for 24 h before being cooled at the rate of 1.5^{o}C h^{-1}. The stolons were cooled at this rate until reaching the intended target temperature of 2 ^{o}C, 0 ^{o}C, -2 ^{o}C, or -4 ^{o}C. They were then held at that temperature for 24h before being brought back to 3^{o}C and held for an additional 12 h. The sprigs were planted in flats, placed in the greenhouse, and grown for 28 d after which percent survival of the nodes was measured. Mean day and night temperatures in the greenhouse were 41 ^{o}C and 24 ^{o}C , respectively. Each temperature treatment was replicated four times and plants were placed randomly in the greenhouse for recovery. The response measured was the proportion of nodes that survived out of 30 (15 stolons, each with 2 nodes, per rep). This data was transformed using an arcsin transformation in an attempt to stabilize the variance of each cultivar. All data on low temperature tolerance were subjected to an Analysis of Variance (ANOVA) using the Statistical Analysis System (SAS Institute Inc., 2001).

Results and Discussion

The nested model used in the analysis of the data is as follows:

$$\mu_{ijk} = \mu + \alpha_i + \beta_j + (\alpha B)_{ij}$$

where i= cultivar, j= temperature, and k= replication. This allows for cultivar by temperature interaction effects $(\alpha B)_{ij}$, cultivar effects α_i, and temperature effects β_j. No differences were found among cultivars in their ability to survive 2°C, 0°C, and –2°C as indicated in Table 12.

Table 12. Number of nodes that survived exposure to 2°C, 0°C, -2°C, and -4°C for a period of 24 hours.

Genotype	Cold Stress Temperature 2° C	0°C	-2°C
	Number of nodes surviving†		
TifSport	23.0a	19.3a	18.5a
Tifway	25.0a	19.5a	8.7a
GN-1	22.2a	11.0a	9.0a
Navy Blue	21.2a	21.2a	11.0a
Quickstand	20.0a	19.5a	13.2a
Tifton 10	20.2a	18.7a	11.5a

NOTE: No stolons survived the -4°C treatment.

*Means with the same letter are not statistically different at $P \leq 0.05$ using the Waller-Duncan k-ratio t test. Data were transformed prior to ANOVA using an arcsin transformation [sqrt(cover/100)].

† Number of surviving nodes out of 30 subjected to cold temperature stress

There was also no evidence of a cultivar by temperature interaction effect. However, evidence does exist that mortality increases as temperature decreases. Contrast data showed that survival at 2^{o}C was significantly higher than survival at 0^{o}C and -2^{o}C. Survival at 0^{o}C was also higher than survival at -2^{o}C. Data were also analyzed using a generalized linear mixed model. This model uses the individual stolons as the replications instead of the total number of nodes that survived out of 15 stolons. Results from this analysis were similar to the nested model in that no differences were found among cultivars in their ability to tolerate low temperatures.

It is important to note there was 100% mortality among the sprigs at the -4^{o}C treatment. Beard (1973) found the LT_{50} of bermudagrass to be between –5^{o}C and -8^{o}C, yet in this study no stolons survived -4^{o}C. This could be because the field plots the stolons were taken from were in their first year of establishment and may not have developed their maximum tolerance to below-freezing temperatures. It has been documented in previous studies that bermudagrass is more susceptible to winter injury during its first year of establishment than subsequent years (Munshaw et al., 2001). The winter was also mild at the field plots so it is possible that the grasses may not have completely hardened off.

Previous low temperature tolerance research has been performed on several of the cultivars included in this study. In one particular study completed at Oklahoma State University by Anderson and Taliaferro , T_{mid} values were calculated which represent the midpoint of a fitted survival-temperature response curve. It was found that GN-1 was significantly less freeze tolerant than TifSport and Quickstand, but not significantly different than Tifway 419 (Anderson et al. 2002). This is not surprising given the fact that TifSport was derived by irradiating stolons of Midiron bermudagrass(*C. Dactylon x C. transvaalensis*), which is known to have superior freeze tolerance. Studies performed in

Franklin, TN and Stillwater, OK have demonstrated that Tifsport is significantly more cold hardy than Tifway 419 and Tifgreen (Hanna,1999). Quickstand[*Cynodon dactylon*(L.) Pers.] was released by the USDA-NRCS in 1993 in part due to its superior cold hardiness (Phillips,1997). Anderson and Taliaferro (2002) found that Quickstand, like TifSport, was also significantly more cold hardy than Tifgreen (Anderson and Taliaferro, 2002). The data in this study display a trend that supports this previous research. GN-1 had the lowest amount of surviving sprigs at 0^{o}C and the second lowest amount of surviving sprigs at -2^{o}C. TifSport and Quickstand had the highest number of surviving sprigs at -2^{o}C. Even though this trend did exist the differences were not statistically different due to a high variability within replications of each cultivar. Data from this study indicate that there were no significant differences in the ability of these six cultivars to tolerate low temperatures.

Literature Cited

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

Anderson, J.A., and C.M. Taliaferro. 2002. Freeze tolerance of seed-producing turf bermudagrasses. Crop Sci. 42:190-192.

Beard, J.B. and C.R. Olien. 1963. Low temperature injury in the lower portion of *Poa annua* L. crowns. Crop Sci. 3:362-363.

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

Chalmers, D.R., and R.E. Schmidt. 1978. Bermudagrass survival as influenced by deacclimation, low temperatures, and dormancy. Agron. J. 71: 947-949.

Davis, D.L., and W.B. Gilbert. 1970. Winter hardiness and changes in soluble protein fractions of bermudagrass. Crop Sci.10:7-9.

DiPaola, J.M. and J.B. Beard. 1992. Physiological effects of temperature stress. p. 231-262. *In* Waddington et al. Turfgrass. Agron. Monogr. 32. ASA, CSSA, and SSSA. Madison, WI.

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

Gilbert, W.B., and D.L. Davis.1971. Influence of fertility ratios on winter hardiness of bermudagrass. Agron. J. 63:591-593.

Hanna, Wayne. 1999. Tift 94 Bermudagrass. USDA-ARS, Athens, GA.

Ibitayo, O.O., and J. D. Butler. 1981. Cold hardiness of bermudagrass and *Paspalum vaginatum* Sw[1]. HortScience. 16(5): 683-684.

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

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

SAS Institute, Inc. 2001. The SAS system for Windows. Release 8.0 SAS Inst., Cary, NC.

Weiser, C.J. 1970. Cold resistance and injury in woody plants. HortScience 169:1269-1278.

Economic Implications of This Research on the Turfgrass Industry in North Carolina

There are over two million acres of maintained turf in North Carolina that result in over $1.2 billion in yearly maintenance cost. These turf areas include home lawns, roadsides, parks, golf courses, and athletic fields. The intended uses for these areas each require different grasses with different management regimes. For example, tall fescue, (cool-season species) is the most popular grass for home lawns, whereas bermudagrass (warm-season species) is the primary choice for athletic fields and golf courses. There are obvious agronomic differences in the management of these two species. There are also vast differences in the money that is typically spent to maintain these two species as well. In 1999, golf courses in North Carolina spent an average of $2,574 per acre on maintenance costs, whereas the cost to maintain a single-family home was only $495 per acre (NCDA, 2001). This is primarily due to the fact that the level of acceptable quality is much higher on golf courses and professional athletic fields than it is on home lawns. Also, superintendents at these facilities typically have much higher budgets than the average homeowner. This high expense per acre means that golf courses and athletic fields account for a significant portion of the turfgrass industry in North Carolina. Therefore, in 1999 the North Carolina Turfgrass Foundation, the Turfgrass Council of North Carolina, and the North Carolina Sod Producers Association set aside $75,000 in funds to be allocated to study six cultivars of bermudagrass for use on athletic fields and golf courses.

The study was established at the Sandhills Research Station in Jackson Springs, NC during June 2001. Six cultivars of bermudagrass were sprigged by hand at the rate of

522 bushels/acre. This is within the standard rate of 400-600 bushels/acre typically used on golf courses and athletic fields. The six cultivars included in the study were TifSport, Tifway, GN-1, Quickstand, Navy Blue, and Tifton 10. Tifway has been the standard since being released in 1960. However, new cultivars such as TifSport and GN-1, which were released in 1994 and 1989, respectively are gaining popularity.

TifSport was released in part due to its fine texture and high quality (Hanna, 1999). The results of this study show that TifSport does possess higher quality than Tifway, however it is not as aggressive as exhibited by the establishment and lateral spread data. This implies that TifSport would be more suitable for high-budget, high profile areas for two reasons. First, high-profile areas such as professional athletics require a cultivar with high quality, which TifSport possesses. TifSport also possesses the ability to produce this high level of quality at low mowing heights. Studies have shown that TifSport produces significantly higher quality turf than Tifway at 1/2inch, which again would be typical of a professional or college facility with the budget to maintain this low mowing height.

Second, its lack of recuperative capacity means that any high-wear areas such as between the hash marks on football fields, goal mouths of soccer fields, and golf course tee boxes are likely going to have to be re-established by sod or sprigs. This limits its use in low-budget situations where the cost of re-establishment is prohibitive. The initial cost of TifSport is also higher than all of the other varieties except GN-1, which costs $2.00/bushel. TifSport sells for $1.75/bushel, whereas Tifway is $1.25/bushel. Quickstand, Navy Blue, and Tifton 10 costs $1.40/bushel, $1.35/bushel, and $1.10/bushel, respectively.

GN-1 produced turf that is equal to the quality of Tifway in this study. It also exhibited very aggressive lateral growth. Although aggressive lateral growth is a beneficial characteristic of this cultivar, it could also result in higher maintenance cost due to thatch accumulation. Thatch is the build-up of living and dead plant material at or above the soil surface (Turgeon, 1991). Thatch must be controlled through top-dressing, verti-cutting, and aerification in order to prevent it from being a long-term problem. The aggressive nature of GN-1 could also result in higher maintenance costs around the skinned areas of baseball and softball infields. These areas must be routinely edged to keep the grass infield and outfield from encroaching onto the clay infields. The same is true for bermudagrass collars around bentgrass putting greens. GN-1 in these areas would result in substantially more time, labor, and expense. This fact combined with the high initial cost of GN-1 sprigs implies that this cultivar, much like TifSport, is more suited for high budget facilities.

Unlike TifSport, GN-1, and Tifway the results of this study show that Tifton 10 may be the cultivar of choice for low-budget, low profile areas. Tifton 10 establishes rapidly from rhizomes and stolons and performs well under low maintenance conditions (Hanna and Burton, 1998). In tests conducted at the University of Georgia, Tifton 10 produced quality ratings similar to Tifway and Tifway II under low management conditions consisting of 2.5 lbs N/1000ft^2/year, irrigated only in dry periods, and mowed once per week at 1.5 inches (Hanna and Burton, 1998). Tifton 10 is a coarse-textured cultivar somewhat similar to common bermudagras. This texture would not be acceptable on most golf courses and professional or collegiate athletic facilities. However, it would be acceptable at high schools, parks and recreation sites, and any other low-profile situation. Tifton 10 also is the cheapest of the six cultivars selling for $1.10/bushel.

Quickstand and Navy Blue are the last of the six cultivars included in this study. Quickstand consistently produced the poorest quality due to a very coarse texture and light green color that is not very appealing in comparison to the other cultivars. Quickstand sprigs and sod are more expensive than Tifway and Tifton 10 and offer no real advantage over either regarding quality or recuperative capacity. Navy Blue is very similar to Tifway in its texture and quality, however it had a significantly higher incidence of disease than all other cultivars. Dollar spot (*Sclerotinia homoeocarpa*) was observed on the plots in fall 2001, and the only cultivar really affected was Navy Blue.

The results of this study show that there are substantial differences among each of these six cultivars of bermudagrass. Golf course and athletic field superintendents can use this data to decide which cultivar of bermudagrass is most suitable for their particular situation. This decision is based on many factors including initial cost, desired quality, maintenance, budget, and many other factors. Choosing the right cultivar initially will save much time and money by avoiding the costly process of re-establishment. It will also result in the safest, most aesthetically pleasing playing surface, which in the end is the goal of every turfgrass manager.

Literature Cited

Hanna, W. 1999. Tift 94 Bermudagrass. USDA-ARS, Athens, GA.

Hanna, W., and G.W. Burton. 1998. Notice of release of Tifton 10 bermudagrass. USDA-ARS, Tifton, GA.

North Carolina Agricultural Statistics Services. 2001. North Carolina Turfgrass Survey, 1999. NC Dept. of Agric., Raleigh.

Turgeon, A.J. 1991. Turfgrass Management: Third Edition. Prentice-Hall Inc. New Jersey.

Conclusions

The following conclusions are based upon results obtained during the course of this project. A comprehensive discussion of the evidence leading to these conclusions is presented in Chapters I through III.

(1) Tifton 10 demonstrated the ability to establish faster from sprigs than all other varieties by ranking among the best on all six observation dates. This was followed by Quickstand and GN-1, which had four and five top rankings, respectively.

(2) No differences were found among the six cultivars regarding rooting mass in 2001 or 2002.

(3) Navy blue exhibited susceptibility to dollar spot (*Sclerotinia homoeocarpa*) by having significantly higher incidence on two observation dates during fall 2001.

(4) GN-1 had a higher incidence of large patch (*Rhizoctonia solani*) than all other cultivars during fall 2001 with TifSport and Navy Blue having no incidence of large patch.

(5) TifSport maintained its color longer in the fall than all other cultivars except Tifway while Tifton 10 and Quickstand exhibited the least capacity to maintain fall color.

(6) TifSport exhibited the earliest spring green-up on the first observation date but was ultimately surpassed by Tifway and GN-1. After week one, Tifway ranked in the highest category five of the remaining six weeks and GN-1 ranked in the highest category all six weeks.

(7) No differences were found among the six cultivars regarding rhizome mass.

(8) Tifton 10 and GN-1 exhibited the highest recuperative potential from the digital imaging data followed by Quickstand and Tifway. TifSport and Navy Blue were the slowest to recover over the six week re-growth period.

(9) Quickstand produced a harder surface than all other cultivars on 24 July, while Tifton 10, GN-1, and TifSport were the softest. The only differences found on 2 and 7 August were between Tifton 10, which had the lowest CIST readings and Quickstand, which had the highest. All other cultivars were equal on these two dates.

(10) Navy Blue and GN-1 produced more seedheads than all other cultivars by means of a ring toss method. Visual ratings data show that Navy Blue produced more seedheads than all other cultivars.

(11) TifSport consistently produced the highest turf quality of the six cultivars followed by Tifway, GN-1, and Navy Blue. Quickstand and Tifton 10 had the poorest quality over four observation dates, primarily due to their coarse texture and off-green color.

(12) No differences were found among the cultivars in their ability to tolerate low temperatures. However, there was a temperature effect showing that survival decreased as temperature decreased with 100% mortality occurring at $-4^{o}C$.

Literature Cited

Agnew, M.L. and R.N. Carrow. 1985. Soil compaction and moisture stress preconditioning on Kentucky bluegrass. II. Stomatal resistance, leaf water potential, and canopy temperature. Agron. J. 77: 878-884.

Anderson, J.A., and C.M. Taliaferro. 2002. Freeze tolerance of seed-producing turf bermudagrasses. Crop Sci. 42:190-192.

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

Beard, J.B. and C.R. Olien. 1963. Low temperature injury in the lower portion of *Poa annua* L. crowns. Crop Sci. 3:362-363.

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

Carrow, R.N. and A.M. Petrovic. 1992. Effects of traffic on turfgrass. p. 285-324. *In* Waddington et al. Turfgrass. Agron. Monogr. 32. ASA, CSSA, and SSSA. Madison, WI.

Chalmers, D.R., and R.E. Schmidt. 1978. Bermudagrass survival as influenced by deacclimation, low temperatures, and dormancy. Agron. J. 71: 947-949.

Davis, D.L., and W.B. Gilbert. 1970. Winter hardiness and changes in soluble protein fractions of bermudagrass. Crop Sci.10:7-9.

DiPaola, J.M. and J.B. Beard. 1992. Physiological effects of temperature stress. p. 231-262. *In* Waddington et al. Turfgrass. Agron. Monogr. 32. ASA, CSSA, and SSSA. Madison, WI.

Dudeck, A.E., Peacock, C.H., and T.E. Freeman. 1985. Response of selected bermudagrasses to nitrogen fertilization. p. 495-504. *In* F. Lemaire (ed.) Proc.5th Int. Turfgrass Res. Conf., Avignon, France. 1-5 July. Inst. Natl. de la Rcherche Agron., Paris, France.

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

Gilbert, W.B., and D.L. Davis.1971. Influence of fertility ratios on winter hardiness of bermudagrass. Agron. J. 63:591-593.

Hanna, W. 1999. Tift 94 Bermudagrass. USDA-ARS, Athens, GA.

Hanna, W., and G.W. Burton. 1998. Notice of release of Tifton 10 bermudagrass. USDA-ARS, Tifton, GA. Crop Sci. 37: 1674.

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

Ibitayo, O.O., and J. D. Butler. 1981. Cold hardiness of bermudagrass and *Paspalum vaginatum* Sw[1]. HortScience. 16(5): 683-684.

Kidwell, Jack. 1998. Navy Blue: New Bermudagrass Release. U.S. Patent 09/121,850.

Lafayette Instrument Co. Clegg Impact Soil Tester Instruction Manual. Lafayette Instrument Co. Lafayette, IN.

Madison, J.H. 1971. Principles of turfgrass culture. Van Nostrand Reinhold Co., New York.

Morris, Kevin. 2001. National Turfgrass Evaluation Program:1997 National Bermudagrass Test.USDA-ARS. Beltsville, Maryland.

Mueller, J.P., Green, J.T., Nelson, L.A., and J.V Hall. 1992. Establishment of two bermudagrasses in three soil environments. Agron. J. 84: 38-43.

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

O'Neil, K.J. and R. N. Carrow. 1983. Perennial ryegrass growth, water use, and soil aeration status under soil compaction. Agron. J. 75: 177-180.

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

Richardson, M.D., Karcher, D.E., and L.C. Purcell. 2001. Quantifying turfgrass cover using digital image analysis. Crop. Sci. 41: 1884-1888.

Rogers, J.N. and D.V. Waddington. 1992. Impact absorption characteristics on turf and soil surfaces. Agron. J. 84: 203-209.

SAS Institute, Inc. 2001. The SAS system for Windows. Release 8.0 SAS Inst., Cary, NC.

Shoulders, J.F., and R.E. Schmidt. 1985. Establishing *Cynodon* spp. from dormant vegetative propagules. p. 307-310. *In* F. Lemaire (ed.) Proc.5th Int. Turfgrass Res. Conf., Avignon, France. 1-5 July. Inst. Natl. de la Rcherche Agron., Paris, France.

Smiley, R.W., Dernoeden, P.H., and B.B. Clarke. 1992. Compendium of Turfgrass Diseases. 2nd ed. American Phytopathological Society.

Sowers, R.S., and M.S. Welterlen. 1988. Seasonal stablishment of bermudagrass using plastic straw mulches. Agron J. 80:144-148.

SPSS Science. 2002. Sigmascan Pro. SPSS Science. Chicago, IL.

Steel, R.G. and J.H. Torrie. 1980. Principles and Procedures of Statistics: A biometrical approach. 2nd ed. McGraw-Hill Inc. New York, NY.

Tani, T. and J.B. Beard. 1997. Color Atlas of Turfgrass Diseases. Ann Arbor Press. Chelsea, MI.

Tredway, L.P. and L.L. Burpee. 2001. *Rhizoctonia* Diseases of Turfgrass. The Plant Health Instructor. DOI:10.1094/PHI-I-2001-1109-01.

Trenholm, L.E., Carrow, R.N., and R.R. Duncan. 2000. Mechanisms of wear tolerance in seashore paspalum and bermudagrass. Crop Sci. 40: 1350-1357.

Turgeon, A.J. 2002. Turfgrass Management: Sixth Edition. Prentice-Hall Inc. New Jersey.

USDA-NRCS Soil Survey Division. 1999. Official Series Description [Online] Available at http://www.statlab.iastate.edu/cgi-bin/osd/osdname.cgi?-P (Verified 14 August 2002.)

Weiser, C.J. 1970. Cold resistance and injury in woody plants. HortScience 169:1269-1270.